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

by

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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, 3LNO). The M_{50} values for maturity at length and age for females were estimated to vary between 25.5 and 26.5cm and at a corresponding age around 8 years. A trend of decreasing fish age with increasing latitude suggests 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 by 90% 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 is characterized by nearly continuous losses. During 1990-94, young fish (0-6 years old) have dominated the stock population, contributing 70% to total stock abundance in 1994. The recently depleted status of the American plaice stock off West Greenland is reflected by significant reductions in mean age from 7.8 years in 1982 to 5.8 years in 1994. Older age groups have suffered the biggest losses during the entire period 1982-94 when relative values are considered. Losses are reflected by high total and fishing mortality coefficients, which have been 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 found, a stock recovery in the near future seems unlikely because of low recruitment being expected from the extremely low spawning stock biomass in 1992-94.

INTRODUCTION

Based on annual groundfish surveys commenced in 1982, American plaice was found to be the second dominating species of the demersal fish assemblage off West Greenland and has undergone great changes in abundance and biomass. During 1982-94, a sharp decline in abundance and biomass indices by 85% and 94% was observed, respectively (Rätz, 1994a; Lloret, 1995). Although there is no fishing effort directed to groundfish since 1990, the stock lacked any signs of recovery, but continued to decline. The recently depleted status of the American plaice stock off West Greenland is reflected by significant fish size reductions from 28.1cm in 1982 to 20.3cm in 1990, remaining relatively constant at that low level since then. During 1990-94, small fish (15-18cm) have dominated the stock population. By contrast, big fish (40-50cm) has been reported to be relatively abundant in trawl captures in 1973 (López de Veiga and Vázquez, 1974). Although fish was observed to decrease from all strata covered by surveys, the pronounced decline of the total estimates 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 period 1982-94. No preference in depth distribution was described but American plaice has been found to be more abundant in shallow strata (0-200m) than in deep strata (201-400m) according to their different sizes.

Significant reductions of the 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, 1994a), i.e. cod (*Gadus morhua*), golden and beaked redfish (*Sebastes marinus, S. mentella*), Atlantic and spotted wolffish (*Anarhichas lupus, A. minor*) and starry skate (*Raja radiata*). Furthermore, it is evident that other American plaice stocks in the Northwest Atlantic have collapsed recently, e.g. in NAFO Division 3M (Vázquez, 1994; De Cárdenas and Godinho, 1994), NAFO Divisions 3LNO (Brodie, Morgan and Power, 1994) and NAFO Divisions 2J and 3KL (Atkinson, 1994).

There are controverse discussions about the effects of climatic conditions and fishing effort and their weight as controlling factors of population dynamics of West Greenland fish stocks (Buch and Hansen, 1988; Rätz, 1994a; Stein and Lloret, 1995). While climate at West Greenland has undergone very marked changes, fishing activities have been affected the ichtyofauna of this area during the past 70 years (Rätz, 1991). American plaice, like other species inhabiting the zone, has been usually caught as by-catch in cod, redfish and shrimp fisheries.

A trend of decreasing fish size for American plaice with increasing latitude has been reported (Lloret, 1995) and suggested the existence of nursery grounds in the northern area off West Greenland. By contrast, no indications for depth dependent size distribution was observed.

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

MATERIALS AND METHODS

Abundance and biomass estimates

Analysis of the stock abundance and biomass indices are based on data derived from annual groundfish surveys established in 1982. The stratified-random surveys covered the shelf area and continental slope off West Greenland (NAFO Div. 1B-1F, south of 67°N) outside the 3-mile limit to the 400m isobath. The autumn season was chosen for the survey because of favourable weather and ice conditions.

The area of investigation is divided in 4 geographic strata, which are represented in Figure 1. Each of these 4 strata was subdivided into 2 strata according to the bathymetry: shallow strata (0-200m) and deep strata (201-400m). Table 1 specifies names of the 8 resulting strata, their boundaries, depth zones and areas.

The standard gear used was the 140-feet bottom trawl with 22m horizontal net opening. This trawl was rigged with a heavy ground gear and equipped with a small mesh liner (11mm) inside the cod end. Standard towing required 30 minutes and 4.5 knots were aimed as the towing speed. In case of net damage or hangup before 15 minutes towing time, the haul was rejected from evaluation. In 1987 and 1988, some hauls were not excluded although their towing time was intentionally reduced to 10 minutes due to large catches being expected from traces of the echo sounder.

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

Catch number and weight of American plaice (*Hippoglossoides platessoides*) were recorded. Total lengths measurements were determined to the centimeter below. In 1994, 1,589 individual round fish weightings on board were conducted with a precision of 5g.

Stratified abundance and biomass estimates are calculated using the "swept area" method (Cochran, 1953; Saville, 1977). Coefficient of catchability is set arbitrarily to 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 including less than 5 hauls are excluded from calculations. The variation in survey area arising therefrom is 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 per cent of stratified mean abundance and biomass.

Otolith sampling, preparation and reading

During the annual groundfish survey carried out in 1994, 1589 left sagittae of individual specimens were collected. The otoliths, especially those of bigger specimens, are opaque (Figure 2) and were therefore embedded in a solution of black polyester resin and cut diagonally across the centre using two thin, copperbladed saws running in diamond dust (Bedford, 1983). The cutting method resulted in lamines of 0.6mm 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 (sommer) appearing dark (opaque) while zones representing slower growth (winter) appeared bright (hyaline) (Figure 3). Otoliths of specimens at an age 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 reproduable, which represents 60% of the 1589 otoliths collected initial.

Calculation of age composition and growth

Age determinations for 1994 were summaryzed to age-length keys by sex (Table 3) because of expected differences in growth between sexes, and assigning 1st January as the date of birth. Calculation of the age structure of the stock prior to 1994 was done aplying the age-length key found for 1994 to the length composition of those years, with the underlying assumption of non-existing growth variations for all age groups during 1982-94.

Growth of American plaice off West Greenland is described for 1994 in both terms of length and weight by the von Bertalanffy growth equations (Bertalanffy, L.v., 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 of Table 8 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 few number of aged otoliths. The estimated and theoretical weights of fish were computed from the observed and theoretical lengths, respectively, by means of the weight-length relationship equation $W = 0.0036105*L^{3.253315}$, parameters of correlation being $r^2=0.977$ and $p<0.00000$ (Lloret, 1995). Thus, the theoretical curve of growth in weight is derived from the theoretical weights, and a value of $W_{infinite}$ is estimated.

Sex and Maturity

Data on sex and maturity were obtained from the same fish that were sampled during the survey in 1994. Individuals were visually classified as males (wide and short gonad), females (long thick gonad) and undetermined sex (when sex was impossible to determine). All individuals less than 11.5cm 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), and mature stages III/IV (when the ovary was white or redish and eggs were observed). No complete information was colected for males 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 colected 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 in Table 18. 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 standard value of M=0.2 was assumed for older age groups. Based on total mortality coefficients (Z) calculated, age groups older than 6 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 (Table 17). Input values of weight at age were taken from the 1994 estimates.

RESULTS

1. Growth

Parameters of the von Bertalanffy equation for growth in length for total individuals (males + females + undetermined sex) in 1994 are:

$L_{infinite}$ = 72.52cm
K = 0.049
t_o = -0.74 years

resulting in the equation $Lt=72.5(1-e^{-0.049(t+0.74)})$.

The fitted theoretical curve based on values of both sexes is shown in Figure 4. Theoretical lengths from the fitted curve and the observed lengths are given in Table 4. This Table 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 $W_{infinite}$ value of 4072 g. Both Figures 4 and 5 show a good fit over a wide range of length and weight at age.

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

2. Stock size and structure

2.1 Abundance and biomass indices

Tables 6 and 7 list the abundance and biomass indices respectively by stratum and total, 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 among 55-110 million individuals and 7,000-13,000 tons, respectively. In 1988, the decline of both indices was most pronounced and continued since then.

2.2 Age composition and age distribution pattern

Table 8 and 9 and Figures 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 Tables and Figures is that all fully recruited age groups (>5 years) suffered pronounced losses with the last years 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 in 1994. During 1990-94, young fish (0-6 years old) have dominated the stock population, and contributed 70% to total stock abundance in 1994.

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

2.3 Recruitment. Spawning stock-recruitment relationship

Recruitment success during last years appears to be very poor compared to former years, although being relatively stable when compared to the total stock abundance (no dominant year classes are 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, Figures 9A and 9B). Calculation of SSB data was done using values of maturity at age estimated in Table 17. Results of this analysis show a clear relationship between spawning stock biomass and recruitment. It seems evident that recruitment is significantly lower when the spawning stock biomass amounts to less than 4,000 tons.

2.4 Spawning Stock. Sex composition and sexual maturity

Length and age compositions of males and females for all aggregated strata by abundance and per cent are plotted in Tables 11 and 12 and shown in Figures 10 and 11, for 1994. Fish younger than 3 years old, corresponding to a length less than 11.5cm, 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 17.5cm length classes because of their slower growth. Beyond this age (6 years) and this length (17.5cm), the relative percentage of females increased. Males occurred up to an age of 13 years (28.5cm), although there were encountered only few older than age 8 (21.5cm). Females were observed up to age 15 (38.5cm), although the numbers of females older than 10 years (32.5cm) 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 19.5cm and 4 years. All were mature at a length of 33.5cm and an age of 11-12 years. The length and age at which 50% were mature were estimated to be between 25.5 and 26.5cm and almost 8 years. No complete information was derivable for males; nevertheless it was observed that length at which mature males first occurred was 12.5cm (which corresponds to an age of 3 years old) and that nearly all individuals caught were mature with running testis.

3. 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 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 difference to the mean over years 1992-94. Years of positive trend in stock abundance (e.g. 1982-83, 1985-86) display negative coefficients when compared the average Z, while periods of stock decline (e.g. 1983-85, 1986-88 or 1992-93) are characterized by positive deviations. In particular the time period 1992-1993 shows 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, independently if there was a period of positive trend in stock abundance or a period of stock decline. Thus, age groups 10 and 11 present mean values of total mortality overall years of 0.89 and 2.54, respectively, which turn to be much bigger than those of age groups 6 and 7 (0.40 and 0.48, respectively). Furthermore, total mortalities during the 3 most recent years are consistently higher as compared to the mean value of the entire period 1982-94 (1.02). Assuming a standard value of natural mortality = 0.2 for all age groups 3-11, coefficients of fishing mortality are obtained (Table 16).

4. Yield and SSB per recruit analysis. Biological reference points $F_{0.1}$ and F_{max}.

Figure 14 and Table 19 show the resulting yield and spawning stock biomass in weight per recruit with fishing mortality based on data listed in Table 18. The maximum value of the yield per recruit -0.0521 kg- is reached at a value of fishing mortality of 0.427 (F_{max}). $F_{0.1}$ 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 difficulties in otolith ageing. Otoliths have been prepared for ageing in several ways, e.g examining the whole otolith stored in glycerine-ethanol, breaking them in halfes and examining the broken surfaces or examining thin sections from fish greater than 35 cm. Recently, Zamarro and Brodie (1990) read the otoliths by polishing the whole otolith in glycerine meanwhile Godinho (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, 1990) confirmed the difficulties for ageing, as agreement was found to be only 27% for Division 3M and 56% for Division 3L, in contrast with the exchange for Division 3N where the agreement was 80%. For these authors, the main reasons of such a high level of disagreement were difficulties in identifying the first annual ring, the presence of double or splitted rings and difficulties with interpretation of otolith edges. The method of Bedford (1983) used here, resulting in lamines of 0.6mm thickness, can be considered as acceptable for reading otoliths of American plaice, as demonstrated from Figure 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 results 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-existing 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, 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, which shows a growth pattern which is 2 times faster than the presented here (Bowering and Brodie, 1994). Lengths and ages of the West Greenland stock ranged up to 28-29cm and 13 years for males, and 38-39cm and 15 years for females during 1994. Contrarily lengths and ages of the Flemish Cap stock ranged up to 46-47cm and 14 years for males, and 58-59cm and 16 years for females during 1993 (Vázquez, 1994. The same differences are found when comparing with American plaice in Divisions 3LNO (Brodie, Morgan and Power, 1994), whose mean lengths at age in 1993 are usually 1.5 times bigger than the values of 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 enhanced when comparing with those of redfish in the same area (Kosswig, 1980).

Growth indications are hardly derivable from total length distributions for 1982-94 because no clear reappearing peaks at frequent length groups are observed. The same applies when looking for frequent length groups between successive years, and 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 indicates an acceptable precission 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 Divisions 3LNO during 1993 by Brodie, Morgan and Power (1994), which was observed to be between 8.5 and 9 years. On the other hand, the estimated length at 50% maturity corresponding to that A_{50} value, 40cm, is considerably larger than the one shown here (25.5-26.5cm) 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 lengths differ largely. For other areas, like Flemish Cap or Grand Bank, females have been observed to have different lengths and ages at M_{50} than those presented here, e.g. 39.7 cm and 6.2 years for Flemish Cap during 1978-95 (Bowering and Brodie 1994), and 41.5-43.7cm and 8.8-14 years for Grand Bank (Pitt, 1975). Nevertheless, the gap of time between these values and those computed here, and the fact that age at M_{50} of females can change over years as demonstrated for Divisions 3LNO (Brodie, Morgan and Power, 1994) should be considered. Bowering and Brodie (1994) suggest that attainment of sexual maturity could be more a function of body size than age, since the lengths at M_{50} were similar throughout these areas whereas ages sometimes varied by several years.

Comparing the weighted mean age of shallow and deep strata, no pronounced differences are derivable, indicating that there is 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, 1994b).

It is clear from the presented indices that the stock declined in the mid-1980's, showing a sudden drop from 1986 to 1988. This effect coincides with a 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 continued to decline. Older age groups have always suffered the biggest and most spectacular losses when relative values are 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, independently if there was a period of positive trend in stock abundance or a period of stock decline. The obseved decreasing trend of the mean age of the stock from 7.8 years in 1982 to 5.8 in 1994 is also a direct consequence of the observed higher mortality of older fish. During 1990-94, young fish (0-6 years old) have dominated the stock population. Although these age groups contributed 70% to total stock abundance last year (1994), recruitment is considered to be low. Pre-recruiting age groups 3-5 and the 6 and 7 years old 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) appear to be smaller than the computed F_{max}. When the $F_{0.1}$ is considered, only the estimate of 1985-86 is below this value. Although direct fishing effort for groundfish ended in 1990, fishing mortalities during recent years appear 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) is 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 Divisions 3LNO ($F_{0.1} = 0.25$, $F_{max} = 0.50$; NAFO SCR 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. Contrarily, Vázquez (1994), De Cárdenas and Godinho (1994) and Bowering and Brodie (1994) while studying American plaice in Flemish Cap, and Brodie and Bowering (1991) for Grand Bank, noted the presence of dominant year classes throughout those areas. Walsh (1994) reported an increasing south to north latitudinal gradient in recruitment, which is in contrast with the relative stability showed 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 is 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 is relatively short (13 years). A stock-recruitment relationship has been also observed for other American plaice stocks, e.g. in Divisions 3LNO (Brodie, Morgan and Power, 1994).

Fishing activities directed to groundfish in former years could have been the main responsible factor of the observed continuous losses of these large old fish, as no indication of movement to deep waters is 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 is no depth dependent size distribution and that only few American plaice were caught in some deep trawls (>400m) carried out in 1994 indicates that there may exist a small part of the spawning stock beyond the depth range covered by surveys, which is mainly the same 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 inhabite, 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 refered 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 fish - especially 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 absence of groundfish fisheries is not observed, and the possible negative effect of by-catches in the shrimp fishery taking place nowadays in the area off West Greenland is formulated. Unfortunatelly, 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 Divisions 3LNO (Brodie, 1990).

Optimistic future predictions are hardly to expect from the presented data. 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 dynamics of American plaice off West Greenland may also include consideration of more global processes impacting fish assemblages, like the „ecosystem stress" effect reported by Rätz (1991), or the existence of possible „ecological cycles" as those suggested by Larrañeta for American plaice in Divisions 3LNO (1984). Anyway, whatever the mechanisms influencing dynamics of this stock, knowledge of by-catches by the shrimp fishery should be taken in future in consideration to look for a possible incompatibility between this fishery and recovery of the American plaice stock off West Greenland.

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Table 1 Specification of strata.

Stratum	geographic boundaries south	north	east	west	depth (m)	area (nm2)
1.1	64°15'N	67°00'N	50°00'W	57°00'W	1-200	6805
1.2	64°15'N	67°00'N	50°00'W	57°00'W	201-400	1881
2.1	62°30'N	64°15'N	50°00'W	55°00'W	1-200	2350
2.2	62°30'N	64°15'N	50°00'W	55°00'W	201-400	1018
3.1	60°45'N	62°30'N	48°00'W	53°00'W	1-200	1938
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	2568
4.2	59°00'N	60°45'N	44°00'W	50°00'W	201-400	971
Sum						18273

Table 2 Numbers of valid hauls by stratum and total, 1982-94.

YEAR	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	TOTAL
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

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

Males

L_t (cm)	Age (years) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14+	Total
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

Lt (cm)	Age (years) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14+	Total
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

Undetermined sex

Lt (cm)	Age (years) 0	1	2	3	4	5	Total
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 weighths for age groups 0-10 years used in the regression model to fit the Von Bertalanffy growth equations in length and weight, 1994.

AGE	OBSERVED LENGTH (cm) L	THEORETICAL LENGTH (cm) $Lt=72.5(1-e^{-0.049(t+0.74)})$	ESTIMATED WEIGHT (g) $W(g)=0.0036105*L(cm)^{3.253315}$	THEORETICAL WEIGHT (g) $W(g)=0.0036105*Lt(cm)^{3.253315}$
-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 Observed weighted lengths per age group for males and females, used to be compared with the theoretical curve in length, 1994.

AGE	OBSERVED LENGTH FEMALES	OBSERVED LENGTH MALES	THEORETICAL LENGTH 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 (n*1,000) by stratum and total, 1982-94. Confidence intervals (CI) are given in per cent 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 per cent 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 (1000) 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	1489	3388	4040	3733	7479	2718	2824	3806	4614	3556	3237	2494	1663
4	3272	8184	8041	6718	14623	4575	3905	5606	6326	4390	4193	2803	2553
5	4146	9163	7682	5762	12167	4228	2741	3413	2850	2356	2576	1369	1274
6	12953	25757	20475	13825	28045	11372	6457	7442	4926	4551	4966	2476	2155
7	13398	22653	17072	11080	20395	10121	5554	6259	3609	3263	3672	1680	1535
8		17903	13942	8667	13190	8723	4545	5233	2755	2170	2350	1057	1102
9	8720	10836	8898	5102	7110	5537	2740	3060	1670	1120	1229	501	545
10	5568	5044	3776	2496	3020	3132	1541	1520	709	439	423	171	204
11	3711	3230	1977	1519	1792	1971	984	864	352	233	186	78	88
12	379	333	300	238	258	285	120	110	64	26	17	1	9
13	1534	1454	991	816	1152	911	467	454	172	145	92	57	73
14	605	570	294	273	327	290	148	157	51	42	17	19	15
+14	2516	2012	749	552	781	851	410	325	121	144	86	17	32
Total	71921	110618	88479	61547	110746	55436	33154	38762	29029	23576	24098	13271	11492

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	1909	1517	1024	2078	843	478	551	365	337	368	183	160
7	1379	2331	1757	1140	2099	1042	572	644	371	336	378	173	158
8	1982	2619	2040	1268	1930	1276	665	766	403	317	344	155	161
9	1493	1855	1523	873	1217	948	469	524	286	192	210	86	93
10	1363	1234	924	611	739	766	377	372	173	107	104	42	50
11	1162	1012	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	1004	803	299	220	312	340	164	130	48	57	34	7	13
Total	10402	13215	9847	6573	10645	6671	3567	3896	2289	1822	1870	908	870

Table 10 Spawning stock biomass-recuitment at age 3 derived from survey data. Recruitment was calculated using Ricker's model (Ricker, 1975).

YEAR	SSB (tons)	AGE 3 obs. (1000)	AGE 3 cal. (1000)	AGE 4 obs. (1000)	AGE 4 cal. (1000)
1982	8007	3733	4302	14623	6323
1983	9446	7479	4109	4575	6418
1984	6843	2718	4362	3905	6104
1985	4553	2824	4061	5606	5160
1986	7006	3806	4360	6326	6143
1987	4843	4614	4140	4390	5325
1988	2512	3556	3023	4193	3524
1989	2664	3237	3136	2803	3678
1990	1434	2494	2022	2553	2252
1991	1124	1663	1658		

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	1276	848	321	107	66.47	25.15	8.38
16.5	1204	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	1250	654	884	455	166	78	0	0	0	12	0	0	3923
F	0	0	0	709	907	521	1170	1048	914	473	203	88	9	61	15	32	6150
U	7	149	89	529	395	99	101	32	22	0	1	0	0	0	0	0	1419
Total	7	149	89	1663	2553	1274	2155	1535	1102	541	204	88	9	73	15	32	11492
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

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

Table 15 Coefficients of total mortality (Z) for age 3-11 disaggregated abundance indices, 1982-94.

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 92-94	Mean 82-94
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

Table 16 Coefficients of fishing mortality (F) for age 3-11 disaggregated abundance indices, 1982-94.

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 92-94	Mean 82-94
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 Proportion mature at age of females (F), males (M*estimated) and weighted 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

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

AGE GROUP	MEAN WEIGHT (Kg)	PROPORTION MATURE AT AGE	PARTIAL RECRUITMENT	NATURAL MORTALITY
4	3.1e-002	0.4	0	0.2
5	4.9e-002	0.4	0	0.2
6	7.4e-002	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	1	0.2
13	0.245	1	1	0.2
14	0.364	1	1	0.2
15	0.399	1	1	0.2

Table 19 Results from the yield and spawning stock 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
F0.1	0.227	0.3514	0.0484	
Fmax	0.427	0.4556	0.0521	

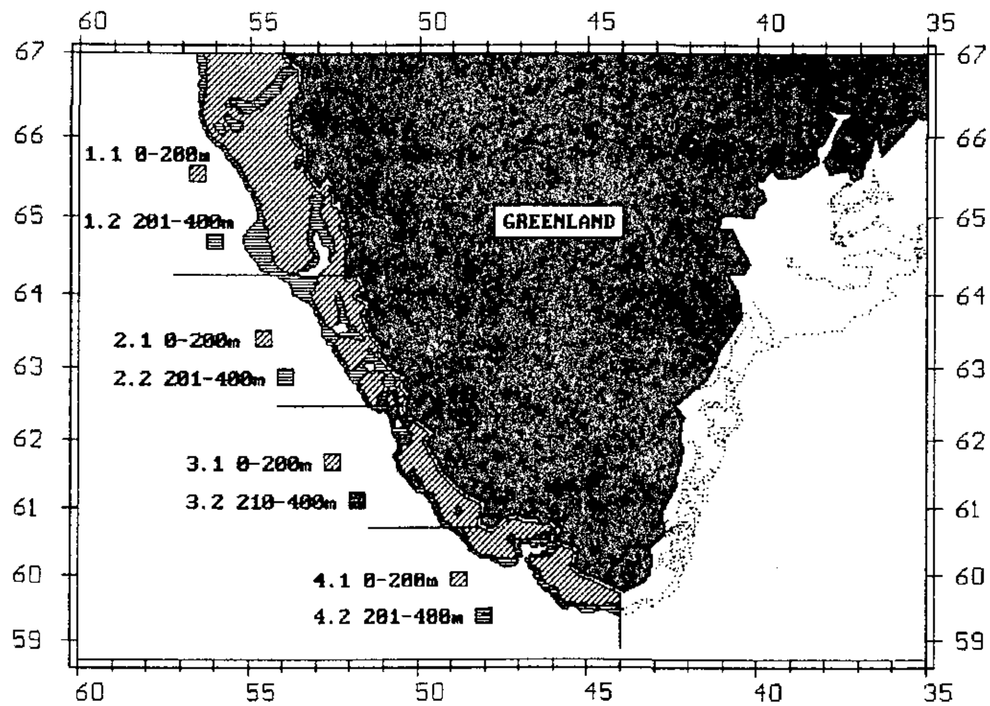

Fig. 1 Survey area and stratification as specified in Table 1.

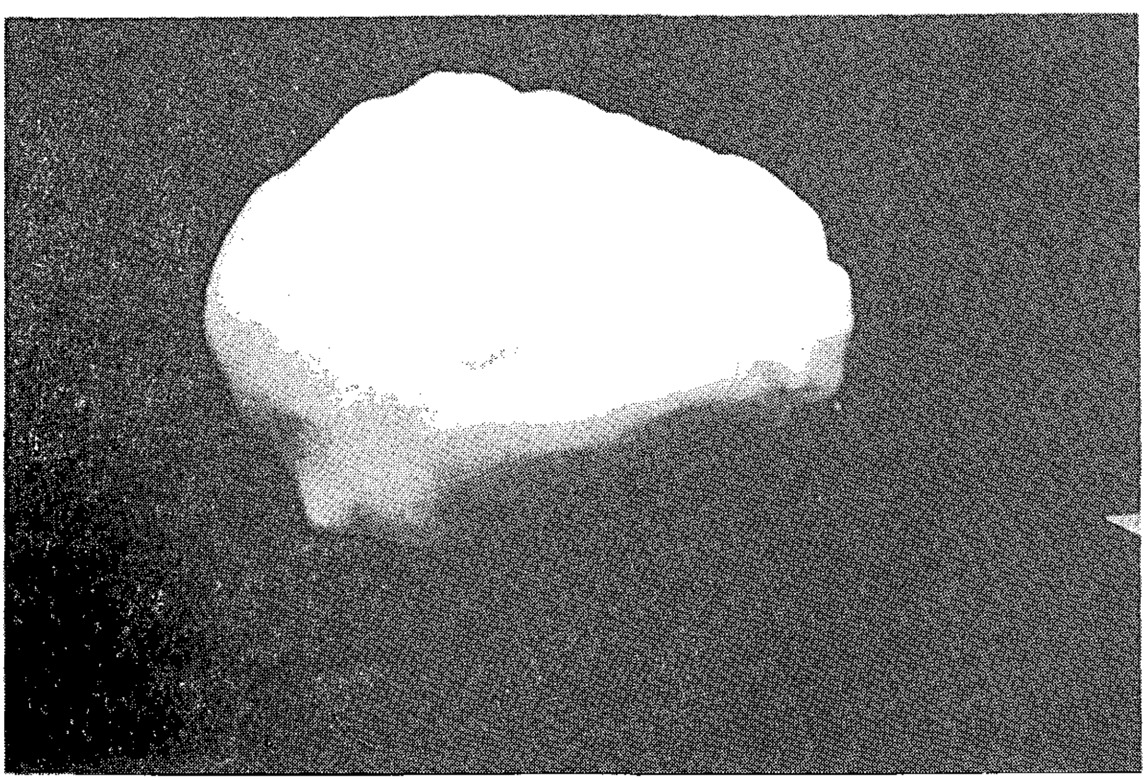

Fig. 2 Whole otolith of American plaice under binocular.

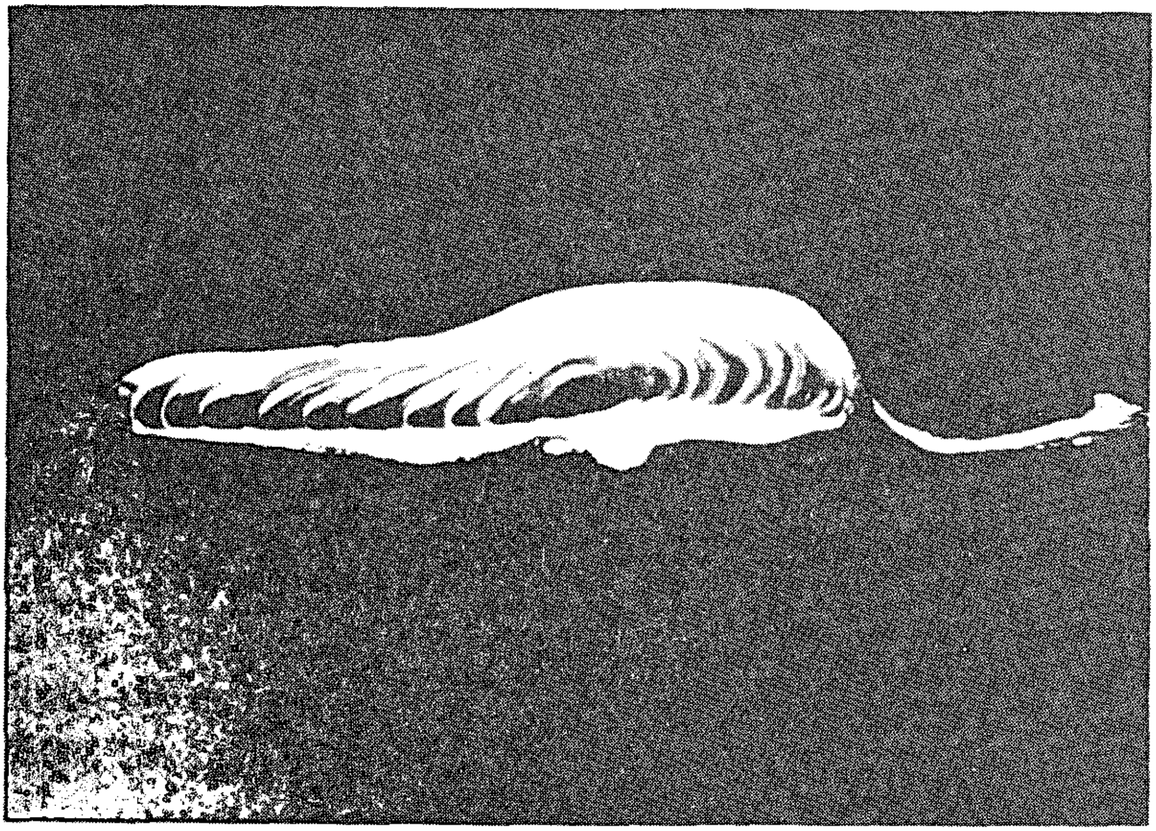

Fig. 3 Otolith section 0.6mm thickness (Bedford's method, 1983) of a 10 years specimen American plaice.

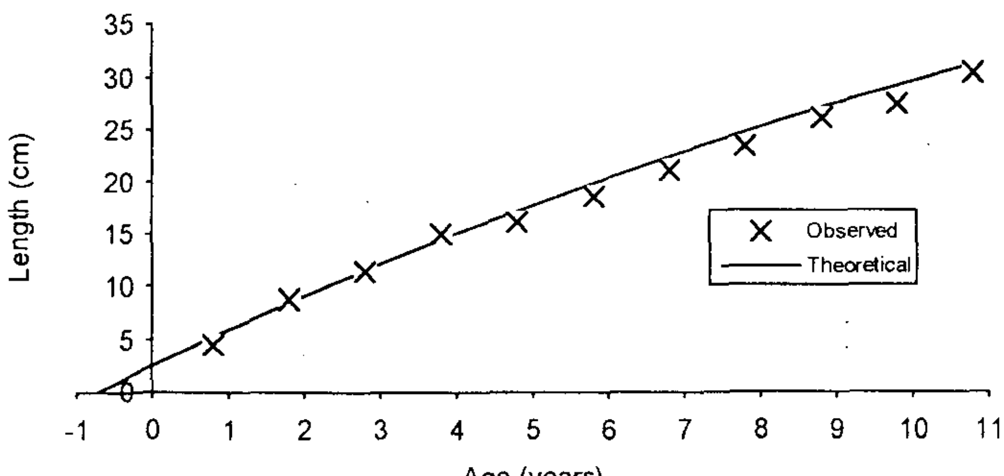

Fig. 4 Growth in length of American plaice off West Greenland (both sexes combined, 1994).

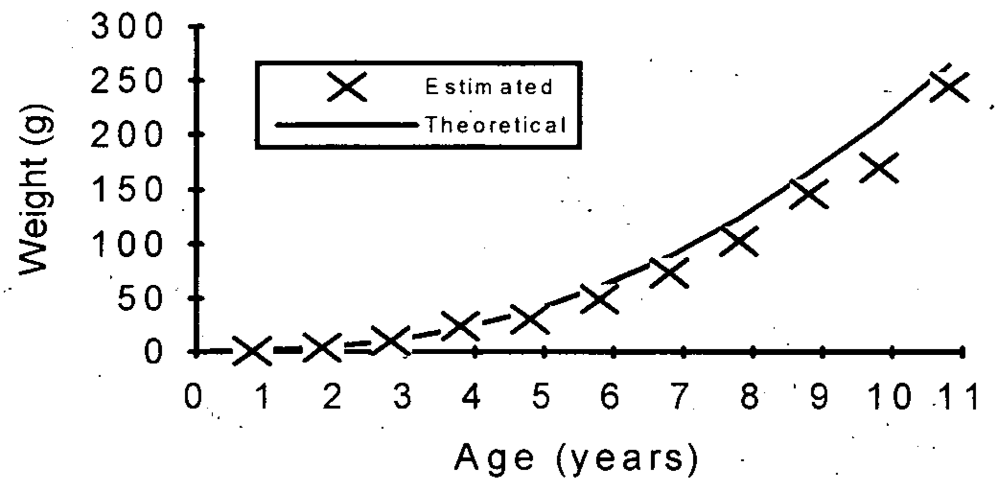

Fig. 5 Growth in weight of American plaice off West Greenland (both sexes combined, 1994)

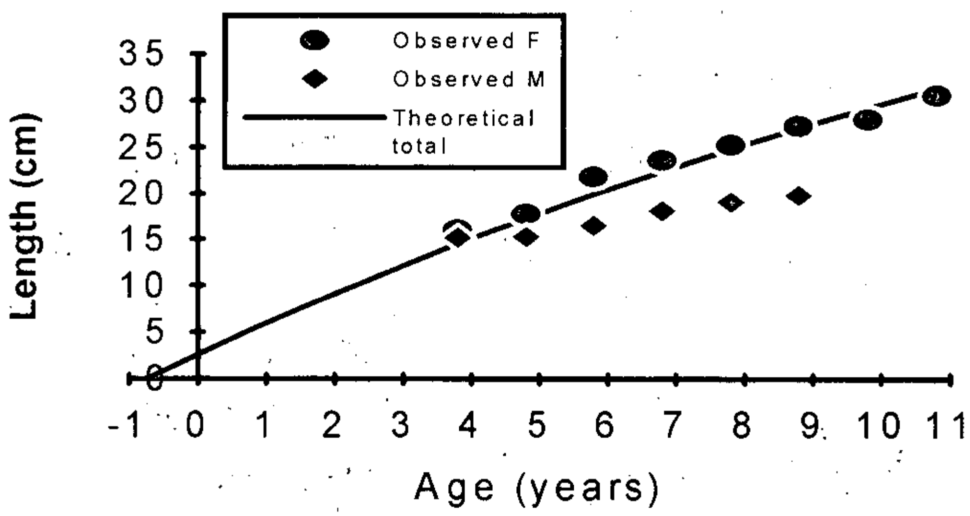

Fig.6 Growth in length of American plaice off West Greenland in 1994. Comparison between observed females (F), observed males (M) and theoretical total.

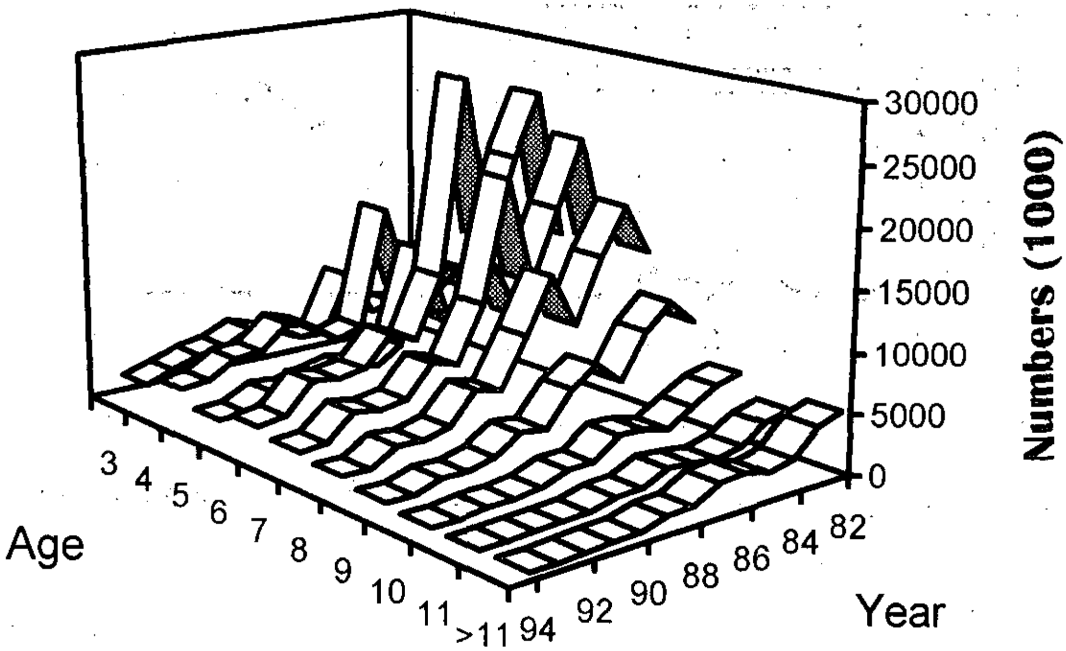

Fig. 7 Age (0-+11) disaggregated abundance indices for American plaice off West Greenland, 1982-94.

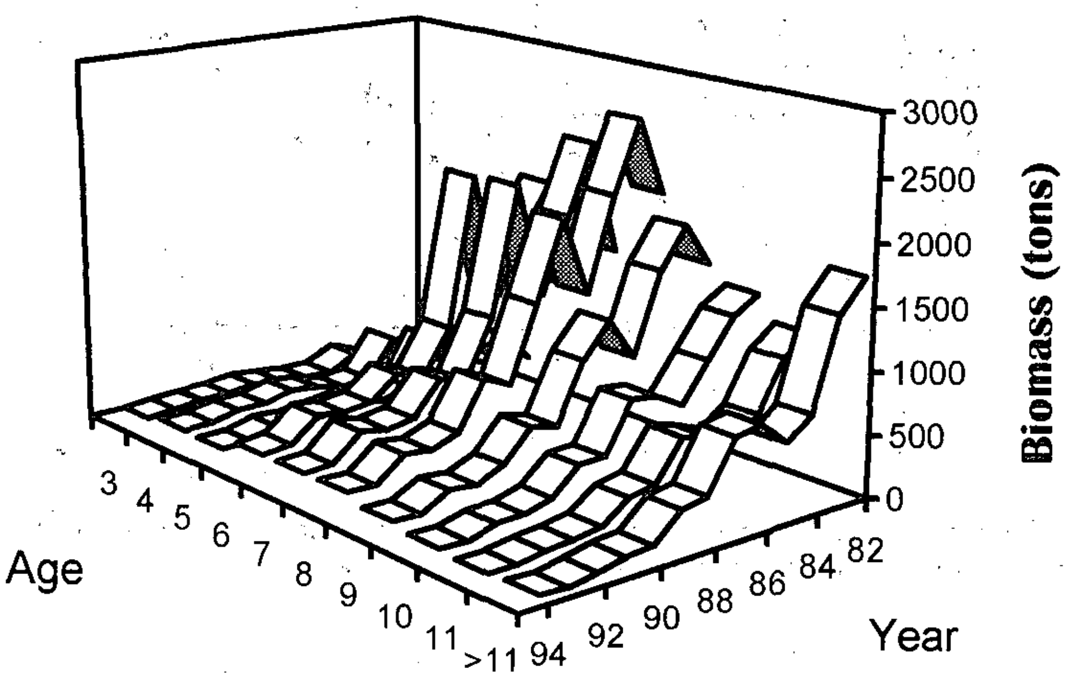

Fig. 8 Age (0-+11) disaggregated biomass indices for American plaice off West Greenland, 1982-94.

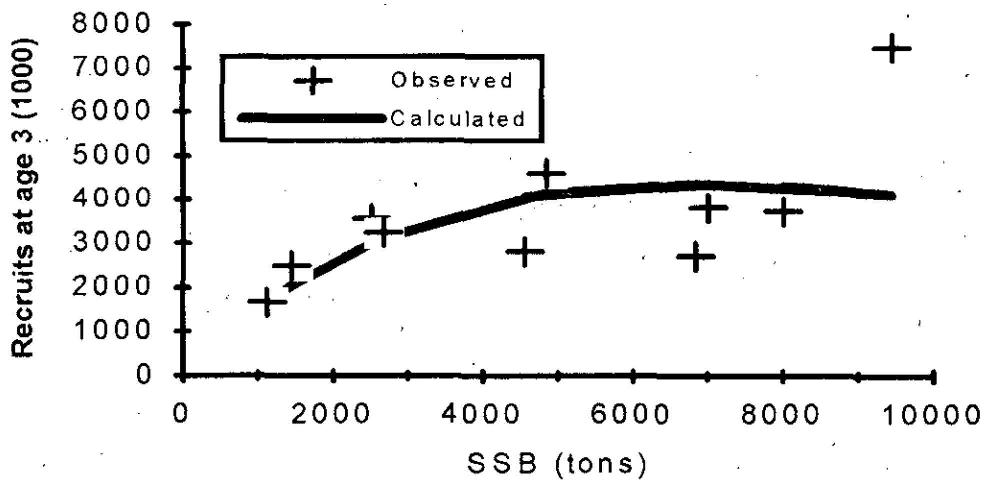

Fig. 9A Spawning stock biomass-recruitment relation at age 3 R=SSB*exp(a(1-SSB/SSBr)), (Ricker, 1975), parameters being a=0.55, SSBr=3774.41.

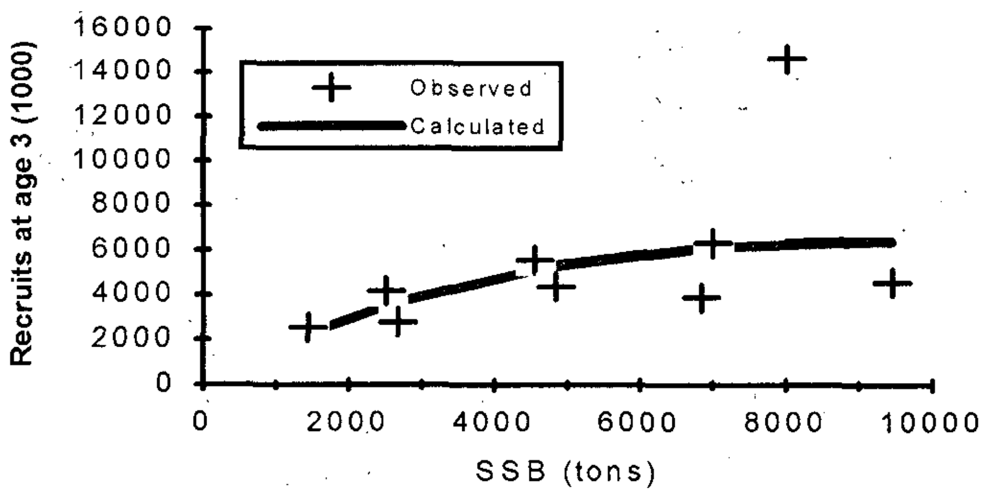

Fig. 9B Spawning stock biomass-recruitment relation at age 4 R=SSB*exp(a(1-SSB/SSBr)), (Ricker, 1975), parameters being a=0.60, SSBr=5749.54

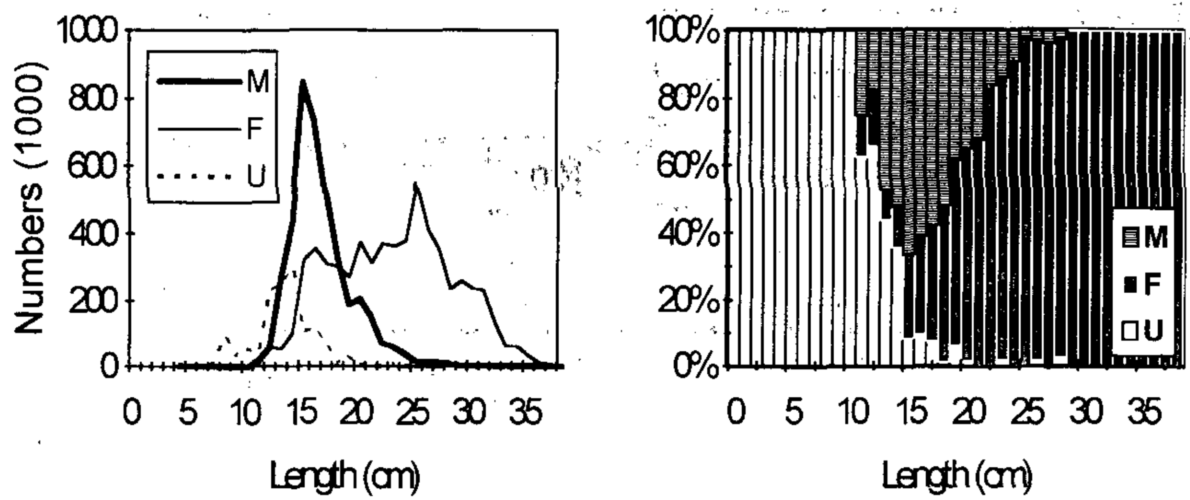

Fig. 10 Length composition in numbers and percent of American plaice off West Greenland in 1994. Males (M), Females (F) and Undetermined sex (U).

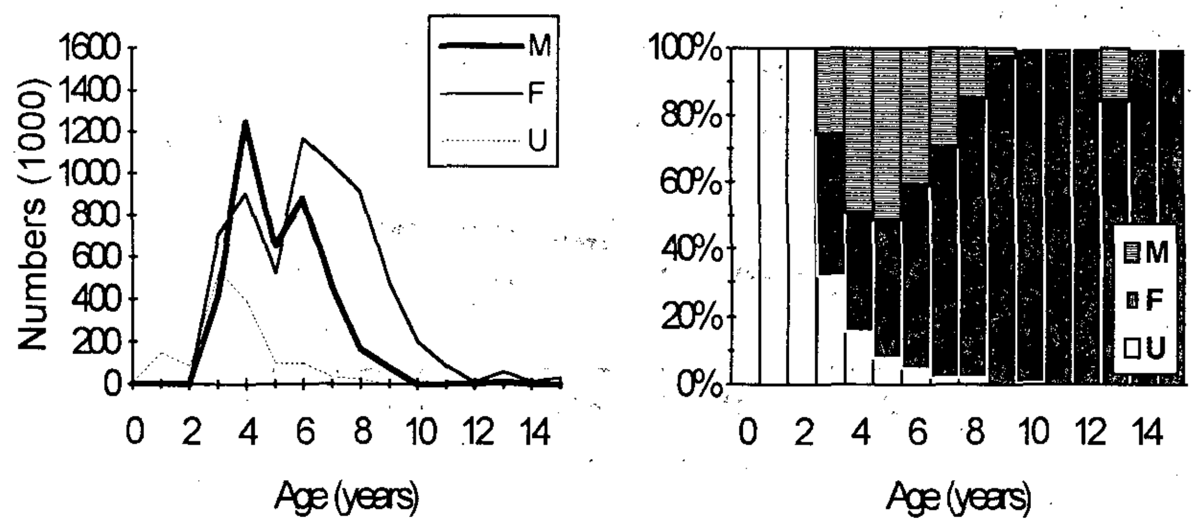

Fig. 11 Age composition in numbers and percent of American plaice off West Greenland in 1994. Males (M), Females (F) and Undetermined sex (U).

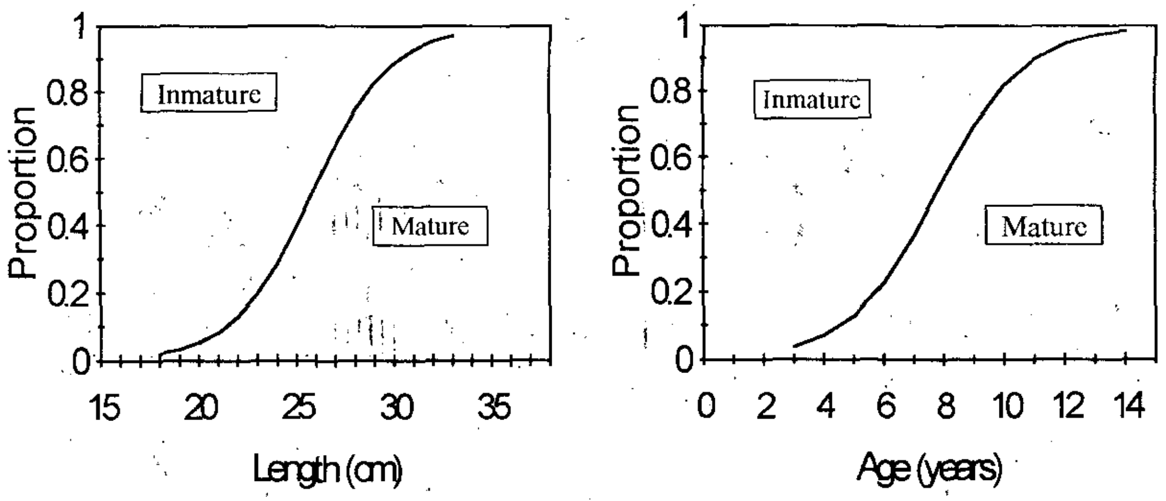

Fig. 12 Maturity ogive by length and age for females American plaice off West Greenland, 1994 (data fitted by logistic regression method).

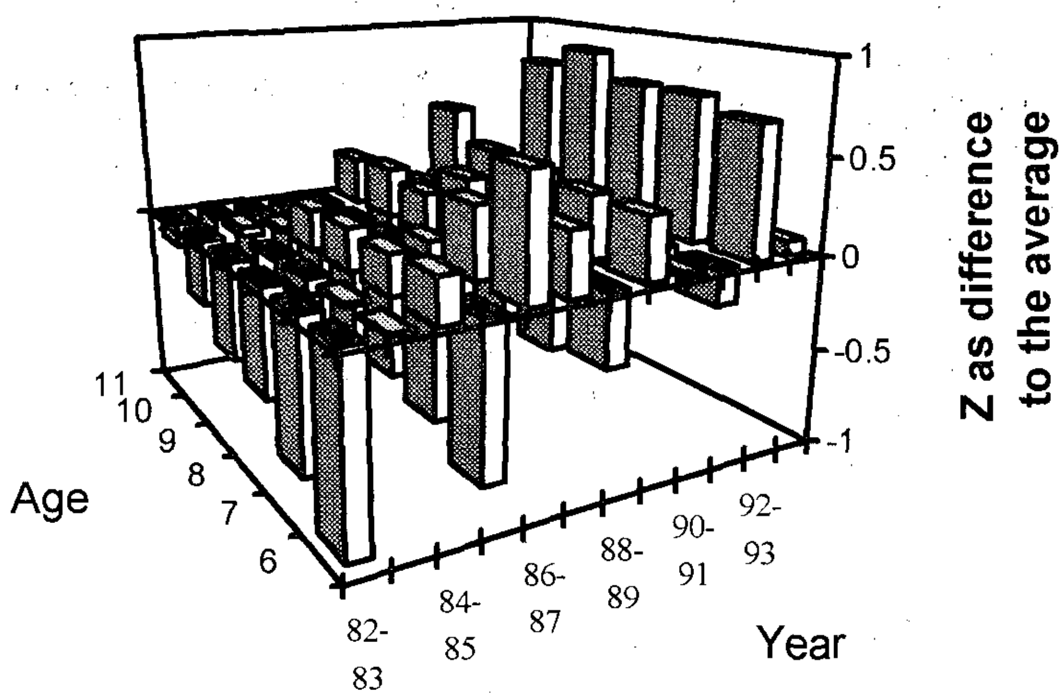

Fig. 13 Coefficients of total mortality (Z) as difference to average 82-94 as listed in Table 11 for American plaice off West Greenland, 1982-94 (age 11 / 1992-93 value not considered).

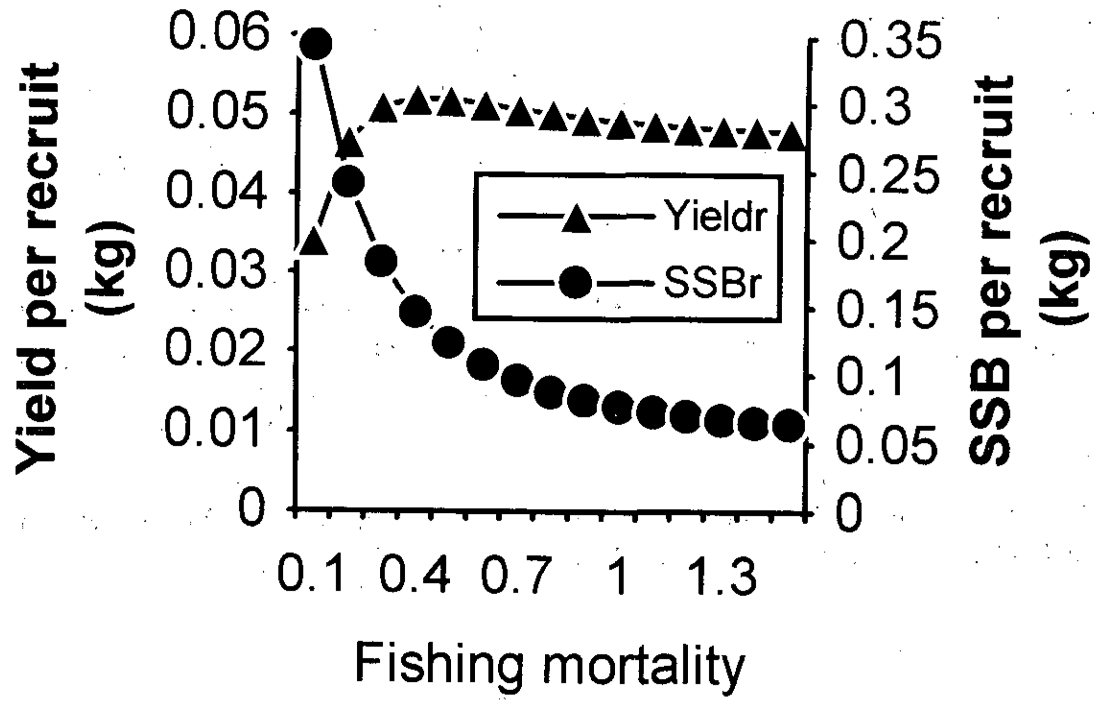

Fig. 14 Yield per recruit (Yieldr) and spawning stock biomass per recruit (SSBr) against fishing mortality for American plaice off West Greenland.