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Population Dynamics of American Plaice (*Hippoglossoides platessoides*) off West Greenland (NAFO Divisions 1B–1F), 1982–94

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Abstract

Growth, mortality, stock composition by sex, age distribution and female sexual maturity were determined for American plaice (*Hippoglossoides platessoides*) off West Greenland for the first time. Examination of otoliths revealed that females grew at a faster rate than males. Growth rates were observed to be lower than those of adjacent stocks of American plaice (NAFO Div. 3M, Div. 3LNO). The length at 50% maturity and age at 50% maturity values for females were estimated to vary between 25.5 and 26.5 cm and at a corresponding age around 8 years. A trend of decreasing fish age with increasing latitude suggested the existence of nursery grounds in the northern area off West Greenland. No indications for different distributions by depth were found.

During 1982–94, a severe decline of the American plaice stock off West Greenland in abundance and biomass was observed. Until 1987, the survey indices were found to vary at a high level. In 1988, the decline of both abundance and biomass was most pronounced and the following period until 1990 was characterized by nearly continuous losses. During 1990–94, young fish (0–6 years old) dominated the stock population, contributing 70% to total stock abundance in 1994. The recently depleted status of the American plaice stock off West Greenland was reflected by significant reductions in mean age from 7.8 years in 1982 to 5.8 years in 1994. Older age groups suffered the biggest losses during the entire period 1982–94 when relative values were considered. Losses were reflected by high total and fishing mortality coefficients, which were usually higher than the reference $F_{0.1}$ and F_{max} values derived from a yield-per-recruit analysis.

Based on the spawning stock-recruitment relationship, a stock recovery in the near future seemed unlikely because of low recruitment being expected from the extremely low spawning stock biomass in 1992–94.

Key words: distribution, growth, American plaice, maturity, population dynamics, West Greenland

Introduction

The European Union–Germany annual groundfish surveys off West Greenland commenced in 1982 (Rätz, 1996). American plaice (*Hippoglossoides platessoides*) has been found in these surveys to be the second most dominant species of the demersal fish assemblage off West Greenland. The stock has undergone great changes during the period 1982–94, with sharp declines in the observed abundance and biomass indices by 85% and 94%, respectively (Rätz, MS 1994a; Lloret, MS 1995). American plaice, like many other species of the demersal fish assemblage inhabiting the area, has been usually caught as by-catch in the cod, redfish and shrimp fisheries. Although there has been no fishing effort directed to groundfish since 1990, the stock lacked any signs of recovery, and has continued to decline. This recently depleted status of the American plaice stock off West Greenland has also been reflected by significant reductions in fish size from 28.1 cm in 1982 to 20.3 cm in 1990 and, remaining relatively constant at that low level since then. During 1990–94, small fish (15–18 cm) dominated the stock population. By contrast, big fish (40–50 cm) have been reported to be relatively abundant in trawl captures in 1973 (López Veiga and Vázquez, MS 1974). Although fish abundance was observed to decrease in all strata covered by the surveys, the pronounced decline in the total estimate was finally determined by the losses from the northern and shallow strata, where the largest portion of the West Greenland American plaice occurred during the whole 1982–94 period. No preference in depth distribution was described but American plaice has been found to be more abundant in the shallow strata (0–200 m) than in the deep strata (201–400 m) according to their different sizes (Lloret, MS 1995). A trend of decreasing fish size for American plaice with increasing latitude has also been reported (Lloret, MS 1995) and the existence of nursery grounds in the northern area off West Greenland has been suggested. By contrast, no indications for depth dependent size distribution was observed.

Significant reductions in abundance, biomass and fish size of other ecologically and economically important fish species off West Greenland have also been observed during the last 13 years (Rätz, MS 1994a); e.g. cod (*Gadus morhua*), golden and beaked redfish (*Sebastes marinus*, *S. mentella*), Atlantic and spotted wolffish (*Anarhichas lupus*, *A. minor*) and starry skate (*Raja radiata)*. Similarly, it is evident that other American plaice stocks in the Northwest Atlantic have collapsed recently; e.g. in NAFO Div. 3M (Vázquez, MS 1994; De Cárdenas and Godinho, MS 1994), NAFO Div. 3LNO (Brodie *et al.*, MS 1994) and NAFO Div. 2J and 3KL (Atkinson, 1994).

There are considerable discussions about the effects of climatic conditions and fishing effort, and their relative importance as controlling factors of population dynamics of West Greenland fish stocks (Buch and Hansen, 1988; Rätz, MS 1994a; Stein and Lloret, 1995). While climate at West Greenland has in recent years undergone marked changes, fishing activities have been affecting the ichtyofauna of this area during the past 70 years (Rätz, MS 1991).

Up to now, no studies have been conducted on the dynamics of the American plaice stock off West Greenland. This paper describes for the first time the population dynamics of that stock, and also for the first time for this species, uses Bedford's method (1983) for preparing otoliths.

Materials and Methods

Abundance and biomass estimates

Analysis of the stock abundance and biomass indices were based on data derived from the European Union annual groundfish surveys since 1982. The stratified-random surveys covered the shelf area and continental slopes off West Greenland (NAFO Div. 1B–1F, south of 67°N) from outside the 3-mile line to the 400 m isobath. The autumn season had been chosen for the survey because of favourable weather and ice clear conditions.

The area of investigation was divided in 4 geographic strata, which are represented in Fig. 1. Each of these 4 strata was subdivided into 2 strata

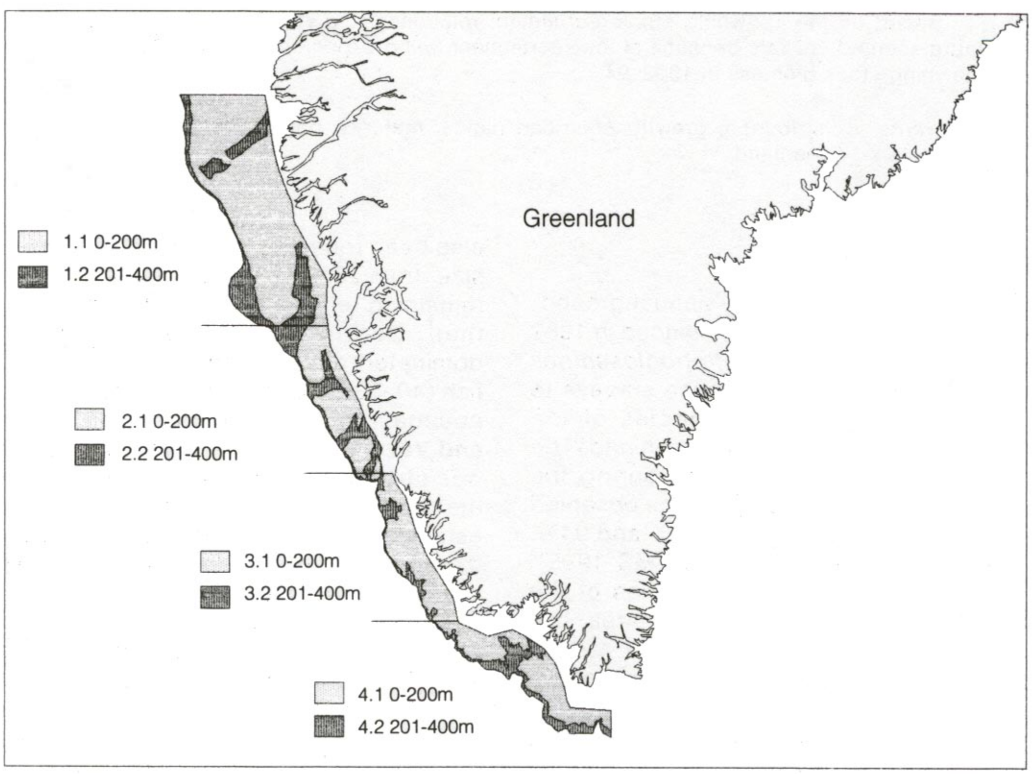

Fig. 1. Survey area and stratification as specified in Table 1.

according to the bathymetry: shallow strata (0–200 m) and deep strata (201–400 m). Table 1 specifies names of the 8 resulting strata, their boundaries, depth zones and areas.

The standard gear used was the 140-ft (42.67 m) bottom trawl with 22 m horizontal net opening. This trawl was rigged with a heavy ground gear and equipped with a small mesh liner (11 mm) inside the codend. The standard towing was for 30 min and 4.5 knots was aimed at as the towing speed. In case of net damage or hangup before 15 min of towing time, the haul was rejected from evaluation. In 1987 and 1988, some hauls were intentionally reduced to 10 min due to expected large catches based on traces of the echo sounder. These hauls were not excluded from the evaluations.

The surveys were primarily designed for the assessment of cod. The applied strategy was to distribute the sampling effort according to both stratum areas and cod abundance. Consequently, 50% of the hauls were allocated proportionally to strata by stratum area, while the other 50% were apportioned on the basis of review of the historical mean cod abundance per square naut. mile. Hauls were randomly distributed within trawlable areas of the strata. Numbers of valid hauls per stratum are listed in Table 2. The main features of effort distribution were the high number of tows allocated in shallow strata 1.1, 2.1, 3.1 and 4.1 (0–200 m), while the deep strata 1.2, 2.2, 3.2 and 4.2 (201–400 m) were characterized by extremely rough trawling grounds. Since 1992, effort had been reduced significantly (by 50%) due to technical reasons and a combination of West and East Greenland surveys.

In each haul, catch numbers and weight of American plaice were recorded. Total length measurements were determined to the centimeter below. In 1994, individual round weights were taken on board of 1 589 fish with a precision of ±5 g.

Stratified abundance and biomass estimates were calculated using the "swept area" method

TABLE 1. Specification of strata.

Stratum	Geographic boundaries				Depth	Area
	South	North	East	West	(m)	(nm^2)
1.1	64°15'N	67°00'N	50°00'W	57°00'W	1–200	6 805
1.2	64°15'N	67°00'N	50°00'W	57°00'W	201–400	1 881
2.1	62°30'N	64°15'N	50°00'W	55°00'W	1–200	2 350
2.2	62°30'N	64°15'N	50°00'W	55°00'W	201–400	1 018
3.1	60°45'N	62°30'N	48°00'W	53°00'W	1–200	1 938
3.2	60°45'N	62°30'N	48°00'W	53°00'W	201–400	742
4.1	59°00'N	60°45'N	44°00'W	50°00'W	1–200	2 568
4.2	59°00'N	60°45'N	44°00'W	50°00'W	201–400	971
Sum						18 273

TABLE 2. Numbers of valid hauls by stratum, 1982–94.

Year	Stratum								Total
	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	
1982	20	11	16	7	9	6	13	2	84
1983	26	11	25	11	17	5	18	4	117
1984	25	13	26	8	18	6	21	4	121
1985	10	8	26	10	17	5	21	4	101
1986	27	9	21	9	16	7	18	3	110
1987	25	11	21	4	18	3	21	3	106
1988	34	21	28	5	18	5	18	2	131
1989	26	14	30	9	8	3	25	3	118
1990	19	7	23	8	16	3	21	6	103
1991	19	11	23	7	12	6	14	5	97
1992	6	6	6	5	6	6	7	5	47
1993	9	6	9	6	10	8	7	0	55
1994	16	13	13	8	10	6	7	5	78

(Cochran, 1953; Saville, 1977). Coefficient of catchability was set arbitrarily at 1.0 for all species. Consequently, estimates can be considered only as trawlable abundance and biomass defined as "relative indices of total stock abundance and biomass". Strata containing less than 5 hauls were excluded from these calculations. The variation in survey area arising from this was negligible as the haul distribution was fairly consistent over the total time series. Respective confidence intervals (CI) are given at the 95% level of significance in percent of stratified mean abundance and biomass.

Otolith sampling, preparation and reading

During the survey carried out in 1994, left sagittae of individual specimens were collected from the same 1 589 fish which were measured for total length. The otoliths, especially those of bigger specimens, were opaque (Fig. 2) and were therefore embedded in a solution of black polyester resin and cut diagonally across the centre using two thin, copper-bladed saws running in diamond dust (Bedford, 1983). The cutting method resulted in sections of 0.6 mm thickness, which were mounted on translucent resin between two glass-plates. Examination through a binocular microscope using transmitted light revealed the zones of faster growth (summer) appearing dark (opaque) while zones representing slower growth (winter) appeared bright (hyaline) (Figure 3). Otoliths of specimens at ages up to 6 years were also possible to be read as a whole, but these observations were found to be less clear in comparison with the thin sections. When comparing the otoliths which could be aged by both methods, the agreement amounted to 75%. Finally, age readings of 954 otoliths were considered reproducable, which represented 60% of the total 1 589 otoliths collected initially.

Calculation of age composition and growth

Age determinations for 1994 were summarized to age-length keys by sex (Table 3) because of expected differences in growth between sexes, and assigning 1 January as the date of birth. Calculation of the age structure of the stock prior to 1994 was done applying the age-length key found for 1994 to the length composition of each year, with the underlying assumption that growth variations do not exist for all age groups during 1982–94.

Growth of American plaice off West Greenland is described for 1994 in terms of both length and weight by the von Bertalanffy growth equations (Bertalanffy, 1938).

Table 4 gives the average length of American plaice in each age-group during 1994. The samples from which these data were obtained are the same as those from which the age compositions (see below) were computed. Consequently the average length of each age-group is related to an age equal to the age-group number plus a period of 0.8 year to account for length data obtained in October. Age groups 11 and older were not used in the regressions because of the small sample size of aged otoliths. The estimated and theoretical weights of fish were computed from the observed and theoretical lengths, respectively, using the weight-length relationship equation $W = 0.0036105{*}L^{3.253315}$ with parameters of correlation being r^2=0.977 and

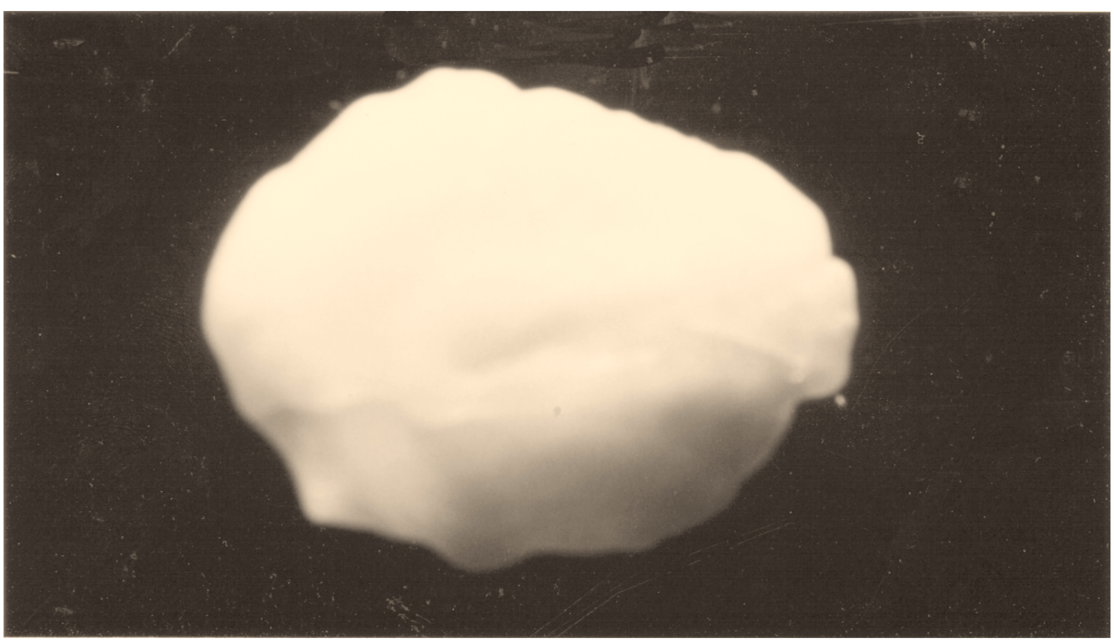

Fig. 2. Whole otolith of American plaice under binocular microscope.

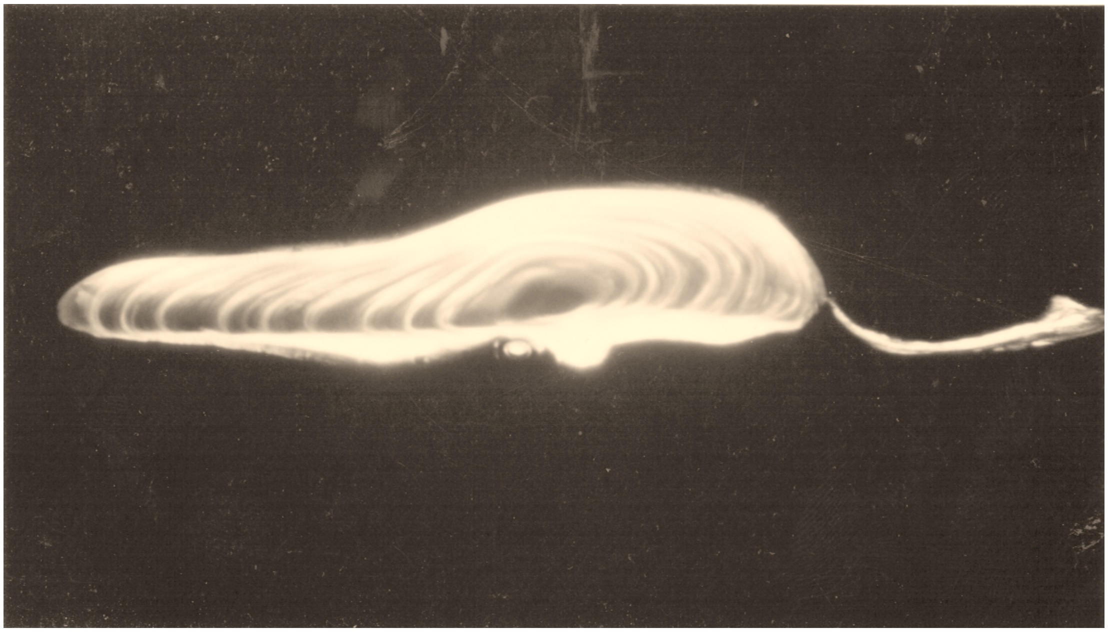

Fig. 3. Otolith section 0.6 mm in thickness (Bedford's method, 1983) of a 10 year specimen of American plaice.

p<0.0001 (Lloret, MS 1995). Thus, the theoretical curve of growth in weight was derived from the theoretical weights, and a value of W_∞ was estimated.

Sex and Maturity

Data on sex and maturity were obtained from the same 1 589 fish that were sampled during the survey in 1994. Individuals were visually classified as males (wide and short gonads), females (thick and long gonads) and undetermined sex (when sex was impossible to determine). All individuals less than 11.5 cm length were considered as undetermined.

Females were classified as immature stage I (when the ovary was pink-transparent and without eggs, and no eggs were visible under binocular microscope), and mature stages II/III/IV (when the ovary was redish and eggs were observed). No complete information was collected for male maturity, although it must be said that nearly all males captured were in the maturity stage III/IV (white testis with sperm).

As maturity data were not collected during the spawning time, the resulting maturity ogive by age must be only considered as rough estimates.

Yield and SSB per recruit analysis

Analysis of yield and spawning stock biomass per recruit was carried out (using parameters listed below). Young age groups 1, 2 and 3 were not taken in consideration for the analysis because of the unknown magnitude of their natural mortality coefficients, while the oldest age group 15 was not regarded as a plus group. A standard value of M = 0.2 was assumed for all age groups. Based on total mortality coefficients (Z) calculated, age groups older than 6 years were considered fully recruited, while partial recruitment of younger age groups was set at 0. Maturity-at-age was estimated combining the values of the female maturity ogive and an estimation, for males. Input values of weight-at-age were taken from the 1994 estimates.

Results

Growth

Parameters of the von Bertalanffy equation for growth in length for all individuals (males + females + undetermined sex) in 1994 are L_∞ = 72.52 cm, K = 0.049, and t_o = -0.74 years, with the resulting equation:

$$L_t = 72.5\,(1 - e^{-0.049\,(t + 0.74)})$$

The fitted theoretical curve based on values of both sexes is shown in Fig. 4. Theoretical lengths from the fitted curve and the observed lengths are given in Table 4. Table 4 also lists the estimated and theoretical weigths derived from the observed and theoretical lengths, respectively, by means of the equation resulting from the length-weight relationship. The estimated weights, together with the theoretical curve of growth in weight are shown in Figure 5, the latter being calculated with a W_∞ value of 4 072 g. Both Fig. 4 and 5 show a good fit over a wide range of length and weight-at-age.

TABLE 3. Age-length keys for American plaice off West Greenland (samples taken in 1994).

	Age (years)																
L_t (cm)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14+	Total
Males																	
11.5				1													1
12.5				3	3												6
13.5				7	21												28
14.5				6	31	8		1									46
15.5				17	40	24	10										91
16.5				3	21	15	22	3									64
17.5				2	8	8	18	11	2								49
18.5				2	2	4	7	6	3								24
19.5							5	7	4								16
20.5				1		2	9	5	2								19
21.5							7	1	2	2				1			13
22.5						1		1		1							3
23.5							1	1		1							3
24.5								2	1								3
25.5																	0
26.5										1							1
Total	0	0	0	42	126	62	79	38	14	5	0	0	0	1	0	0	367
Females																	
11.5				1													1
12.5				7													7
13.5				4	2												6
14.5				4	9												13
15.5				16	11	1											28
16.5				10	15	1											26
17.5				9	10	1	3										23
18.5				6	5	5	2	2									20
19.5				3	7	5	4										19
20.5					8	4	11	2	1								26
21.5					1	3	12	10	1								27
22.5					2	6	12	8	2	1							31
23.5					1	3	8	5	2	2							21
24.5					1	4	11	9	5	1							31
25.5						4	9	12	18	4	1						48
26.5							2	13	10	5							30
27.5						1	5	7	7	5	2						27
28.5						1	4	3	5	4	1						18
29.5							2	2	7	5	4	1					21
30.5							2	4	3	5							14
31.5							1	1	5		1			2			10
32.5								1		1	3	2					7
33.5										2	2	2	1				7
34.5									1			1		1	1		4
35.5																1	1
36.5											1	1					2
Total	0	0	0	60	72	39	88	79	67	35	15	7	1	3	1	1	468

TABLE 3. (Continued) Age-length keys for American plaice off West Greenland (samples taken in 1994).

	Age (years)						
L_t (cm)	0	1	2	3	4	5	Total
Undetermined sex							
4.5	2						2
5.5							
6.5							
7.5		1					1
8.5		5					5
9.5		2		1			3
10.5		1	2				3
11.5			2	3			5
12.5			3	16	3		22
13.5				11	6		17
14.5				15	11	2	28
15.5				4	4	2	10
16.5				2	5	3	10
17.5				1	3		4
18.5					1	1	2
19.5					1		1
20.5					1		1
Total	2	9	7	53	35	8	114

TABLE 4. Observed weighted mean lengths and estimated weighted mean weights for age groups 0–10 years used in the regression model to fit the von Bertalanffy growth equations in length and weight, 1994.

Age (years)	Observed length (cm) L	Theoretical length (cm) $L_t = 72.5\,(1–e^{-0.049(t + 0.74)})$	Estimated weight (g) $W = 0.0036105 * L(cm)^{3.253315}$	Theoretical weight (g) $W_t = 0.0036105 * L_t(cm)^{3.253315}$ $W_t = 4072\,(1–e^{-0.049(t + 0.74)})^{3.253315}$
-0.74		0		0
0.8	4.5	5.3	1	1
1.8	8.8	8.5	4	4
2.8	11.4	11.5	10	10
3.8	15.0	14.5	24	22
4.8	16.1	17.2	31	38
5.8	18.6	19.9	49	61
6.8	21.1	22.4	74	89
7.8	23.4	24.8	103	124
8.8	26.1	27.1	146	166
9.8	27.4	29.2	171	211
10.8	30.5	31.3	245	265

Table 5 and Fig. 6 present observed values for length-at-age calculated separately for both sexes. Based on these data it is possible to conclude that males and females have different growth patterns, females growing significantly faster than males.

Stock size and structure

Abundance and biomass indices. Tables 6 and 7 list the abundance and biomass indices respectively by stratum and total for the period 1982–94. Total abundance and biomass decreased from 72 million in 1982 to 11 million individuals in 1994, i.e. a reduction by 85%, and from 11 000 tons in 1982 to 900 tons in 1994, i.e. a reduction by 92%. During 1982–87, abundance and biomass varied enormously ranging 55–110 million individuals and 7 000–13 000 tons, respectively. In 1988, the decline of both indices was most pronounced and has continued since then.

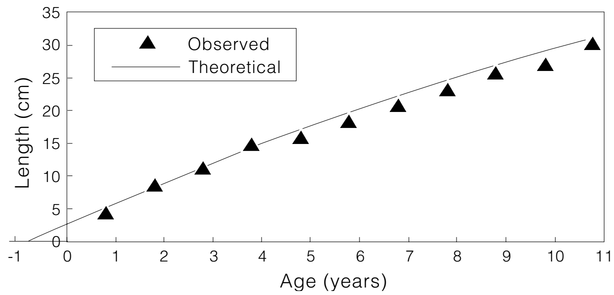

Fig. 4. Growth in length of American plaice, for both sexes combined, off West Greenland, 1994.

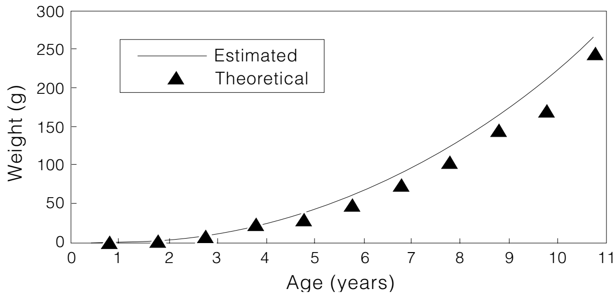

Fig. 5. Growth in weight of American plaice, for both sexes combined, off West Greenland, 1994.

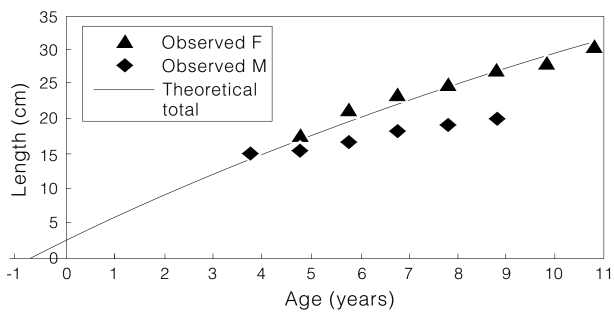

Fig. 6. Growth in length of American plaice off West Greenland in 1994. Comparison between observed females (F), observed males (M) and theoretical total.

Age composition and age distribution pattern. Tables 8 and 9 and Fig. 7 and 8 show the age disaggregated abundance and biomass indices summarized for all strata and for the period 1982–94, respectively. The main feature observed from the age disaggregated data was that all fully recruited age-groups (>5 years) suffered pronounced losses with the last year's estimations being the lowest on record. Thus, recent abundance and biomass of age groups older than 10 years have been assessed to decline by 98%. The mean age of the stock decreased from 7.8 years in 1982 to 5.8 years in 1994. During 1990–94, young fish (0–6 years old) dominated the stock population, and contributed 70% to total stock abundance in 1994.

In a previous paper (Lloret, MS 1995), a steady increase of fish size was found progressing from northern areas, i.e. stratum 1, to southern areas, i.e. stratum 3. By contrast, American plaice showed no preference in depth distribution. In this study, these described distribution features are confirmed by the presence of younger fish in northern areas and the non-existence of an age distribution pattern by depth.

Recruitment/spawning stock-recruitment relationship. Recruitment success during the last years appeared to be very poor compared to former years, although they were relatively stable when compared to the total stock abundance (no dominant year-classes were observed throughout the time period studied).

In order to investigate the presence of a spawning stock – recruitment relationship, the spawning stock biomass (SSB) data in year *n* were plotted against the strength of age groups 3 and 4 in years *n*+3 and *n*+4, respectively, and were applied to the Ricker model (Ricker, 1975) (Table 10, Fig. 9A and 9B). Calculation of SSB data was

TABLE 5. Observed weighted lengths per age group for males and females, used to compare with the theoretical curve in length, 1994.

Age (years)	Observed length (cm) Females	Observed length (cm) Males	Theoretical length (cm) Total
-0.74			0
0.8			5.3
1.8			8.5
2.8			11.5
3.8	16.0	15.2	14.5
4.8	17.7	15.3	17.2
5.8	21.8	16.5	19.9
6.8	23.6	18.1	22.4
7.8	25.3	19.1	24.8
8.8	27.3	19.8	27.1
9.8	28.0		29.2
10.8	30.5		31.3

TABLE 6. Abundance indices ($\times 10^3$) by stratum and total, 1982–94. Confidence intervals (CI) are given in percent of the stratified mean at 95% level of significance.

Year	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	Total	CI
1982	31584.0	5092.6	29597.3	5734.8	2843.8	2133.1	1041.6		78027.5	31.8
1983	46602.0	6481.0	55493.6	2870.4	2725.4	460.8	811.0		115443.3	53.8
1984	18249.6	6257.9	53764.9	4365.7	2928.5	2244.0	1793.2		89603.5	46.6
1985	21386.8	5973.1	22819.7	6185.6	2631.6	238.6	3161.5		62396.8	29.5
1986	22038.0	11392.8	58740.8	9555.6	2936.7	2387.5	4462.2		111512.8	44.6
1987	23322.1	3314.3	26226.2		2356.4		1029.5		56247.9	33.5
1988	10962.9	3475.1	8026.0	5697.7	3564.6	799.4	1035.7		33562.0	25.0
1989	9371.2	4454.0	11362.7	3774.7	8764.2		1445.0		39171.8	34.0
1990	8616.5	6464.4	8226.6	2613.6	1083.0		1491.5	605.4	29101.6	36.3
1991	7825.7	4536.1	5168.4	1898.9	1516.6	638.5	1249.0	951.8	23785.0	25.1
1992	8529.2	4996.7	3018.7	2704.2	1232.6	1707.3	1743.2	174.4	24106.3	29.4
1993	5855.9	3284.2	1201.6	1212.5	630.8	694.0	398.0		13277.0	19.7
1994	2211.6	3524.2	1488.0	1514.1	623.6	282.2	1660.5	188.8	11493.7	23.9

TABLE 7. Biomass indices (tons) by stratum and total, 1982–94. Confidence intervals (CI) are given in percent of the stratified mean at 95% level of significance.

Year	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	Total	CI
1982	6048.3	946.9	7797.1	1151	919.2	376.2	155.9		17394.1	33.7
1983	7450.1	1154.2	11772.3	606.9	1008.3	87.7	166.1		22245.6	47.3
1984	1704.0	761.1	8663.0	807.0	606.6	387.2	364.9		13293.6	51.0
1985	1940.1	600.8	3861.8	1061.6	520.0	48.7	321.3		8354.4	30.1
1986	2149.0	1147.2	8429.2	1385.1	703.3	452.1	459.7		14726.2	40.6
1987	3128.9	338.2	5469.6		645.4		227.5		9808.9	39.9
1988	918.7	292.9	1698.8	807.5	814.3	136.6	236.3		4904.5	29.0
1989	519.9	296.3	1476.7	370.5	2120.2		287.6		5070.8	54.7
1990	393.3	396.7	1219.9	313.6	212.8		286.8	221.3	3044.3	35.2
1991	348.9	398.6	487.3	259.7	265.3	125.4	188.4	172.4	2246.0	27.9
1992	581.8	419.3	228.5	183.4	150.9	250.3	151.7	25.1	1991.0	28.1
1993	324.2	221.7	83.1	101.8	66.6	70.7	25.5		893.6	20.6
1994	144.9	415.7	133.7	142.8	64.3	33.8	109.1	28.4	1072.6	32.9

TABLE 8. Age disaggregated abundance indices ($\times 10^3$) summarized for all strata, 1982–94.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	0	0	0	0	0	10	7	0	5	10	0	0	7
1	40	39	110	360	146	322	354	157	307	681	468	181	149
2	43	52	131	405	262	390	356	358	500	452	586	368	89
3	1 489	3 388	4 040	3 733	7 479	2 718	2 824	3 806	4 614	3 556	3 237	2 494	1 663
4	3 272	8 184	8 041	6 718	14 623	4 575	3 905	5 606	6 326	4 390	4 193	2 803	2 553
5	4 146	9 163	7 682	5 762	12 167	4 228	2 741	3 413	2 850	2 356	2 576	1 369	1 274
6	12 953	25 757	20 475	13 825	28 045	11 372	6 457	7 442	4 926	4 551	4 966	2 476	2 155
7	13 398	22 653	17 072	11 080	20 395	10 121	5 554	6 259	3 609	3 263	3 672	1 680	1 535
8		17 903	13 942	8 667	13 190	8 723	4 545	5 233	2 755	2 170	2 350	1 057	1 102
9	8 720	10 836	8 898	5 102	7 110	5 537	2 740	3 060	1 670	1 120	1 229	501	545
10	5 568	5 044	3 776	2 496	3 020	3 132	1 541	1 520	709	439	423	171	204
11	3 711	3 230	1 977	1 519	1 792	1 971	984	864	352	233	186	78	88
12	379	333	300	238	258	285	120	110	64	26	17	1	9
13	1 534	1 454	991	816	1 152	911	467	454	172	145	92	57	73
14	605	570	294	273	327	290	148	157	51	42	17	19	15
+14	2 516	2 012	749	552	781	851	410	325	121	144	86	17	32
Total	71 921	110 618	88 479	61 547	110 746	55 436	33 154	38 762	29 029	23 576	24 098	13 271	11 492

TABLE 9. Age disaggregated biomass indices (tons) summarized for all strata, 1982–94.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	2	1	1	2	1	1	3	2	1	1
2	0	1	1	4	3	4	4	4	5	5	6	4	1
3	36	83	99	91	182	66	69	93	113	87	79	61	41
4	100	250	245	205	446	140	119	171	193	134	128	85	78
5	202	445	373	280	591	206	133	166	139	115	125	67	62
6	960	1 909	1 517	1 024	2 078	843	478	551	365	337	368	183	160
7	1 379	2 331	1 757	1 140	2 099	1 042	572	644	371	336	378	173	158
8	1 982	2 619	2 040	1 268	1 930	1 276	665	766	403	317	344	155	161
9	1 493	1 855	1 523	873	1 217	948	469	524	286	192	210	86	93
10	1 363	1 234	924	611	739	766	377	372	173	107	104	42	50
11	1 162	1 012	619	476	561	617	308	270	110	73	58	24	28
12	125	110	99	79	85	94	40	36	21	9	6	0	3
13	376	357	243	200	282	223	114	111	42	36	23	14	18
14	220	207	107	99	119	105	54	57	18	15	6	7	5
+14	1 004	803	299	220	312	340	164	130	48	57	34	7	13
Total	10 402	13 215	9 847	6 573	10 645	6 671	3 567	3 896	2 289	1 822	1 870	908	870

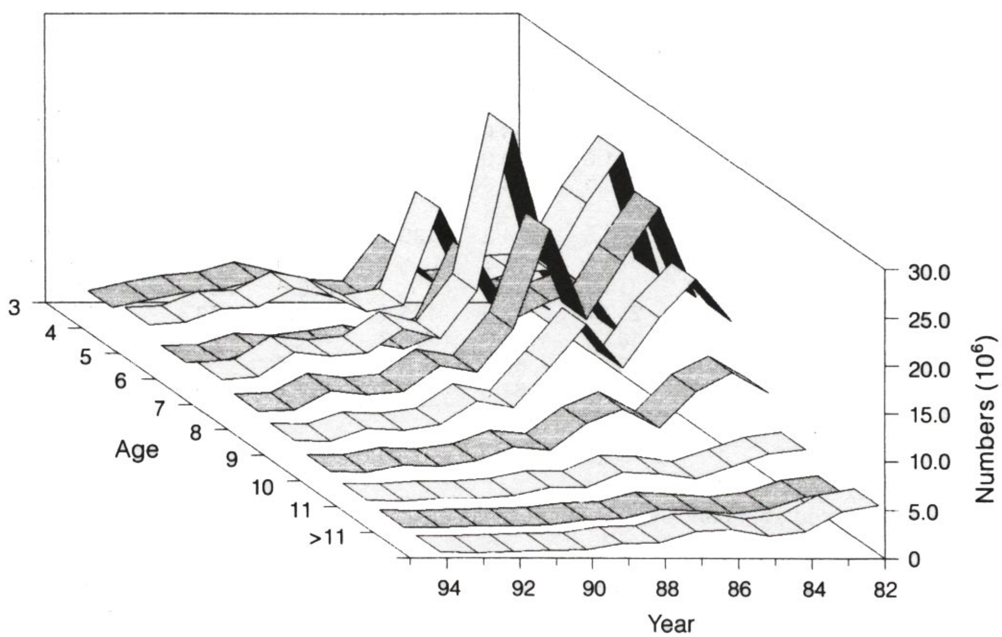

Fig. 7. Ages 0 to +11 years disaggregated abundance indices for American plaice off West Greenland, 1982–94.

done using values of maturity-at-age (estimated below). Results of this analysis show a clear relationship between SSB and recruitment. It seems evident that recruitment was significantly lower when the SSB amounts to less than 4 000 tons.

Spawning Stock

Sex composition and sexual maturity. Length and age compositions of males and females for all aggregated strata by abundance and percent are plotted in Tables 11 and 12 and shown in Fig. 10 and 11, for 1994. Fish younger than 3 years old, corresponding to a length less than 11.5 cm, were considered as undetermined. Both sexes (male and female) were observed in a more or less equal proportions up to age 6, although males dominated the 14.5, 15.5, 16.5 and 17.5 cm length-classes because of their slower growth. Beyond age 6 years and length 17.5 cm, the relative percentage of females increased. Males occurred up to an age of

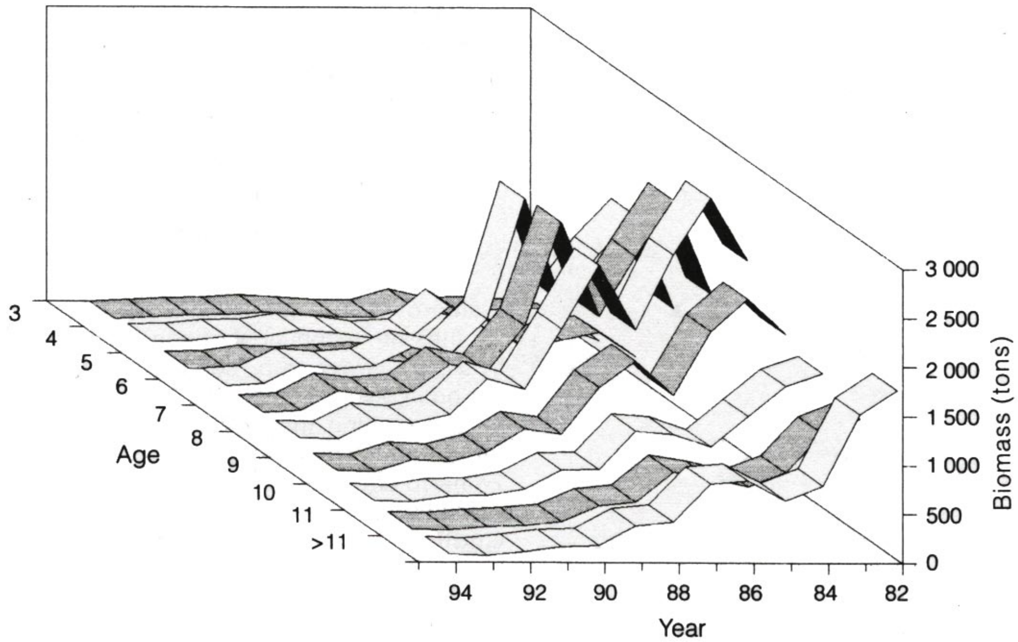

Fig. 8. Ages 0 to +11 years disaggregated biomass indices for American plaice off West Greenland, 1982–94.

TABLE 10. Spawning stock biomass (SSB)-recuitment at age 3 and 4 in numbers and derived from survey data. Recruitment was calculated using Ricker's model (Ricker, 1975).

		Age 3 ($\times 10^6$)		Age 4 ($\times 10^6$)	
Year	SSB (tons)	Observed	Calculated	Observed	Calculated
1982	8 007	3.733	4.302	14.623	6.323
1983	9 446	7.479	4.109	4.575	6.418
1984	6 843	2.718	4.362	3.905	6.104
1985	4 553	2.824	4.061	5.606	5.160
1986	7 006	3.806	4.360	6.326	6.143
1987	4 843	4.614	4.140	4.390	5.325
1988	2 512	3.556	3.023	4.193	3.524
1989	2 664	3.237	3.136	2.803	3.678
1990	1 434	2.494	2.022	2.553	2.252
1991	1 124	1.663	1.658		

13 years (28.5 cm), although only few older than age 8 (21.5 cm) were encountered. Females were observed up to age 15 years (38.5 cm), although the numbers of females older than 10 years (32.5 cm) were also negligible. As a total, sex composition for 1994 was distributed as follows: 34% males, 54% females and 12% undetermined sex.

Sexual maturity ogives at length and age for females are presented in Tables 13 and 14 and Figure 12 (handled with logistic regression fitting procedure, *logit t*) for all aggregated strata. The observed length and age at which mature females first occurred were 19.5 cm and 4 years. All were mature at a length of 33.5 cm and an age of 11–12 years. The length and age at which 50% were mature were estimated to be between 25.5 and 26.5 cm and almost 8 years. No complete information was derivable for males, nevertheless, it was observed that the length at which mature males first occurred was 12.5 cm (which corresponds to an age of 3 years) and that nearly all individuals caught were mature with running testes.

Total and Fishing Mortality

Coefficients of total mortality (Z) are listed in Table 15 and reveal pronounced age and year effects. Pre-recrutis and recruits were caught more

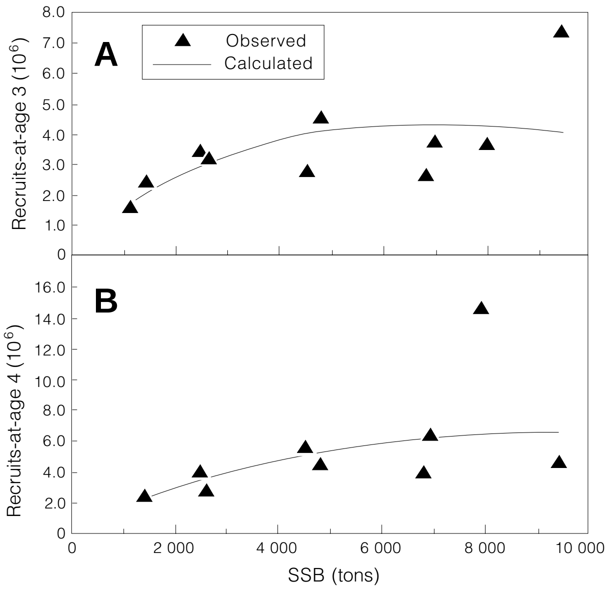

Fig. 9. (**A**) Spawning stock biomass-recruitment relation at age 3. $R = SSB * \exp(a(1 - SSB / SSBr))$, (Ricker, 1975), parameters values a = 0.55, $SSBr$ = 3774.41; (**B**) Spawning stock biomass-recruitment relation at age 4. $R = SSB * \exp(a(1 - SSB / SSBr))$, (Ricker, 1975), parameters values a = 0.60, $SSBr$ = 5749.54.

efficiently with increasing age and seemed to be fully recruited to the gear at an age of 6 years. Figure 13 illustrates these *Z* values as different to the mean over the years 1982–94. Years with a positive trend in stock abundance (e.g. 1982–83, 1985–86) displayed negative coefficients when compared to the average *Z*, while periods of stock decline (e.g. 1983–85, 1986–88 or 1992–93) were characterized by positive deviations. In particular, the time period 1992–93 showed unrealistic mortality rates. However, one of the main characteristics which is remarkable from the Table of *Z* values is that during the entire period 1982–94, coefficients increased with increasing age, independent of whether there was a period of positive trend in stock abundance or a period of stock decline. Thus, age groups 10 and 11 showed mean values of *Z* over all years of 0.89 and 2.54, respectively, which turn out to be much bigger than those of age groups 6 and 7 (0.40 and 0.48, respectively). Furthermore, *Z* during the 3 most recent years were consistently higher as compared to the mean value of the entire period 1982–94 (1.02). Assuming a standard value of natural mortality of 0.2 for all age groups 3–11, coefficients of fishing mortality were obtained (Table 16).

Yield and SSB per recruit analysis

Based on data listed in Tables 17 and 18, the resulting yield and SSB in weight-per-recruit with fishing mortality are shown in Fig. 14 and Table 19. The maximum value of the yield-per-recruit of 0.0521 kg was reached at a value of fishing mortality of 0.427 (F_{max}). The $F_{0.1}$ was calculated to amount to 0.227, which corresponds to a yield-per-recruit of 0.0484 kg.

Discussion

One of the main problems to assess American plaice dynamics is the difficulty in otolith ageing. Otoliths have commonly been prepared for ageing in several ways, e.g. examining the whole otolith stored in glycerine-ethanol, breaking them in halves and examining the broken surfaces or examining thin sections from fish greater than 35 cm. Recently, Zamarro and Brodie (MS 1990) read the otoliths by polishing the whole otolith in glycerine, meanwhile Godinho (MS 1991) polished the otoliths after surrounding them with resin, for investigation under binocular stereomicroscope with reflected light against a dark background. Otolith exchanges between Spanish and Canadian readers (Zamarro and Brodie, MS 1990) confirmed the difficulties in ageing, as agreement among readers was found to be only 27% for Div. 3M and 56% for Div. 3L, in contrast with the exchange for Div. 3N where the agreement was 80%. For these authors, the main reasons of such a high level of disagreement were the difficulties in identifying the first annual ring, due to the presence of double or split rings and difficulties with interpretation of otolith edges. The method of Bedford (1983) used here, resulting in sections of 0.6 mm thickness, can be considered as acceptable for reading otoliths of American plaice, as demonstrated in Fig. 3, and consequently to determine the age structure of the stock.

It must be also considered that the age composition of the stock for years 1982–94 resulted from applying the age-length key in 1994, only with the assumption of unchanged dominance of all age groups within the individual length groups during 1982–94 (non-existence of growth variations).

Differences in growth between sexes of American plaice off West Greenland are evident. Differences have also been reported in other areas, e.g. Flemish Cap (Bowering and Brodie, 1994) and NAFO Subdivision 3Ps (Mahé and Moguedet, MS 1991), showing also the faster growth of females compared to males. However, the main feature of the West Greenland stock growth pattern is that growth rates are slower than in all other areas. This is especially apparent when comparing with the Flemish Cap stock (Bowering and Brodie, 1994), which shows a growth pattern 2 times faster than those presented here. Lengths and ages of the West

TABLE 11. Length composition by sex in numbers and percent, 1994. Males (M), Females (F) and Undetermined sex (U).

Length (cm)	Total	M	F	U	%M	%F	%U
0.5	0	0	0	0			
1.5	0	0	0	0			
2.5	0	0	0	0			
3.5	0	0	0	0			
4.5	7	0	0	7	0.00	0.00	100.00
5.5	0	0	0	0			
6.5	0	0	0	0			
7.5	14	0	0	14	0.00	0.00	100.00
8.5	93	0	0	93	0.00	0.00	100.00
9.5	34	0	0	34	0.00	0.00	100.00
10.5	57	0	0	57	0.00	0.00	100.00
11.5	74	19	9	46	25.00	12.50	62.50
12.5	353	60	60	232	17.07	17.07	65.85
13.5	576	271	52	253	46.97	9.09	43.94
14.5	835	436	102	298	52.17	12.17	35.65
15.5	1 276	848	321	107	66.47	25.15	8.38
16.5	1 204	733	355	116	60.90	29.49	9.62
17.5	882	509	308	65	57.72	34.96	7.32
18.5	634	327	300	7	51.65	47.25	1.10
19.5	488	188	270	30	38.46	55.38	6.15
20.5	587	205	374	7	35.00	63.75	1.25
21.5	463	150	313	0	32.35	67.65	0.00
22.5	439	70	369	0	15.87	84.13	0.00
23.5	428	58	363	7	13.56	84.75	1.69
24.5	415	37	378	0	8.96	91.04	0.00
25.5	566	14	552	0	2.44	97.56	0.00
26.5	430	13	411	6	2.94	95.59	1.47
27.5	367	13	354	0	3.57	96.43	0.00
28.5	247	6	235	6	2.50	95.00	2.50
29.5	259	0	259	0	0.00	100.00	0.00
30.5	237	0	237	0	0.00	100.00	0.00
31.5	231	0	231	0	0.00	100.00	0.00
32.5	133	0	133	0	0.00	100.00	0.00
33.5	60	0	60	0	0.00	100.00	0.00
34.5	60	0	60	0	0.00	100.00	0.00
35.5	32	0	32	0	0.00	100.00	0.00
36.5	11	0	11	0	0.00	100.00	0.00
37.5	5	0	5	0	0.00	100.00	0.00
38.5	5	0	5	0	0.00	100.00	0.00

TABLE 12. Age composition by sex in numbers and percent, 1994. Males (M), Females (F) and Undetermined sex (U).

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	+14	Total
M	0	0	0	425	1 250	654	884	455	166	78	0	0	0	12	0	0	3 923
F	0	0	0	709	907	521	1 170	1 048	914	473	203	88	9	61	15	32	6 150
U	7	149	89	529	395	99	101	32	22	0	1	0	0	0	0	0	1 419
Total	7	149	89	1 663	2 553	1 274	2 155	1 535	1 102	541	204	88	9	73	15	32	11 492
M%	0	0	0	25.6	49.0	51.3	41.0	29.7	15.0	14.5	0	0	0	15.8	0	0	34
F%	0	0	0	42.6	35.5	40.9	54.3	68.3	83.0	87.5	99.4	100	100	84.1	100	100	54
U%	100	100	100	31.8	15.5	7.8	4.7	2.1	2.0	0	0.6	0	0	0.1	0	0	12

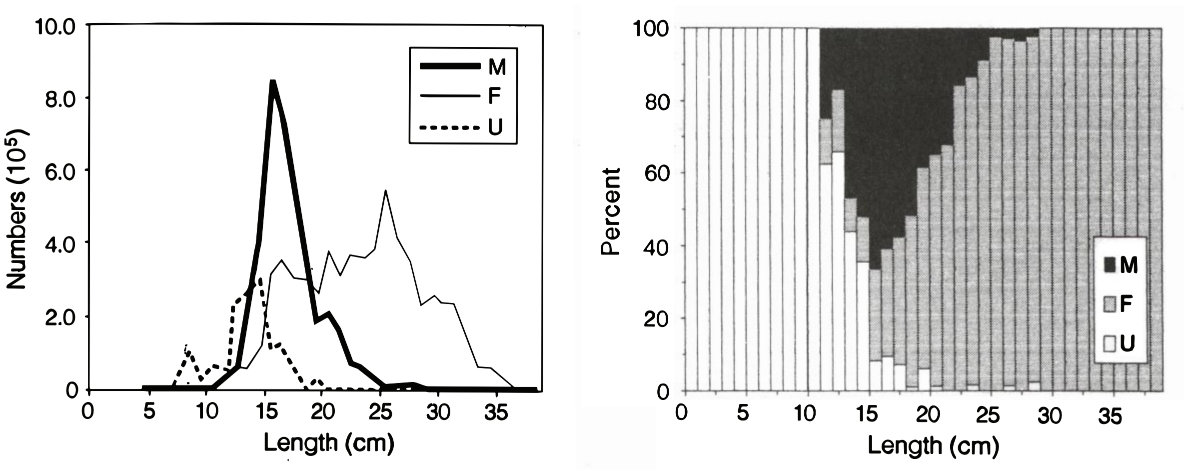

Fig. 10. Length composition in numbers and percent of American plaice off West Greenland in 1994. Males (M), Females (F) and Undetermined sex (U).

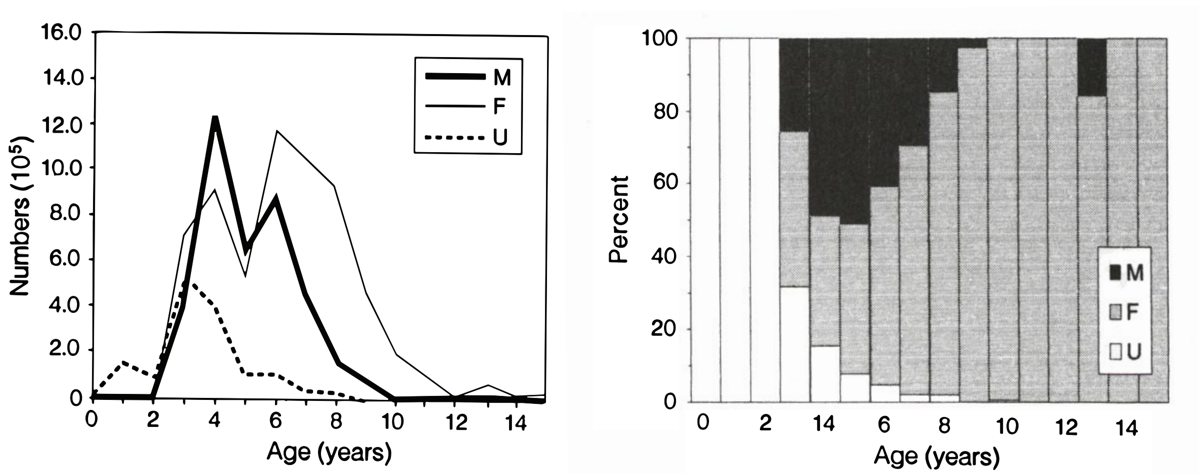

Fig. 11. Age composition in numbers and percent of American plaice off West Greenland in 1994. Males (M), Females (F) and Undetermined sex (U).

TABLE 13. Proportion mature-at-length for females, 1994.

Length (cm)	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5
%	0.00	2.78	0.00	2.17	5.66	22.0	26.2	42.5	56.9	75.9	68.4	68.3	93.9	87.1	88.9	100

TABLE 14. Proportion mature-at-age for females, 1994.

Age	3	4	5	6	7	8	9	10	11	12	13	14	+14
%	0.00	0.01	0.14	0.24	0.39	0.55	0.65	0.79	0.92	1.00	0.91	1.00	1.00

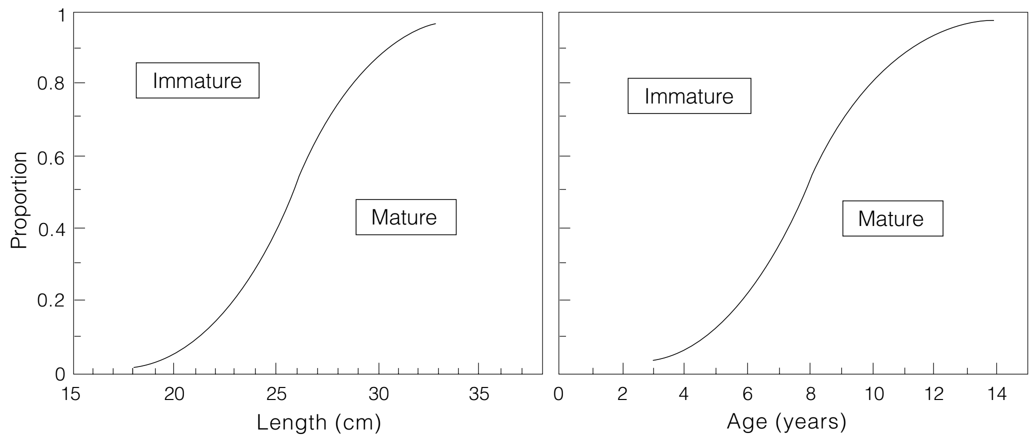

Fig. 12. Maturity ogive by length and age (years) for females American plaice off West Greenland, 1994 (data fitted by logistic regression method).

TABLE 15. Coefficients of total mortality (*Z*) for age 3–11 disaggregated abundance indices, 1982–93.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Mean 92–93	Mean 82–93
3	-1.70	-0.86	-0.51	-1.37	0.49	-0.36	-0.69	-0.51	0.05	-0.16	0.14	-0.02	-0.01	-0.46
4	-1.03	0.06	0.33	-0.59	1.24	0.51	0.13	0.68	0.99	0.53	1.12	0.79	0.81	0.40
5	-1.83	-0.80	-0.59	-1.58	0.07	-0.42	-1.00	-0.37	-0.47	-0.75	0.04	-0.45	-0.39	-0.68
6	-0.56	0.41	0.61	-0.39	1.02	0.72	0.03	0.72	0.41	0.21	1.08	0.48	0.59	0.40
7	-0.29	0.49	0.68	-0.17	0.85	0.80	0.06	0.82	0.51	0.33	1.25	0.42	0.67	0.48
8	0.22	0.70	1.01	0.20	0.87	1.16	0.40	1.14	0.90	0.57	1.55	0.66	0.93	0.78
9	0.55	1.05	1.27	0.52	0.82	1.28	0.59	1.46	1.34	0.97	1.97	0.90	1.28	1.06
10	0.54	0.94	0.91	0.33	0.43	1.16	0.58	1.46	1.11	0.86	1.69	0.67	1.07	0.89
11	2.41	2.38	2.12	1.77	1.84	2.80	2.19	2.60	2.61	2.62	4.97	2.21	3.27	2.54
Mean 6–11	0.48	0.99	1.10	0.38	0.97	1.32	0.64	1.37	1.15	0.93	2.09	0.89	1.30	1.02

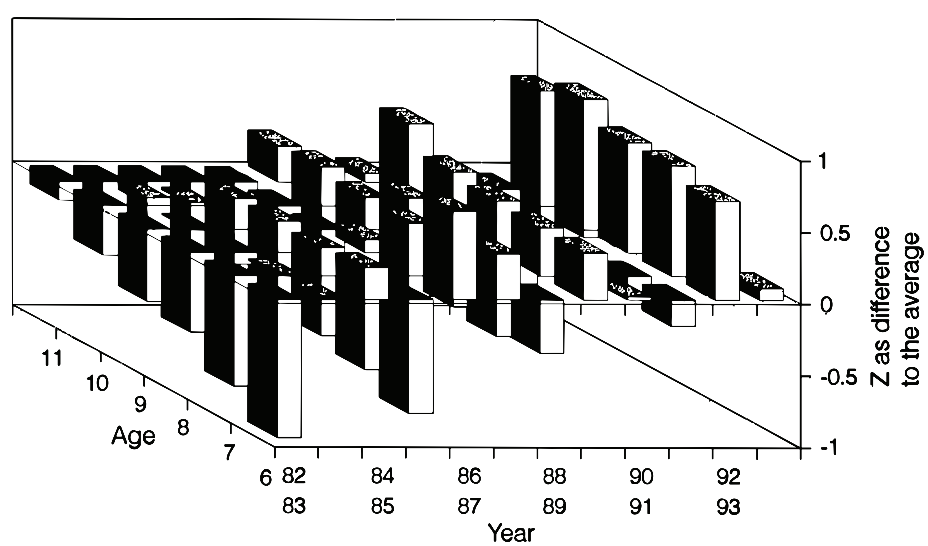

Fig. 13. Coefficients of total mortality (*Z*) as difference to the average 82–94 for American plaice off West Greenland, 1982–94 (age 11 / 1992–93 value not considered).

TABLE 16. Coefficients of fishing mortality (F) for age 3–11 disaggregated abundance indices, 1982–93.

Age	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	Mean 92–93	Mean 82–93
3	-1.90	-1.06	-0.71	-1.57	0.29	-0.56	-0.89	-0.71	-0.15	-0.36	-0.06	-0.22	-0.21	-0.66
4	-1.23	-0.14	0.13	-0.79	1.04	0.31	-0.07	0.48	0.79	0.33	0.92	0.59	0.61	0.20
5	-2.03	-1.00	-0.79	-1.78	-0.13	-0.62	-1.20	-0.57	-0.67	-0.95	-0.16	-0.65	-0.59	-0.88
6	-0.76	0.21	0.41	-0.59	0.82	0.52	-0.17	0.52	0.21	0.01	0.88	0.28	0.39	0.20
7	-0.49	0.29	0.48	-0.37	0.65	0.60	-0.14	0.62	0.31	0.13	1.05	0.22	0.47	0.28
8	0.02	0.50	0.81	-0.00	0.67	0.96	0.20	0.94	0.70	0.37	1.35	0.46	0.73	0.58
9	0.35	0.85	1.07	0.32	0.62	1.08	0.39	1.26	1.14	0.77	1.77	0.70	1.08	0.86
10	0.34	0.74	0.71	0.13	0.23	0.96	0.38	1.26	0.91	0.66	1.49	0.47	0.87	0.69
11	2.21	2.18	1.92	1.57	1.64	2.60	1.99	2.40	2.41	2.42	4.77	2.01	3.07	2.34
Mean 6–11	0.28	0.79	0.90	0.18	0.77	1.12	0.44	1.17	0.95	0.73	1.89	0.69	1.10	0.82

TABLE 17. Parameter values used for the yield and spawning stock biomass per recruit analysis. Proportion mature-at-age substracted from Table 18.

Age-group	Mean weight (kg)	Proportion mature-at-age	Partial recruitment	Natural mortality
4	0.031	0.4	0	0.2
5	0.049	0.4	0	0.2
6	0.074	0.5	1	0.2
7	0.103	0.6	1	0.2
8	0.146	0.7	1	0.2
9	0.171	0.8	1	0.2
10	0.245	0.9	1	0.2
11	0.313	0.9	1	0.2
12	0.330	1.0	1	0.2
13	0.245	1.0	1	0.2
14	0.364	1.0	1	0.2
15	0.399	1.0	1	0.2

TABLE 18. Proportion mature-at-age of females (F), males (M*estimated) and weighted total (Total*estimated), 1994.

Age	3	4	5	6	7	8	9	10	11	12	13	14	+14
F.	0.00	0.01	0.14	0.24	0.39	0.55	0.65	0.79	0.92	1.00	0.91	1.00	1.00
M*	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total*	0.40	0.40	0.50	0.60	0.70	0.80	0.90	0.90	1.00	1.00	1.00	1.00	1.00

Greenland stock ranged up to 28–29 cm and 13 years for males, and 38–39 cm and 15 years for females during 1994. In contrast, the lengths and ages of the Flemish Cap stock ranged up to 46–47 cm and 14 years for males, and 58–59 cm and 16 years for females during 1993 (Vázquez, MS 1994). The same differences are found when comparing with American plaice in Divisions 3LNO (Brodie *et al.*, MS 1994), where mean lengths-at-age in 1993 are usually 1.5 times bigger than the values for West Greenland presented here for 1994. This different growth pattern might be mainly related to the different water temperature, being much colder in Greenland than in southern areas. The slow growth rates of American plaice off West Greenland are highlighted when they are compared with those of redfish in the same area (Kosswig, MS 1980).

Growth indications were hard to derive from total length distributions for 1982–94, because no

TABLE 19. Results from the yield and spawning stock (SSB) biomass per recruit analysis.

	Fishing mortality	Catch per recruit	Yield per recruit (kg)	SSB per recruit (kg)
	0.1	0.2123	0.0341	0.3423
	0.2	0.3290	0.0467	0.2421
	0.3	0.3995	0.0510	0.1830
	0.4	0.4458	0.0520	0.1463
	0.5	0.4784	0.0519	0.1226
	0.6	0.5026	0.0514	0.1065
	0.7	0.5213	0.0507	0.0953
	0.8	0.5362	0.0502	0.0871
	0.9	0.5484	0.0496	0.0810
	1.0	0.5586	0.0492	0.0764
	1.1	0.5672	0.0488	0.0727
	1.2	0.5746	0.0485	0.0698
	1.3	0.5809	0.0483	0.0674
	1.4	0.5865	0.0481	0.0655
	1.5	0.5915	0.0479	0.0639
$F_{0.1}$	0.227	0.3514	0.0484	
F_{max}	0.427	0.4556	0.0521	

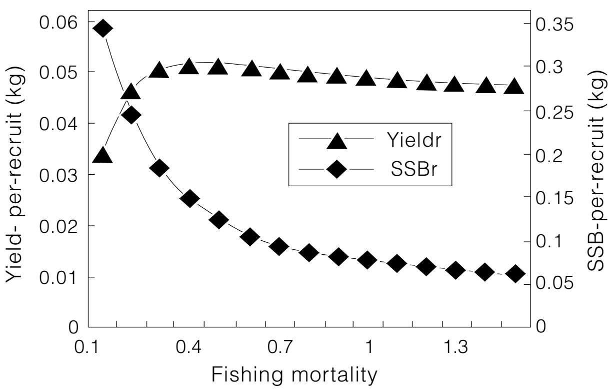

Fig. 14. Yield-per-recruit (*Yieldr*) and spawning stock biomass-per-recruit (*SSBr*) against fishing mortality for American plaice off West Greenland.

clear reappearing peaks at frequent length groups were observed. The same applied when looking for frequent length groups between successive years. These can be due to the relatively slow growth. Furthermore, validation of otolith ageing from age composition is also not possible. Nevertheless, the general fit of the mean length-at-age data to the von Bertalanffy growth model indicated an acceptable precision of the methodology used.

The mean age at 50% maturity (A_{50}) found for females in 1994, i.e. about 8 years old, is similar to that reported for females in Div. 3LNO during 1993 by Brodie *et al.*, (MS 1994), which was observed to be between 8.5 and 9 years. On the other hand, the estimated length at 50% maturity (L_{50}) corresponding to that A_{50} value, 40 cm, is considerably larger than the one shown here (25.5–26.5 cm) for West Greenland. It would appear, therefore, that the attainment of sexual maturity for American plaice for these two areas may be more a function of age than body size, since A_{50} are similar whereas the L_{50} differ largely. For other areas, like Flemish Cap or Grand Bank, females have been observed to have different lengths and ages at 50% maturity than those presented here, e.g. 39.7 cm and 6.2 years for Flemish Cap during 1978–95 (Bowering and Brodie, 1994), and 41.5–43.7 cm and 8.8–14 years for Grand Bank (Pitt, 1975). Nevertheless, the gap of time between those values and those computed here, and the fact that A_{50} of females can change over years as demonstrated for Div. 3LNO (Brodie *et al.*, MS 1994) should be considered. Bowering and Brodie (1994) suggested that attainment of sexual maturity could be more a function of body size than age, since the L_{50} were similar throughout these areas whereas ages sometimes varied by several years.

Comparing the weighted mean age of American plaice in shallow and deep strata, no pronounced differences could be derived, indicating that there was no depth dependent age distribution. By contrast, the resulting trend of decreasing fish age with increasing latitude confirms the existence of nursery grounds in the northern area off West Greenland, a phenomenon that is also expected for other species in the area, i.e. redfish (Rätz, MS 1994b).

It is clear from the presented indices that the stock declined in the mid-1980s, showing a sudden drop from 1986 to 1988. This effect coincided with high fishing activity in the area. In 1994, abundance and biomass indices have been observed to be nearly 90% lower than those of 1982. Although there has been no fishing effort directed to groundfish since 1990, the stock lacked any signs of recovery but in fact continued to decline. Older age groups were observed to have always suffered the biggest and most spectacular losses when relative values were considered. This is reflected by the fact that total mortality coefficients of older age groups have been much higher than those of youngest age groups for all years considered, independent of whether there was a period of positive trend in stock abundance or a period of stock decline. The observed decreasing trend of the mean age of the stock from 7.8 years in 1982 to 5.8 in 1994 was also a direct consequence of the observed higher mortality of older fish. During 1990–94, the young fish (0–6 years old) dominated the stock population. Although these age groups contributed 70% to total stock abundance in 1994, recruitment was considered to be low. Pre-recruiting age groups 3–5 and the 6 and 7 year olds showed the lowest abundance indices since 1982.

Total and fishing mortality coefficients have been observed to fluctuate in magnitude according to changes in abundance indices over the surveyed years. Annual mean fishing mortalities have been usually higher than calculated $F_{0.1}$ and F_{max} biological reference points (0.227 and 0.427, respectively). Only the 1982–83 and 1985–86 fishing mortality coefficients (0.28 and 0.18, respectively) appeared to be smaller than the computed F_{max}. When the $F_{0.1}$ was considered, only the estimate of 1985–86 was below this value. Although direct fishing effort for groundfish ended in 1990, fishing mortalities during recent years appeared to be still very high, ranging close to values of former years or even greater as demonstrated by the fact that the mean value for age groups 3–11 over last 3 years 1992–94 (1.10) was above the mean value of the entire period 1982–94 (0.82). Similar values of $F_{0.1}$ and F_{max} have been reported recently for American plaice in Div. 3LNO ($F_{0.1}$ = 0.25, F_{max} = 0.50; NAFO, 1993).

As demonstrated from the age composition, the population abundance of American plaice off West Greenland did not appear to be dominated by any year-class through the time period studied. Thus, recruitment in this area might be considered as being relatively stable. The same characteristic was also found by Pitt (1975) for Labrador and Newfoundland areas. On the contrary, Vázquez (MS 1994), De Cárdenas and Godinho (MS 1994) and Bowering and Brodie (1994), while studying American plaice in Flemish Cap, noted the presence of dominant year-classes throughout that area. Walsh (1994) reported an increasing south to north latitudinal gradient in recruitment, which is in contrast with the relative stability shown here for American plaice inhabiting a northern area such as West Greenland. In this sense, it may be suggested that the sharp decline suffered by the spawning stock of American plaice off West Greenland with the consequent recruitment failure, has masked any possible recruitment variability due to biotic or abiotic processes. However, there was a good fit of the data with the Ricker curve (Ricker, 1975), although the stock was in a poor condition and the period of investigation was relatively short (13 years). A stock-recruitment relationship has been also observed for other American plaice stocks, e.g. in Div. 3LNO (Brodie *et al.,* MS 1994).

Fishing activities directed to groundfish in former years appeared to have been the main responsible factor for the observed continuous losses of these large old fish, as no indication of movement to deep waters was observed when contrasting the weighted mean ages of strata aggregated by depth between successive years. Comparison of coefficients of fishing mortality over the years with the spawning stock biomass per recruit, supports this idea. Furthermore, the fact that there was no depth dependent size distribution and that only few American plaice were caught in some deep trawls (>400 m) carried out in 1994 indicates that a small part of the spawning stock may exist beyond the depth range covered by surveys, which is mainly where fishing activities developed for years. Thus, as the area where heavy fishing activities have been taking place coincides with the depth range where most of spawning stock of American plaice is believed to inhabit, without any additional recruitment being expected from mature fishes other than those inhabiting this area, the suggested culpability of overfishing on stock decline is formulated. The possible contribution of environmental factors to the stock collapse, like the West Greenland climate cooling since 1989 (Stein and Lloret, 1995), seems to have less weight because it is hard to believe that climatic conditions could cause an increase of natural mortality in large fish. As described, total mortalities during recent years are still observed to be very high, and especially the supposed large old mature females-continued to disappear, although there has been no direct fishing effort for groundfish since 1991. The expected stock recovery with the absence of groundfish fisheries has not been observed. There is however a possible negative effect of by-catches in the shrimp fishery taking place nowadays in the area off West Greenland. Unfortunately, no information is available on the quantity of these by-catches. The causes which could have led to stock size reductions of other American plaice stocks in the Northwest Atlantic are still under discussion too, e.g. in Div. 3LNO (Brodie, MS 1990).

It is hard to expect optimistic future predictions from the data presented here. A stock recovery in the near future seems unlikely because of low recruitment being expected from extremely low spawning stock biomass in 1992–94, and the persistence of high mortality coefficients. The interpretation of population dynamics of American plaice off West Greenland could possibly also include consideration of more global processes impacting fish assemblages, like the "ecosystem stress" effect reported by Rätz (MS 1991), or the existence of possible "ecological cycles" as those suggested by Larrañeta (MS 1984) for American plaice in Div. 3LNO. Notwithstanding what mechanisms are influencing dynamics of this stock, the effects of by-catches in the shrimp fishery should be taken into future considerations when looking for a possible relationship between that fishery and a recovery of the American plaice stock off West Greenland.

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