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An Assessment of the Greenland Halibut Stock Component in NAFO Division 1A Inshore

by

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1. Introduction

The Greenland halibut stock component in Div. 1A inshore is considered as a separate part of the Davis Strait stock (Boje et al. 1994). The component do probably not contribute to the spawning stock in Davis Strait (Boje, 1994) and only sporadic spawning is observed in the inshore area (Jørgensen and Boje 1994). Hence, the inshore component is not assumed to be a self-sustainable stock, but dependent on recruitment from the nursery area south of Disko Island (Bech 1995).

2. Description of the fishery and nominal caches

The main inshore fishing grounds for Greenland halibut are in Div. 1A (Fig. 1), where the total landings amounted to 24,594 tons in 1998, and comprising 99.6 % of the total inshore landings in Greenland. The inshore landings in Div. 1A were around 7,000 tons in the late 1980's, but have since then increased steadily (Fig. 2 and Table 1).

The fishery is traditionally performed with longlines from small open boats below 20 GRT, or by means of dog sledges. In the latest years bigger boats (>25 foot) have however increased in numbers. Typically the fishery is carried out in the inner parts of the ice fjords at depth between 500 to 800 m. In the middle of the 1980s gillnets were introduced to the inshore fishery, and were used more commonly in the following years. Authorities have in recent years tried to discourage the use of gillnets, which has lead to an increased proportion of longline catches. A total ban for gillnets is in force from year 2000. Gillnet fishery in 1998 was regulated by a minimum mesh-size of 110 mm (half meshes) while there are no regulations on longline fisheries. Longline catches have the latest years comprised of around 75 % of the catch. The catches allocated on gear throughout the year are shown in figure 3.

The inshore fishery in Div. 1A is located in three main areas: Disko Bay, Uummannaq and Upernavik (Fig. 1). There has not been set quotas on the fishery, but from 1998 a special fishery licence was required to land commercial Greenland halibut catches. In 1998 a total of 1127 licenses were issued, allocated on Disko Bay 364, Uummannaq 377 and Upernavik 386 licenses.

<u>Disko Bay</u>

The Greenland halibut fishery is conducted in, and in front of an ice fjord in the immediate vicinity of Ilulissat town, and in an icefjord north of Ilulissat, Torsukattak (Fig. 1). The winter fishery in Ilulissat Icefjord, Kangia, is a typical fishery from the ice with longlines (mainly field-code LG29, 30 & 31). The fishery near Ilulissat (field-code LG28) is mixtures of gillnet and longline carried out all year around. The fishery in Torsukattak is almost exclusively carried out in the period July - August. Use of gillnets is prohibited in the innermost part of the ice fjords in the Disko Bay area.
The catches in Disko Bay have been increasing almost constantly the latest 10 years (Fig. 2). In 1998 catches once again reached a historic high levels of 10,670 tons (Table 1). Longline catches comprised 61% 1997 and 54% in 1998.

Uummannaq

Uummannaq area is a large system of icefjords where fishery is conducted. The main fishing ground is in the Southwestern part of the fjord system. Beforehand Qaraq Icefjord was the main fishing area but in recent years the fishery has moved further north to Sermilik (field-code LZ29) and Itivillup Ice fjords (field-code MA28-MB25) (Fig. 1). Use of gillnets is prohibited in the inner parts of the fjords in Uummannaq.

The catches at Uummannaq were stable at about 3,000 tons in the period 1987 to 1992. Since then catches have increased. In 1995 landings reach a historic maximum of 7,200 tons, in 1998 the catch was 6,911 tons (Fig. 2 and Table 1). The longline catches comprised 76% in 1997 and 74% in 1998.

Upernavik

The northernmost area consists of a large number of ice fjords. The main fishing grounds are Upernavik Ice fjord (field-code MT & V 8-13) -and Giesecke Ice fjord (field-code ND8). New fishing grounds around Kullorsuaq in the northern part of the area are exploited these years (Fig. 1). Use of gillnets is prohibited in Upernavik.

The catches in the Upernavik area have increased steadily from about 1,000 tons in the late eighties to about 3 to 4,000 tons in 1993 to 1995 (Fig. 2 and Table 1). The total catch in 1998 was the highest on record 7,012 tons.

3. Input data

3.1 Research Fishery

3.1.1 Longline surveys

Before 1993 various longline exploratory fisheries with research vessels were conducted. Due to different survey design and gear, these surveys are not comparable. In 1993 a longline survey for Greenland halibut was initiated for the inshore areas of Disko Bay, Uummannaq and Upernavik. The survey is conducted annually covering two of three areas alternately, with approximately 30 fixed stations in each area.

In July-August 1998 the research longline vessel 'Adolf Jensen' covered the fjord areas of Uummannaq and Upernavik, respectively with 18 and 24 stations. Mean CPUE values and length for Greenland halibut in the different areas are shown in Tables 2-3 and figure 4

3.1.2 Trawl surveys

The Greenland Institute of Natural Resources annually conduct a stratified random trawl survey in the period July to September in the area between 59^{o}N and 72^{o}30'N, from the 3-mile limit to the 600-m depth contour line. The target species is shrimp, hence the trawl used is a shrimp trawl with 20 mm mesh size in codend. However, the survey also covers the offshore nursery grounds for Greenland halibut Southwest of Disko Island, as well as the inshore nursery ground, Disko Bay. An index of abundance of yearclasses 1-3 was provided from the survey, for details see Engelstoft and Jørgensen, 1999.

3.2 Commercial fishery data

3.2.1 Analysis of size distribution in landings

When sold commercial landings of Greenland halibut are separated in price-classes based on weight. In previous assessments the proportion of 'large fish' in longline landings has been used to analyse the relative proportion of big and small fish in landings. But as the definitions of size-classes was beginning to drift as ‘large fish’, which pays the double, was used in the competition between the fishing industries in order to get the fishermen to land the catches at their plants. Therefore these figures was not used in this years assessment.

Random sampling of commercial gillnet and longline landings was carried out in the three main areas in February/Marts and July/August in order to obtain length distributions in the catches (Fig. 5).

3.2.2 Effort

There is no direct measure of the effort in the fishery (logbooks etc). However, each single landing is registered with information on vessel type (dogsledge, dinghy or cutter), gear and fishing area. An indirect measure of effort expressed as number of total fishing days was thus available. Care must be taken interpreting effort presented as more than one landings pr. person on a single day is registered as one landing and landing size are sometimes limited by the fishing industry (eg. 1 tons per boat per day) (Fig. 9).

3.2.3 Estimation of fishing mortality

In order to estimate the level of fishing mortality, catch-curve analyses were performed. Total mortality, Z-values were obtained from catch-curves based on catch composition in longlines catches in each of the three areas and for summer / winter. Age groups 10-14 were used for the linear regressions for all samples. Average values of Z for each of the three areas, Disko Bay, Uummannaq and Upernavik, were compiled as an average of the estimated Z values. The Natural mortality, M was set to 0.15. (Fig. 12)

3.2.4 Yield per recruit analysis

A Yield per recruit analysis was performed for each area. An average of mean weight-at-age and exploitation pattern for the period 1988 to 1998 was used. Missing weight-at-age data were estimated by age-weight regressions. Calculations were performed on single recruits in each area[1.] (Fig. 13)

3.2.5 Catch-at-age data

Catch-at-age for the three inshore areas were based on sampling from the commercial fishery covering area, gear and season. Calculations of catch-at-age data for 1988 to 1990 are described in Boje (1991), for 1991 to 1994 in (Bech 1995), for 1995-97 in Simonsen and Boje (1997) and for 1998 in Simonsen (1998). Also in this years assessment a compiled age length/weight key for the last 3 year was used in each area (Fig. 6 &7). This was done due to frequent shift in personal that reads the otoliths and in that connection, the possible shifts in interpretation of otolith structure. It is thus assumed that the relative shift in growth was less than shift in interpretation of otolith structure. In Upernavik only the years 1998 and 1997 was used, as there was no data for 1996.

3.3 Recruitment data

A recruitment index was provided from the Greenland trawl survey (Engelstoft and Jørgensen 1999).

By use of the Petersen-method ages 1, 2 and 3 were separated from catches taken during the period 1988 to 1998. Catches of age 1, age 2 and age 3+ were standardised as catch in number per hour as described in (Bech 1995). Data were plotted as year classes to visualise the relative year-class strength (Fig. 10).

3.4 Biological data

A review of the tagging experiments in West Greenland in the period 1986-1998 has been conducted (Boje 1999). No fish tagged in the fjords have been caught in the offshore area in Div. 1A or in the more southern offshore spawning area. There is little to no fishing effort in Div. 1A offshore, but considerable fishing effort in the southern area. Therefore the assumption that the stocks in the three main areas do not contribute to the offshore spawning stock in Davis Strait south of Div. 1A can be maintained. Very little intermingling between the fjords was observed why the three inshore areas can be assessed separately. Inshore tagging of Greenland halibut in Div. 1A was continued in 1998.

Observation of sexual maturity of Greenland halibut was done by visual assessment of the gonad. Definition of sexual

1 The software FishLab ver. 1.0 for Excel was used for calc. of reference points.

maturity was done according to table 5, from (Riget and Boje 1989). In August up to 10 fish in each cm group were examined in Uummannaq and Upernavik (Fig. 8). The results showed that: STAGE 1 was dominating for both males and females (~90% and 60 % respectively), no difference was observed between the investigated areas.

4. Assessment

4.1 Long line survey results.

When comparing mean length recorded in the surveys since the 1960 's a decline in length with time is evident (Table 3). In the standardized surveys from 1993 to 1998 mean length was different between years for each of the 3 areas (GLM, $P<0.001$), but a significant change in length with time was not shown (ANOVA, Ilulissat P=0,38, Torssukattak P=0.95, Uummannaq P=0.06, Upernavik P=0.18) (Fig. 4). In Uummannaq the trend was positive while it was negative in Upernavik. CPUE in the standardized surveys showed large variation between stations, but only a difference between years in Uummannaq (GLM, $P<0.05$). However, CPUE in Uummannaq did not show a significant trend with time (ANOVA, P=0.5).

4.2 Estimation of fishing mortality

Fishing mortality was estimated by means of catch-curves, figures are shown in table 4. F values at Uummannaq F_{1998} of 0.41 and at Upernavik F_{1998} of 0.12. F could not be estimated for Disko Bay because of a non-linear decay in the age interval 10-14 in the winter fishery. The F values estimates in 1998 are lower than 1997 and also general lower than values obtained in the beginning of the nineties. This disagrees with information from the fishery, which indicate an increased effort (Fig. 9). The reason for the noisy F values may bee that the fishery is exploiting different age-components in the different seasons and different localities. This could be the reason for the observed situation in Disko Bay where F could not be estimated from catch-curves. The basis input for a catch-curve analysis may thus be violated with the present sampling strategy with only two yearly random samplings from the commercial fishery. Furthermore seasonal migrations in the fjords are observed (Boje, 1999; pers. com. local fishermen), variable recruitment to the fishery and ageing problems may also causes problems in estimating F.

4.3 Effort

The fishing effort, illustrated as fishing days allocated on area and landings per fisherman per day, is shown in figure 9. A close relationship was observed between number of fishing days and total annual landing. The effort in the small-scale fishery (0-100 kg per landing) have declined while it have increased in the bigger scale fishery (>100 kg per landing). Especially landings above 1000 kg constituted a major part of the total annual landing.

4.4 Biological reference points

Y/R analyses performed for each area using long-term averages of mean weight-at-age and exploitation pattern gave the following estimates of $F_{0.1}$ and F_{max}.
At Disko Bay $F_{0.1}$ was estimated to 0.17 F_{max} to 0.29
Earlier estimations of F suggest that F is beyond F_{max}.
At Uummannaq $F_{0.1}$ was estimated to 0.22 F_{max} to 0.42.
As the F_{1998} was estimated to 0.41. The exploitation of the inshore stock in Uummannaq at F_{max}. However, it is noted that Fmax is poorly determined (due to the shape of the curve)
At Upernavik $F_{0.1}$ was estimated to 0.30 F_{max} was 0.54
As the F_{1998} was estimated to 0.12. The exploitation of the inshore stock in Upernavik is below $F_{0.1}$.

4.5 Analysis of size distribution in landings

Samples from the commercial longline landings in the period 1993 to 1998 in Disko Bay, Uummannaq and Upernavik showed (Fig. 5). Fish caught in summer was general smaller than fish caught during winter season.

Disko Bay longline, both summer and winter fish showed an overall positive trend in mean length, but not significant (summer; slope 0.4 cm/year, winter; slope 0.9 cm/year; ANOVA, summer P=0.32; winter P=0.28).

Uummannaq longline, a negative trend for both summer and winter landings both not significant (summer; slope –1.0 cm/year, winter; slope –0.2 cm/year; ANOVA, summer P=0.14; winter P=0.50).

Upernavik longline, a negative trend for both summer and winter fish mean length, a significant decrease in mean length was observed for winter fish (summer; slope –0.2 cm/year, winter; slope –2.0 cm/year; ANOVA, summer P=0,90, winter P=0.003)

4.6 Age compositions in landings

Age compositions in landings are shown in Table 6-8. Fish of age 10 or younger have in recent years constituted a still greater percentage of the total numbers landed (Fig. 11).In 1998 the percentage of fish age 10 or younger was lower than 1997. However, 72% in Disko, 56% in Uummannaq and 69 % in Upernavik of the fish landed consisted of age 10 or younger. The stock composition is still constituted of relative few and young age groups compared to the early nineties.

4.7 Recruitment

Recruitment has fluctuated in the period investigated (Fig. 10A + B). Offshore the numbers of one-year-old from the 1997 yearclass was a little below average (185 spec./hour). The 1995 year-class, that appeared very strong as one year old, had declined in strength as the numbers, both two and tree years old were not above average (respective 73 and 37 spec./hour) (Fig. 10 A). Inshore recruitment in 1997 was the highest in the time series (1039 spec./ hour). The abundance of 2 and 3 yearclasses from 1995 were also still relative strong. (Fig. 10 B).

5. An analytical approach

An analytic analyze was carried out for the Disko Bay area. This area was selected because of longer and more continuous data series compared to Uummannaq and Upernavik.

5.1 Determination of terminal F's

The limited number of years in survey CPUE series (1993-94 and 96-97) did not fit the catch data and was therefore not considered sufficient for a tuning analyses. Instead the surveydata was used to calibarate a seperable VPA.

A separable VPA was run with different terminal F in the interval 0.1-0.7. CPUE from surveys were available from the years 1993, 94, 96 and 97 and the CPUE separated on age-classes 5-14 were used to minimize the sum of squares on the separable generated population numbers from the VPA. A minimum was located with a terminal F of 0.35, hence F 0.35 was used a terminal F (Appendix A, figure 1).

5.3 Separable VPA

A separable VPA was performed (Pope 1977, 1979) using 0.35 as terminal F (see 5.1) Input data is given in Appendix A, Table 2 and 3. M was set to 0.15 for all ages. The chosen run of the separable analysis is given in Appendix A, Table 1, matrix of residuals are also shown i appendix A, figure 2.

The generated terminal F's were used to run a cohorte analysis (part of the Lowestoft VPA suite). Catch in numbers is given in Appendix A, Table 2 and weight at age in Table 3. Catch weights and stock weights at age were assumed similar, thus catch in numbers at age was adjusted in order to adjust the factor [calc. catch]/[norm. landings] around 1. In working paper WP 99/21 the separable VPA with the unadjusted catch in numbers are presented. As only few weight data are available prior to 1993, an average weight at age for the period was applied to the years 1985-1992. M was set to 0.15 for all ages. No maturity data is available so a knife-edge maturity is assumed at age 10, age 10 being first age fully mature. Reference F is chosen for ages 10-14, which are the age-groups fully recruited to the fishery and contributing mostly to the catch in numbers.

5.4 Output

Output from the VPA is given in Appendix A, Table 4, 5 and 6 and Fig. 3. Fishing mortality (Appendix A, Table 4, Figure

3) is low in the beginning of the time series, in the same order of magnitude as M. VPA is known to perform very poor when this is the case. In later years F has fluctuated but a general increase is observed. The corresponding biomasses is given is Appendix A, Table 6 and Fig. 3. Due to the low F's in the first part of the time series, biomass estimates as well as recruitment are not considered reliable in that period. For the recent years as decline in biomass is evident along with the high F's.

Comments on the analytical approach

The present assessment cannot be taken face value due to inaccurate determination of terminal F's and the scarcity of effort data from the commercial fishery, but provides a likely scenario of recent years development of the stock. The analyses suggest that a revision of catch in numbers is required, e.g. as inferred from the selection pattern in the separable VPA. The stock dynamics of the Disko Bay Greenland halibut component is rather unusual , as it is assumed that the component does not spawn and that recruitment originates from the offshore component. This implies that biological reference points should account for this non-existing link between biomass and recruitment,

5. State of the stock components

Disko Bay. Catches have been increasing continuously in the past 10 years from about 2,000 t to 10,671 t. in 1998.

Survey results since 1993 do not indicate any major changes in abundance or mean length. Yield per recruit analysis and earlier estimation of fishing mortality suggests an F level above F_{max}. In commercial catches mean length has increased. The stock component in Disko Bay is composed of younger and smaller individuals than in the other two areas. In spite of the increasing fishery, age and length composition in both commercial and survey catches have not changed significant in recent years.

Uummannaq. Catches have been increasing from a level of 2,00 t before 1987 to a record high in 1995 of 7,000 t. The catch in 1998 was 6,912 t.

Survey results since 1993 do not indicate any major changes in abundance or mean length. Yield per recruit analysis and estimation of present fishing mortality suggests at F level at F_{max}. Catch composition in the commercial fishery has changed significant since the 1980's towards a higher exploitation of younger age-groups, but have been stable the latest years. Commercial catches showed a negative trend in mean length. The stock component in Uummannaq is affected by the increasing fishery and considered growth overfished.

Upernavik. Catches have been increasing from a level of 1,000 t before 1992 to about 5,000 t. in 1996 and 97. In 1998 the catch was the highest on record 7,012 tons.

Survey results since 1993 do not indicate any major changes in abundance. Yield per recruit analysis and estimation of present fishing mortality suggests at F level at or below $F_{0.1}$. Age and length compositions in commercial and survey catches have decreased, in the commercial winter fishery significantly. The increasing fishery thus affects the stock component in Upernavik and younger and fewer age groups are exploited at the old fishing areas. New fishing grounds in the northern part of the district are exploited these years, the stock components in these areas are considered virgin.

5.1 General comments

Concern is expressed by the continuing increase in total landings of Greenland halibut in NAFO Div. 1A inshore, especially because lack of information from the commercial fishery impedes the assessment of the stocks.

The fishing mortalities estimated from catch curves should be interpreted carefully. The inshore fishery does contrary to offshore fishery, takes place on smaller sub-components and size composition in these vary within season and locality.

The output of the separable VPA in Disko Bay was considered to be indicative of trends in fishing mortality and stock size but was not considered to be sufficiently reliable to estimate current fishing mortality.

The inshore stocks depend on recruitment from the offshore nursery grounds and the spawning stock in Davis Strait.

Available information suggests that spawning only occurs sporadic in the fjords, hence the stock is not self-sustainable. The fish remain in the fjords, and do not contribute back to the offshore spawning stock.

Provisional studies of the by-catch of Greenland halibut in the commercial shrimp fishery suggest that the by-catch is considerable and could have a negative effect on the inshore stock component.

Direct measurement of effort in the fishery should be provided. This would make it possible to obtain estimates of Z from the commercial fishery. Furthermore, trends in effort could be compared to trends in F. There is strong indications that effort has increased in recent years. Logbooks will be introduced in near future for parts of the inshore Greenland halibut fishery, so hopefully effort-values will soon be available.

6. References

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Table 1. Landings and Greenland halibut (tons) in Div. 1A distributed on the main fishing grounds: Disko Bay, Uummannaq and Upernavik. Conversion faktor 1.05 for gutted fish with head, 1.50 for gutted fish without head, 1.52 for gutted fish without head and tail fin). Catch figures for 1998 include 5768 tons unreported landings..

Area/year	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Disko Bay	2258	2670	2781	3821	5372	6577	5367	5201	7400	7837	8601	10671
Uummannaq	2897	2920	2859	2779	3045	3067	3916	4004	7234	4579	6294	6912
Upernavik	1634	777	1253	1245	1495	2156	3805	4844	2403	4846	4879	7012
Unknown	407	636	599	507	17	133						
Total in 1A	7196	7003	7492	8352	9929	11933	13088	14049	17037	17262	19774	24595

Table 2. CPUE values (kg/100 hooks) from longline surveys conducted in Div.1A inshore areas. Standardized survey since 1993

Area/year	**1962**	**1985**	**1986**	**1987**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Disko bay	-	-	8.3	16.5	3.1	3.1	-	3.9	4.4	-
Uummannaq	4.6	13.7	-	8.6	2.8	-	6.6	4.5	-	6.1
Upernavik	-	-	-	-	-	5.2	3.9	-	-	4.2

Table 3. Mean length (cm) from catches taken in inshore longline surveys. Standardized survey since 1993

Area/year	**1962**	**1985**	**1986**	**1987**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Disko bay	-	62.4	53.5	62.2	55.9	56.5	-	53.6	57.0	-
Uummannaq	67.8	70.5	-	61.8	57.5	-	57.8	59.5	-	61.2
Upernavik	-	-	-	-	-	64.6	60.8	-	-	57.1

Table 4. Estimates of fishing mortality (F) from catch curve analysis on commercial samples from 1987 to 1998.

Area/year	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Disko Bay	0.42	0.16	0.24	0.51	0.4	0.45	0.51	0.8	0.54	0.44	0.73	
Uummannaq	1.09	1.01	1.01	0.88			1.2	0.98	1.31	0.25	0.45	0.41
Upernavik		0.35	0.41	0.48			0.42	0.58	0.43	0	0.20	0.12

Table 5. Descriptive stage of maturity used for visual analyses of Greenland halibut gonads.

Maturity stage	Physiologiacl stage of gonads	
	Fenale	**Male**
1	Juvenile or immature: overay very small . eggs not visible to the naked eye.	Juvenile or immature: Testes mostly clear and very small having a length of less than ¼ of the abdominal cavity
2	Mature A: Egges becoming visible to the naked eye	Mature A: Testes opaque having a length between ¼ and ½ of the abdominal cavity
3	Mature B: Eggs 1-2 mm in diameter. Less than 50% of the eggs are translucent	Mature B: Testes opaque having a length between ½ and ¾ of the abdominal cavity
4	Mature C: Eggs 2-4 mm in diameter. More than 50% of the eggs are translucent	Mature C: Testes big and white in appearance having a length between ¾ and 1/1 of the abdominal cavity
5	Running stage: Some eggs extruded but several thousands clear eggs remaning	Running stage: sperm is running
6	Spent stage: Overay appears reddish purple. wall is thick and though. some residual clear and opaque eggs are seen	

Table 6. Catch at age of Greenland halibut in 1988-1998 in Disko Bay area.

	Catch in numbers (thousands)										
Age/year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
4	0	0	0	5	34	7	0	0	0	0	0
5	0	0	0	5	92	15	3	0	8	0	0
6	1	0	0	11	122	62	15	0	1	21	74
7	9	0	1	279	332	280	112	45	47	132	397
8	59	14	24	806	476	479	281	459	323	646	775
9	182	106	141	535	390	339	539	639	941	1113	944
10	173	121	185	333	451	280	396	798	651	1168	1248
11	132	94	188	238	532	240	190	463	454	607	754
12	73	49	126	76	309	122	91	185	273	185	346
13	63	33	80	45	140	91	50	127	145	69	132
14	65	39	59	67	92	112	45	27	75	19	68
15	38	31	42	57	18	75	41	36	44	10	27
16	18	19	23	35	0	57	21	12	31	3	4
17	11	14	15	7	0	12	10	15	5	2	1
18	4	8	6	2	0	10	1	0	33	1	0
19	0	0	0	0	0	7	3	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1	0	0	0	0
Total	828	528	890	2501	2988	2188	1799	2806	3031	3976	4780

Table 7. Catch at age of Greenland halibut in Uummannaq area in 1988-1998. -indicates insufficient sampling.

	Catch in numbers (thousands)										
Age/year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
4	0	0	0	-	-	0	0	0	1	0	0
5	0	0	0	-	-	0	0	0	0	0	0
6	1	0	1	-	-	9	24	6	6	0	0
7	5	2	3	-	-	45	105	217	76	69	0
8	20	9	15	-	-	200	226	564	308	377	235
9	52	35	47	-	-	202	271	601	279	793	566
10	121	98	108	-	-	142	346	413	286	702	657
11	143	120	121	-	-	138	139	414	232	460	586
12	121	99	101	-	-	104	105	219	142	206	355
13	96	76	82	-	-	158	34	138	69	75	138
14	49	38	42	-	-	93	12	49	28	32	39
15	23	19	20	-	-	28	0	28	11	10	15
16	13	14	15	-	-	19	0	17	1	3	4
17	4	6	6	-	-	0	2	4	14	3	1
18	0	0	0	-	-	0	0	0	0	0	0
19	0	0	0	-	-	0	0	1	0	0	0
20	0	0	0	-	-	1	0	0	0	0	0
21	0	0	0	-	-	0	0	0	0	0	0
22	0	0	0	-	-	0	1	0	0	0	0
Total	**648**	**516**	**561**	**-**	**-**	**1139**	**1265**	**2671**	**1453**	**2732**	**2595**

Table 8. Catch at age of Greenland halibut in Upernavik area 1988-1998. - indicates insufficient sampling.

	Catch in numbers (thousands)										
age/year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
4	0	0	0	-	-	0	0	0	0	0	0
5	0	0	0	-	-	0	0	0	3	4	0
6	0	0	0	-	-	0	2	0	0	25	116
7	0	0	0	-	-	0	51	13	16	142	343
8	6	2	2	-	-	2	188	55	114	428	538
9	33	16	17	-	-	16	316	84	359	500	535
10	55	34	41	-	-	86	217	128	275	430	505
11	80	59	62	-	-	252	239	133	238	278	410
12	74	66	57	-	-	268	154	147	206	175	275
13	68	69	52	-	-	143	155	117	151	67	112
14	62	73	48	-	-	95	51	103	90	37	84
15	31	40	25	-	-	40	23	45	48	19	39
16	13	18	11	-	-	29	0	28	26	7	10
17	7	10	5	-	-	10	0	8	4	1	0
18	2	3	1	-	-	5	0	3	9	0	0
19	0	0	0	-	-	1	0	1	0	0	0
20	0	0	0	-	-	1	0	2	0	0	0
21	0	0	0	-	-	0	0	0	0	0	0
22	0	0	0	-	-	0	0	0	0	0	0
Total	431	390	321	-	-	948	1396	867	1539	2111	2968

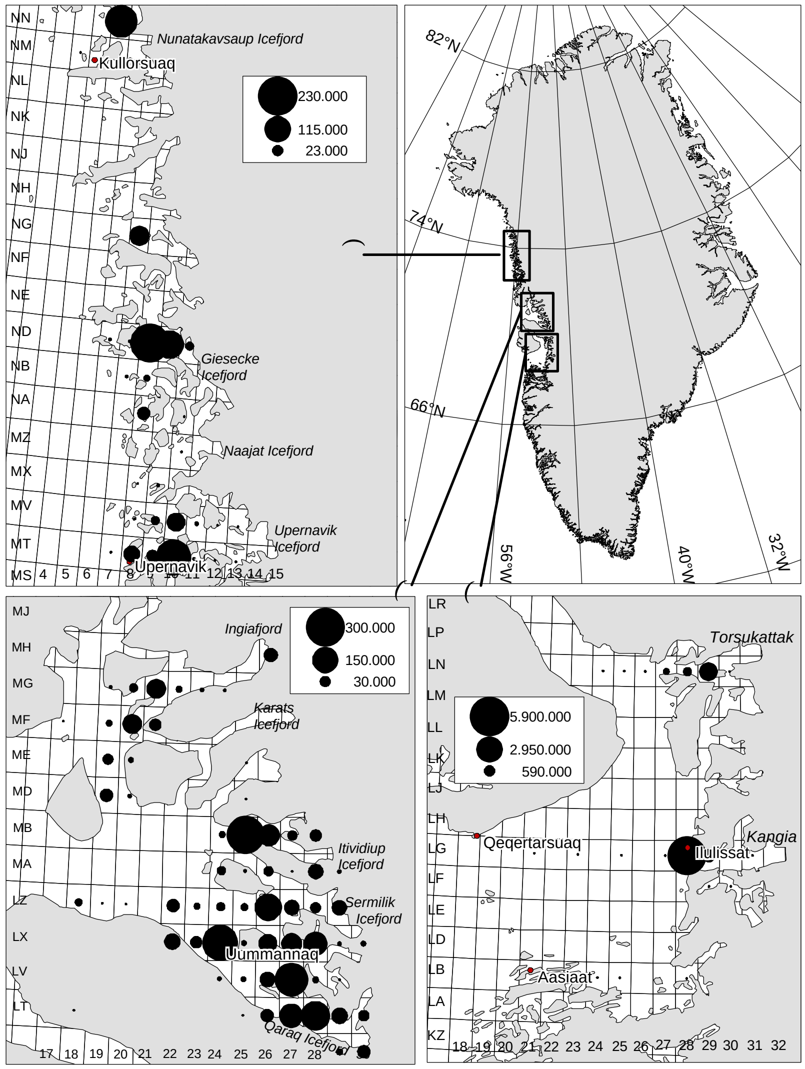


Fig. 1. Location of main inshore fishing grounds for Greenland halibut in Div.1A. Landings is shown in kg per. Squarre (field-code). Catch statistics are provincial. Catch statistic with information on catch area was available from: Disko Bay 86%, Uummannaq 43% and Upernavik 15%

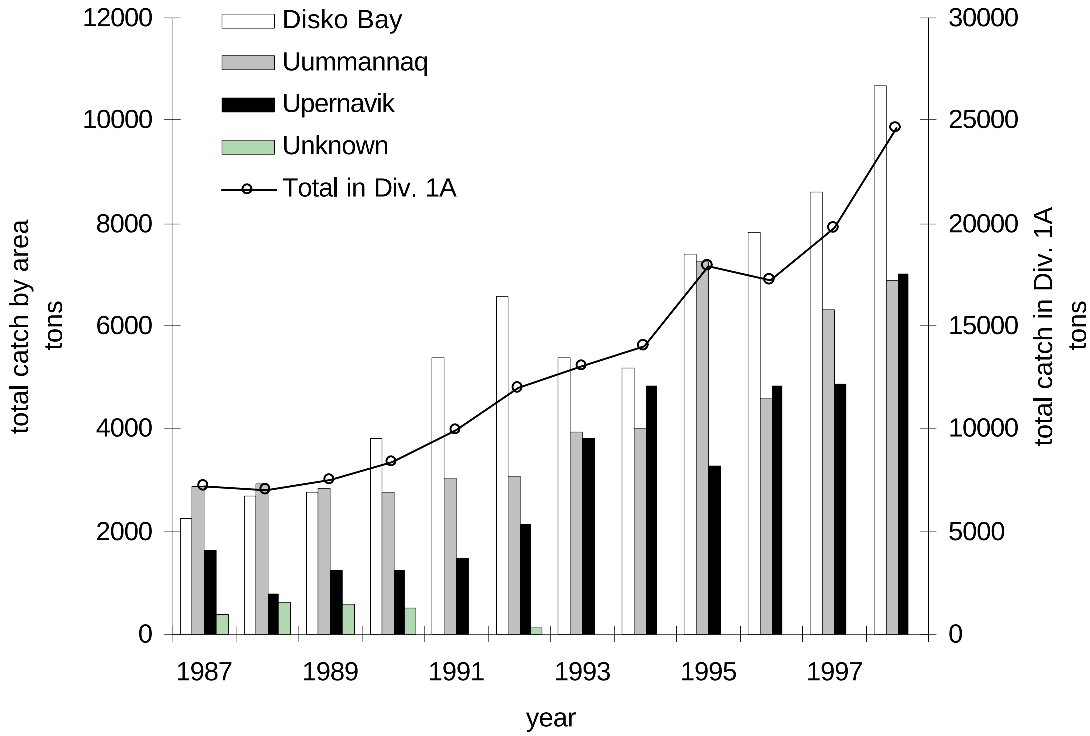


Fig. 2. Landings in NAFO Div. 1A in the period 1987-1998 for the 3 main fishing areas. Landings for 1998 are provisional.

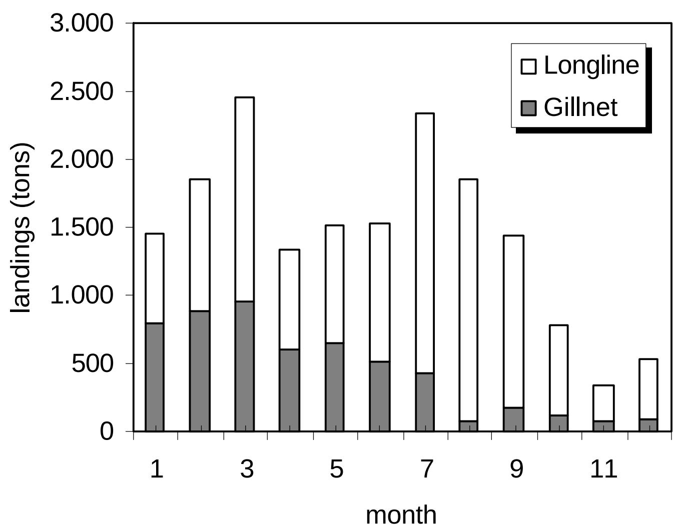


Fig. 3. Landings in NAFO Div.1A in 1998 allocated on gear and month. Catch statistic **not** available for 29% of the estimated landings.

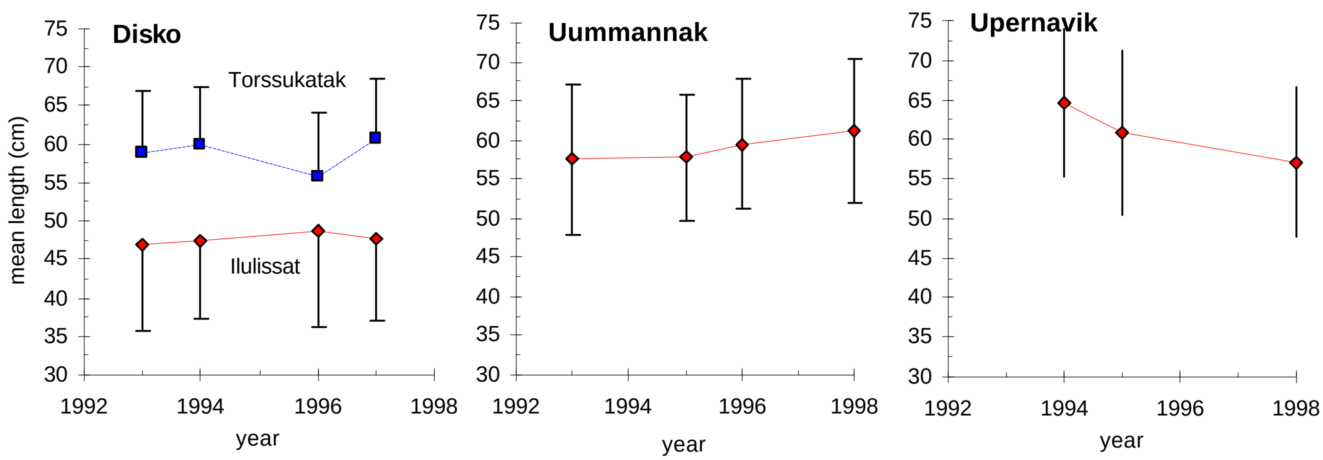


Fig. 4. Mean length for research longline surveys 1993-98. +/- S.D

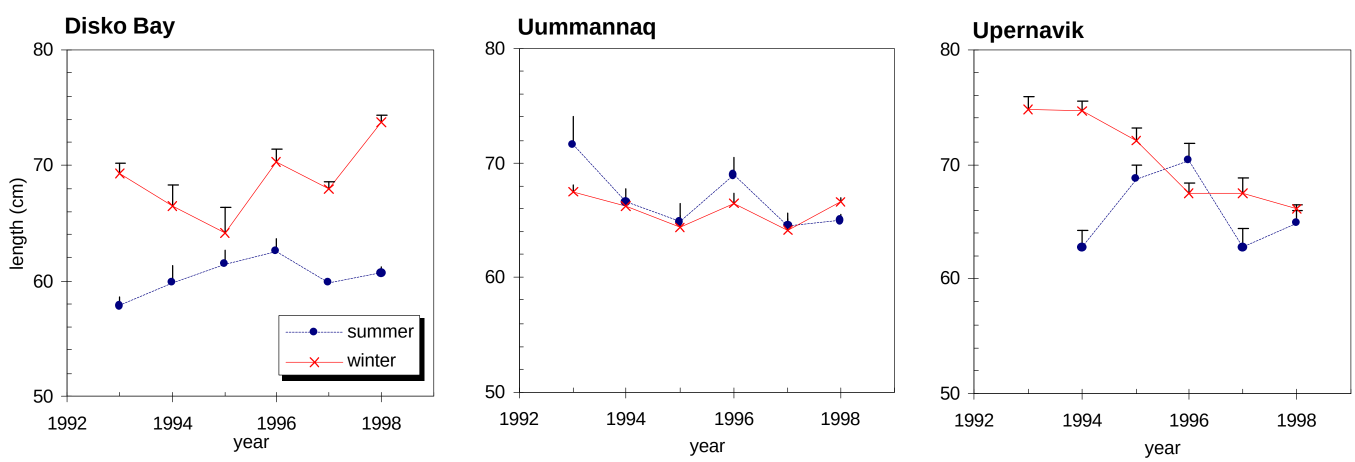


Fig. 5. Mean length of Greenland halibut in commercial longline catches from Ilulissat, Uummannaq and Upernavik +/- 95% conf.

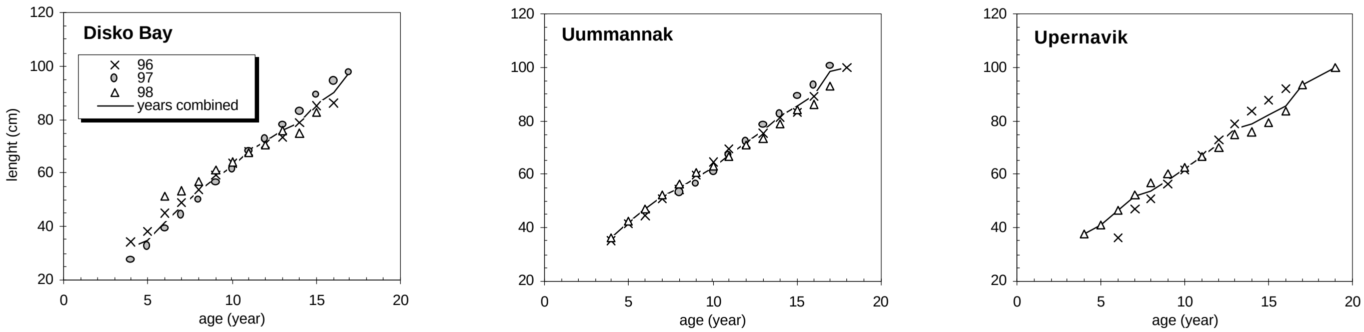


Fig. 6. Length-at-age for Greenland halibut for 1996-98.

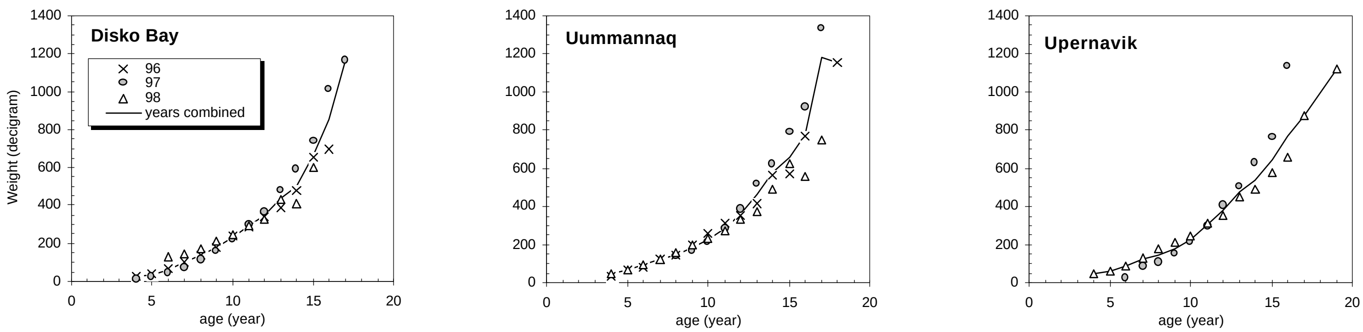


Fig. 7. Weight-at-age for Greenland halibut for 1996-98.

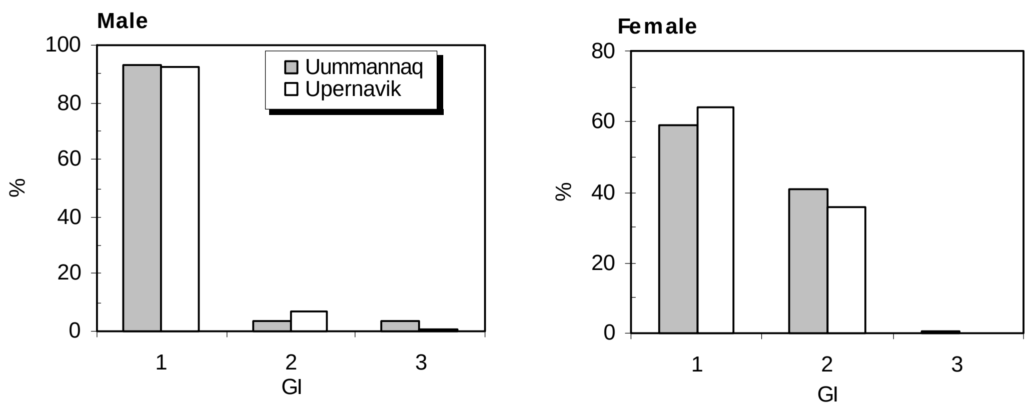
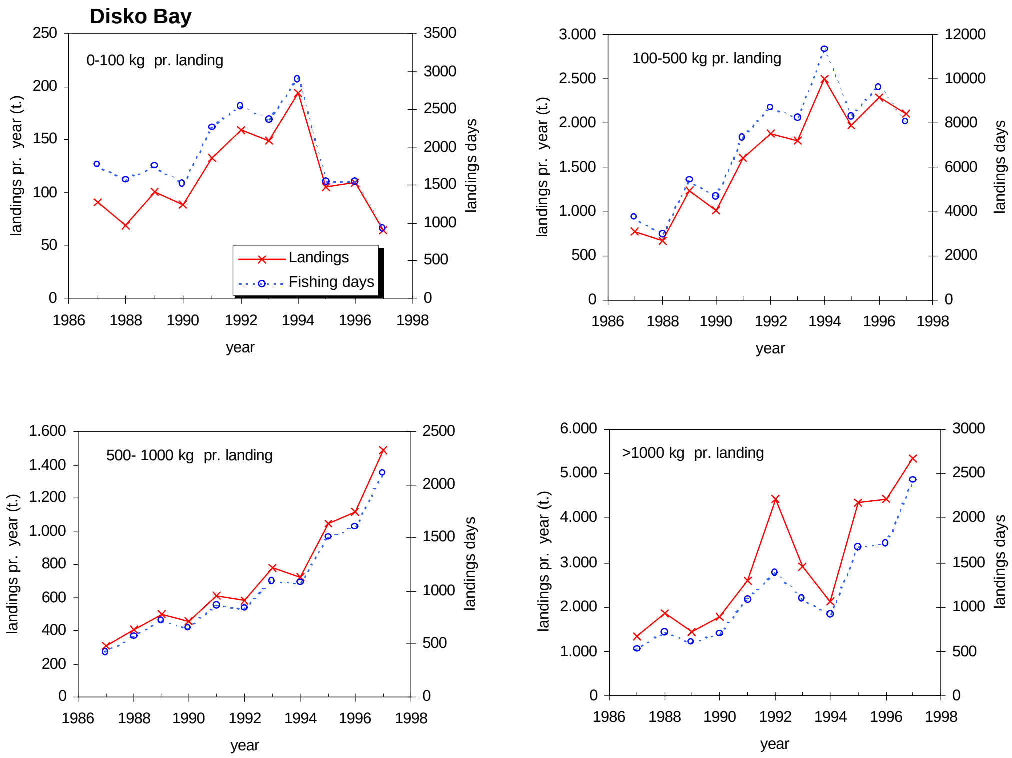
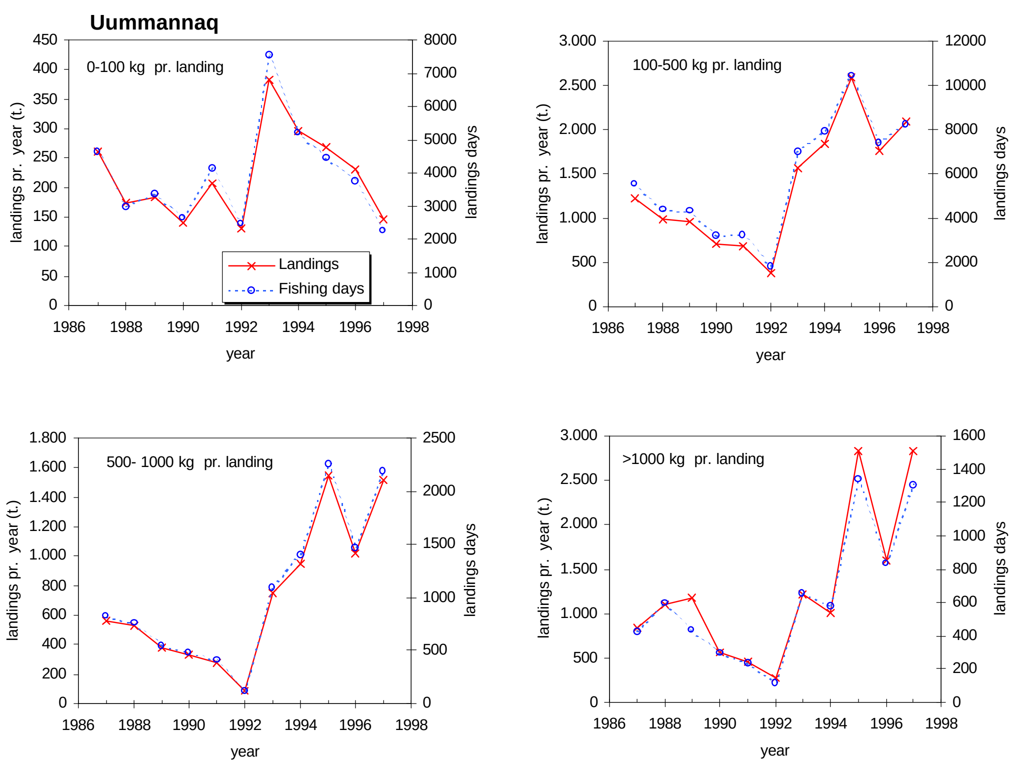


Fig. 8. Sexual maturity of Greenland halibut by visual assessment of the gonad (see table 5).

A)


Disko Bay
0-100 kg pr. landing
100-500 kg pr. landing
500- 1000 kg pr. landing
>1000 kg pr. landing
landings pr. year (t.)
landings days
year
Landings
Fishing days

B)


Uummannaq
0-100 kg pr. landing
100-500 kg pr. landing
500- 1000 kg pr. landing
>1000 kg pr. landing
landings pr. year (t.)
landings days
year
Landings
Fishing days

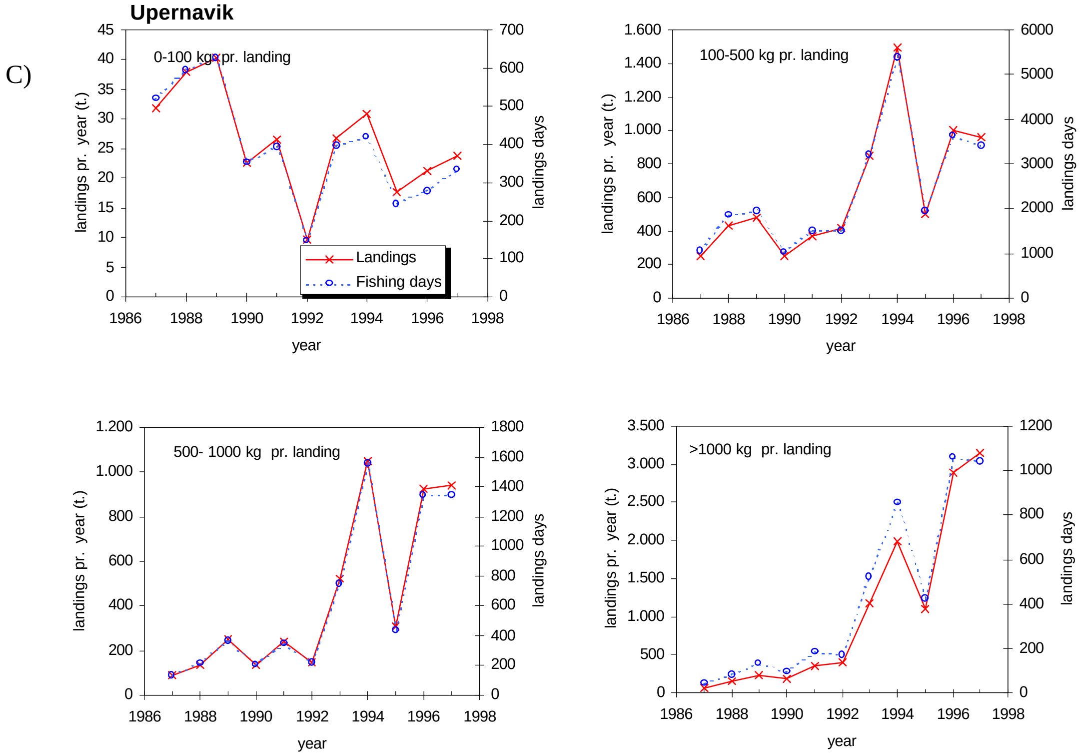


Fig. 9. Development in effort in the fishery by number of fishing days grouped in kg of fish landed per day (0-100, 100-500, 500-1000 and > 1000 kg pr. landing.) A) Disko Bay, B) Uummannaq & C) Uummannaq.

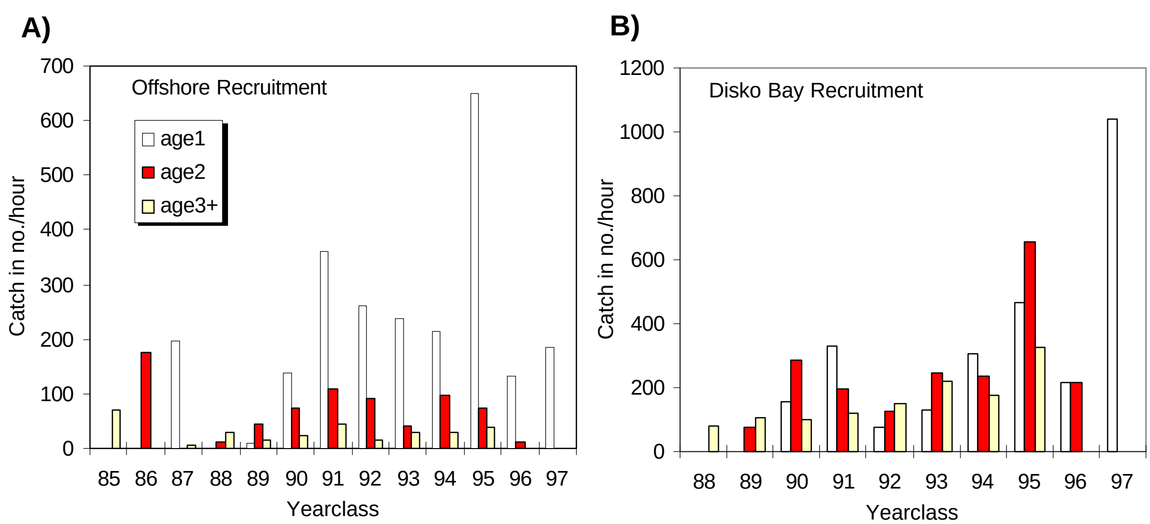


Fig.10. Year-class strength of recruits plotted as catch in numbers per hour, standardized index. The respective year-classes can be followed to age 3 in data from Greenland trawl survey. Missing values are due to missing observations. Offshore area, B) Disko Bay area

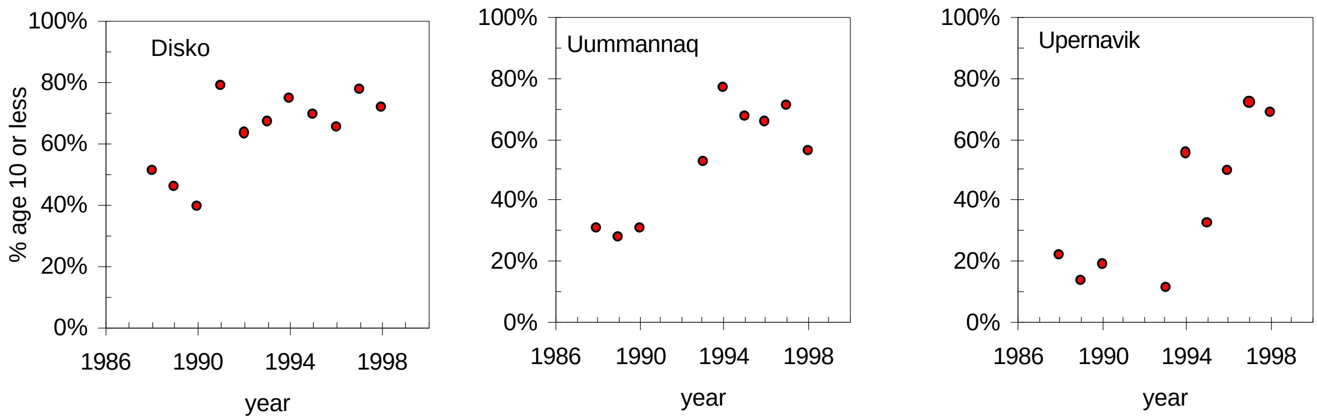


Fig. 11. The development in exploitation of the *age 10 and below* expressed as percentages for each year.

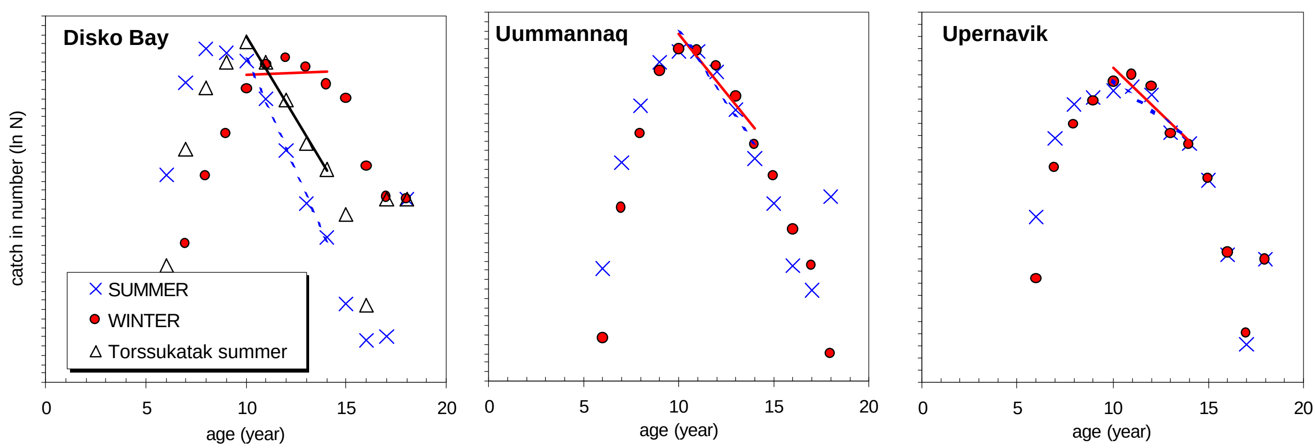


Fig. 12. Catch curves for the 3 main fishing areas bases on catch composition in the longline fishery for each season. Age group 10-14 was used for linear regression. Z was compiles as average of the estimated Z values. M was set to 0.15.

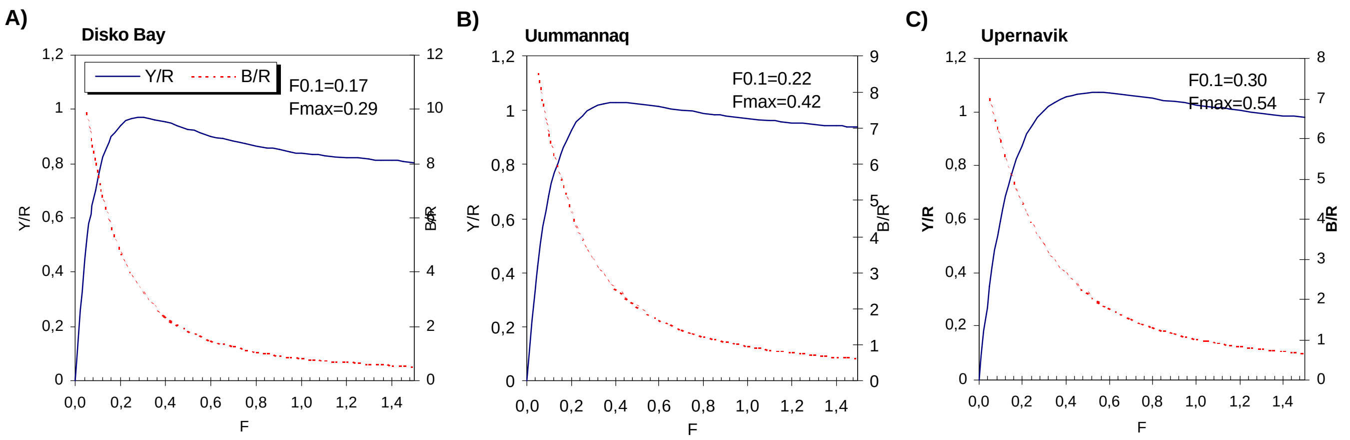


Fig. 13. Yield per Recruit and Spawning Stock biomass per Recruit curve in A) Disko Bay, B) Uumannaq and C) Upernavik area.

Appendix A

Table 1 **Output from Separable VPA**

Title : GREENLAND HALIBUT DIV 1A - ILULISSAT

At 7/06/1999 17:27

Separable analysis

from 1985 to 1998 on ages 5 to 17

with Terminal F of .350 on age 10 and Terminal S of 2.000

Initial sum of squared residuals was 757.006 and

final sum of squared residuals is 460.207 after 129 iterations

Matrix of Residuals

Years / Ages	985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOT	WTS
5/ 6	-5.366	-4.828	-2.321	-0.397	0.373	-4.366	-3.241	0.131	-1.651	3.549	-2.237	4.005	-6.599	-2.953	0.072
6/ 7	1.955	2.539	3.506	5.429	1.594	-4.117	-0.03	2.433	2.435	2.416	-2.628	-1.547	-4.753	-4.063	0.075
7/ 8	0.822	1.384	0.969	0.564	-3.67	-4.629	1.122	1.147	1.279	0.333	-0.119	-1.08	-0.295	0.115	0.122
8/ 9	-0.276	0.287	-0.441	-0.399	-0.853	-1.591	1.465	0.948	0.287	0.045	0.239	-0.774	0.319	0.115	0.293
9/10	-0.163	0.308	-0.032	0.1	0.386	0.087	0.314	0.353	-0.296	-0.061	0.377	-0.138	0.231	0.115	1
10/11	0.41	0.627	0.266	-0.001	0.194	0.333	-0.735	0.252	-0.109	-0.165	0.588	-0.453	0.253	0.115	0.59
11/12	0.186	0.014	0.188	0.115	0.077	1.191	-0.868	0.759	0.16	-0.27	0.243	-0.329	0.31	0.115	0.47
12/13	0.246	-0.134	0.077	-0.034	-0.081	1.318	-1.23	0.494	0.089	-0.608	-0.034	0.185	0.482	0.115	0.395
13/14	0.086	-0.449	-0.515	-0.5	-0.328	0.275	-1.557	-0.725	-0.278	0.193	0.057	0.201	-0.055	0.115	0.464
14/15	0.017	-0.547	-0.137	-0.07	0.329	0.212	0.535	-0.671	0.153	-0.102	-0.892	0.818	0.139	0.115	0.489
15/16	-0.173	-0.801	-0.073	-0.645	0.216	-0.169	5.052	-2.687	-0.197	0.362	-0.807	0.921	0.216	0.495	0.136
16/17	-0.692	-1.453	-0.155	-1.196	0.073	0.824	4.606	-6.366	0.261	-0.546	-0.02	0.557	-0.133	0.115	0.1
TOT	0	0	0	0	0	0	0	0	0	0	0	0	0	-18	
WTS	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1	1	1	1	1		

Fishing Mortalities (F)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
F-values	0.2185	0.1662	0.1545	0.1763	0.1377	0.2324	0.4116	0.4273	0.3517	0.2195	0.2956	0.367	0.2601	0.35

Selection-at-age (S)

	5	6	7	8	9	10	11	12	13	14	15	16	17
S-values	0.001	0.001	0.0339	0.2071	0.5652	1	1.3957	1.566	1.9205	2.1142	2.9877	2.6458	2

Cohort analysis Terminal populations from weighted Separable populations

SEPARABLY GENERATED FISHING MORTALITIES

YEAR		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AGE															
	5	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0004	0.0004	0.0004	0.0002	0.0003	0.0004	0.0003	0.0003
	6	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0004	0.0004	0.0004	0.0002	0.0003	0.0004	0.0003	0.0003
	7	0.0074	0.0056	0.0052	0.006	0.0047	0.0079	0.0139	0.0145	0.0119	0.0074	0.01	0.0124	0.0088	0.0119
	8	0.0453	0.0344	0.032	0.0365	0.0285	0.0481	0.0853	0.0885	0.0728	0.0455	0.0612	0.076	0.0539	0.0725
	9	0.1235	0.0939	0.0873	0.0997	0.0778	0.1314	0.2326	0.2415	0.1988	0.1241	0.1671	0.2074	0.147	0.1978
	10	0.2185	0.1662	0.1545	0.1763	0.1377	0.2324	0.4116	0.4273	0.3517	0.2195	0.2956	0.367	0.2601	0.35
	11	0.305	0.2319	0.2157	0.2461	0.1922	0.3244	0.5745	0.5964	0.4909	0.3064	0.4126	0.5122	0.363	0.4885
	12	0.3422	0.2602	0.242	0.2761	0.2156	0.364	0.6446	0.6691	0.5508	0.3438	0.4629	0.5747	0.4073	0.5481
	13	0.4197	0.3191	0.2967	0.3387	0.2645	0.4464	0.7906	0.8206	0.6755	0.4216	0.5677	0.7048	0.4996	0.6722
	14	0.462	0.3513	0.3267	0.3728	0.2911	0.4914	0.8703	0.9034	0.7436	0.4641	0.625	0.7759	0.5499	0.74
	15	0.6529	0.4964	0.4616	0.5268	0.4114	0.6944	1.2299	1.2766	1.0508	0.6558	0.8831	1.0964	0.7771	1.0457
	16	0.5782	0.4396	0.4088	0.4666	0.3643	0.615	1.0891	1.1305	0.9306	0.5808	0.7821	0.9709	0.6882	0.926
	17	0.4371	0.3323	0.309	0.3527	0.2754	0.4649	0.8233	0.8546	0.7034	0.439	0.5912	0.7339	0.5202	0.7

Table 2 Catch numbers at age

Numbers*10**-3

YEAR		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AGE															
	5	0	0	0	0	0	0	6	103	5	3	0	9	0	0
	6	14	14	10	1	0	0	12	137	64	14	0	1	0	85
	7	47	44	30	10	0	1	316	373	288	102	49	50	97	454
	8	86	81	53	67	23	34	912	535	492	256	501	346	532	887
	9	199	189	125	207	173	198	606	438	348	491	698	1009	1119	1081
	10	254	235	174	197	198	260	377	507	288	361	872	698	991	1429
	11	146	123	116	150	154	264	269	598	247	173	506	487	649	864
	12	91	67	86	83	80	177	86	347	125	83	202	293	291	396
	13	58	41	57	72	54	112	51	157	94	46	139	155	106	151
	14	39	26	41	74	64	83	76	103	115	41	29	80	45	78
	15	33	22	34	43	51	59	65	20	77	37	39	47	14	30
	16	21	13	22	20	31	32	40	0	59	19	13	33	4	5
	17	21	13	23	13	23	21	8	0	12	9	16	5	4	2
+gp		8	4	3	5	13	8	2	0	17	5	0	35	0	0
0 TOTALNUM		1017	872	774	942	864	1249	2826	3318	2231	1640	3064	3248	3852	5462
TONSLAND		2685	2118	2258	2670	2781	3821	5372	6577	5367	5201	7400	7800	8601	10671
SOPCOF %		100	101	100	100	100	100	100	100	100	100	100	100	100	102

Table 3 Catch weights at age (kg)

YEAR		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AGE															
	5	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.759	0.973	0.813	0.61	0.293	0.499
	6	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.93	1.214	0.998	0.774	0.508	0.653
	7	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947	1.14	1.515	1.224	0.981	0.773	0.856
	8	1.199	1.199	1.199	1.199	1.199	1.199	1.199	1.199	1.396	1.891	1.502	1.243	1.148	1.122
	9	1.518	1.518	1.518	1.518	1.518	1.518	1.518	1.518	1.711	2.36	1.843	1.576	1.589	1.47
	10	1.923	1.923	1.923	1.923	1.923	1.923	1.923	1.923	2.096	2.945	2.262	1.997	2.176	1.927
	11	2.435	2.435	2.435	2.435	2.435	2.435	2.435	2.435	2.569	3.675	2.776	2.532	2.975	2.225
	12	3.083	3.083	3.083	3.083	3.083	3.083	3.083	3.083	3.147	4.586	3.406	3.21	3.693	3.309
	13	3.905	3.905	3.905	3.905	3.905	3.905	3.905	3.905	3.857	5.724	4.179	4.069	4.797	4.337
	14	4.945	4.945	4.945	4.945	4.945	4.945	4.945	4.945	4.726	7.143	5.128	5.157	5.953	5.683
	15	6.262	6.262	6.262	6.262	6.262	6.262	6.262	6.262	5.79	8.914	6.292	6.537	7.372	7.448
	16	7.931	7.931	7.931	7.931	7.931	7.931	7.931	7.931	7.095	11.125	7.72	8.287	10.083	9.76
	17	10.043	10.043	10.043	10.043	10.043	10.043	10.043	10.043	8.693	13.884	9.473	10.504	11.683	12.79
+gp		12.719	12.719	12.719	12.719	12.719	12.719	12.719	12.719	10.652	17.327	11.624	13.315	16.761	16.761
0 SOPCOFAC		0.9982	1.0061	1.0021	0.9986	0.9998	1.0017	0.9994	1.0009	1.0011	0.9991	1.0012	1.0018	1.001	1.025

Table 4 Fishing mortality (F) at age

YEAR		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	FBAR 96-98
AGE																
	5	0	0	0	0	0	0	0.0007	0.0091	0.0004	0.0003	0	0.0009	0	0	0.0003
	6	0.0052	0.0046	0.0033	0.0003	0	0	0.0019	0.0197	0.0066	0.0012	0	0.0001	0	0.009	0.0031
	7	0.0221	0.0193	0.0115	0.0038	0	0.0003	0.0777	0.0706	0.0497	0.0124	0.005	0.0067	0.016	0.0605	0.0278
	8	0.0519	0.0458	0.0277	0.0305	0.0102	0.0135	0.3585	0.173	0.1188	0.054	0.0736	0.0419	0.0873	0.1884	0.1059
	9	0.1707	0.1463	0.0878	0.1364	0.0977	0.1085	0.3313	0.2753	0.154	0.1582	0.1935	0.1968	0.1754	0.2426	0.2049
	10	0.2907	0.2948	0.1845	0.1839	0.1773	0.1974	0.2924	0.481	0.2772	0.2239	0.4364	0.285	0.2853	0.3347	0.3016
	11	0.2657	0.2105	0.2189	0.2268	0.2026	0.3574	0.3043	0.9831	0.4303	0.2522	0.5255	0.4385	0.4404	0.4071	0.4287
	12	0.2595	0.1771	0.2111	0.2275	0.1717	0.3564	0.1774	0.7617	0.5213	0.2356	0.4929	0.6257	0.4814	0.498	0.535
	13	0.2801	0.1685	0.2126	0.2596	0.2145	0.3633	0.1547	0.5307	0.4453	0.3461	0.7276	0.8391	0.4549	0.4664	0.5868
	14	0.3343	0.1844	0.2399	0.442	0.3655	0.5573	0.4237	0.4987	0.906	0.3345	0.3608	1.2571	0.5858	0.6781	0.8403
	15	0.3854	0.3013	0.3676	0.401	0.5888	0.6397	1.1353	0.1759	0.8245	0.801	0.5779	1.7041	0.7162	0.9593	1.1265
	16	0.4102	0.2423	0.5251	0.3619	0.5331	0.8785	1.2231	0	1.0765	0.4575	0.6955	1.4659	0.588	0.5697	0.8746
	17	0.4381	0.4537	0.8294	0.6427	0.8738	0.8081	0.5255	0	0.7473	0.4198	0.8384	0.596	0.6333	0.6255	0.6183
+gp		0.4358	0.4513	0.8231	0.6385	0.867	0.8021	0.5225	1.212	0.742	0.4177	0.8321	0.5923	0.6292	0.6215	
FBAR 10-14		0.2861	0.2071	0.2134	0.2679	0.2263	0.3664	0.2705	0.651	0.516	0.2785	0.5086	0.6891	0.4495	0.4769	

Table 5 Stock number at age (start of year) Numbers*10-3**

	YEAR	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	GMST 85-96	AMST 85-96
	AGE																	
	5	3826	3848	4279	5118	6153	7981	8824	12279	14342	10831	8872	11259	11852	0	0	7392	8134
	6	2891	3293	3312	3683	4405	5296	6869	7589	10473	12339	9320	7637	9682	10201	0	5747	6426
	7	2317	2475	2821	2842	3169	3792	4559	5901	6405	8955	10608	8022	6572	8333	8701	4519	5155
	8	1832	1950	2090	2400	2437	2727	3263	3630	4733	5245	7613	9085	6858	5567	6751	3404	3917
	9	1367	1497	1603	1749	2004	2076	2316	1962	2628	3617	4277	6088	7498	5409	3968	2339	2599
	10	1085	992	1113	1264	1314	1564	1603	1431	1282	1939	2658	3034	4304	5416	3653	1512	1607
	11	674	698	636	797	905	947	1105	1030	761	837	1334	1479	1964	2785	3336	903	934
	12	429	445	487	440	547	636	570	702	332	426	560	679	821	1088	1595	509	521
	13	256	285	321	339	301	396	383	411	282	169	290	294	313	437	569	303	311
	14	148	166	207	223	225	209	237	283	208	155	103	121	109	171	236	183	191
	15	111	91	119	140	124	135	103	134	148	72	96	62	30	52	75	108	111
	16	67	65	58	71	81	59	61	29	96	56	28	46	10	12	17	56	60
	17	64	38	44	30	43	41	21	15	25	28	30	12	9	5	6	30	33
	+gp	24	12	6	11	24	15	5	0	35	16	0	84	0	0	2		
0	TOTAL	15092	15857	17096	19108	21731	25875	29919	35396	41750	44688	45789	47900	50021	39475	28909		

Table 6 Summary (without SOP correction)

Cohort analysis Terminal populations from weighted Separable populations

	RECRUITS	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 10-14
	Age 5					
1985	3826	19845	8962	2685	0.2996	0.2861
1986	3848	20225	8539	2118	0.248	0.2071
1987	4279	21799	9189	2258	0.2457	0.2134
1988	5118	24034	10039	2670	0.266	0.2679
1989	6153	26739	10854	2781	0.2562	0.2263
1990	7981	30453	11776	3821	0.3245	0.3664
1991	8824	33693	11611	5372	0.4627	0.2705
1992	12279	37478	11644	6577	0.5648	0.651
1993	14342	48913	9881	5367	0.5432	0.516
1994	10831	72293	14751	5201	0.3526	0.2785
1995	8872	63285	14469	7400	0.5114	0.5086
1996	11259	57364	15830	7800	0.4927	0.6891
1997	11852	54071	20813	8601	0.4133	0.4495
1998	0	51659	23668	10671	0.4509	0.4769
Arith.						
Mean	7819	40132	13002	5237	0.388	0.3862
Units	(Thousan ds)	(Tonnes)	(Tonnes)	(Tonnes)		

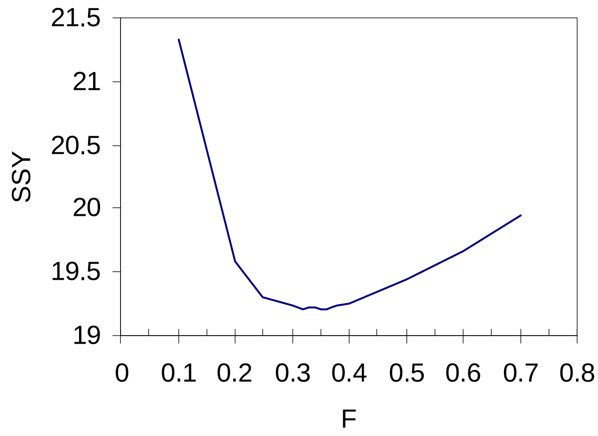


Fig. 1. A separable VPA was run with different terminal F in the interval 0.1-0.7. CPUE from surveys were available from the years 1993, 94, 96 and 97 and the CPUE separated on age-classes 5-14 were used to minimize the sum of squares on the separable generated population numbers from the VPA.

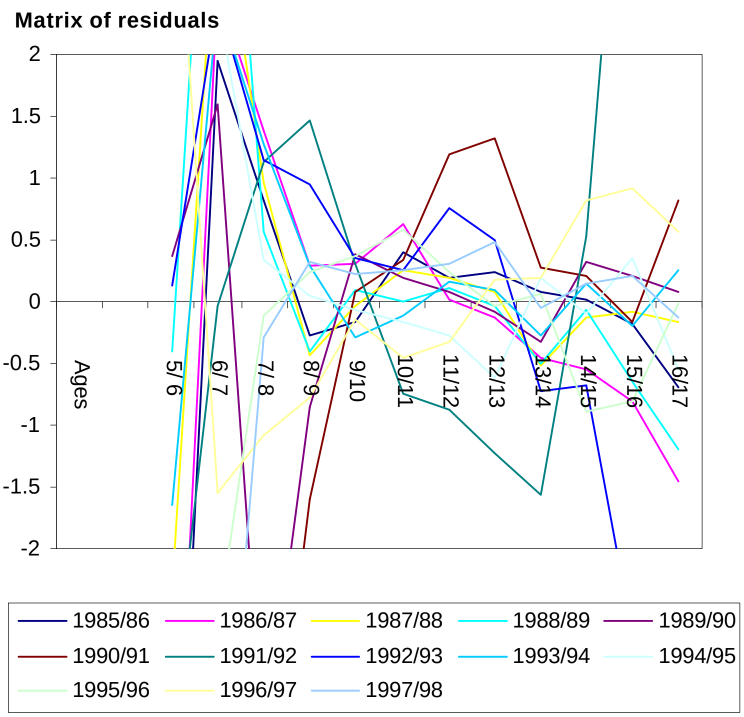


Fig. 2. Matrix of Residuals from Separable VPA. Analyze from 1985 to 1998 on ages 5 to 17. with Terminal F of .350 on age 10 and Terminal S of 2.000.

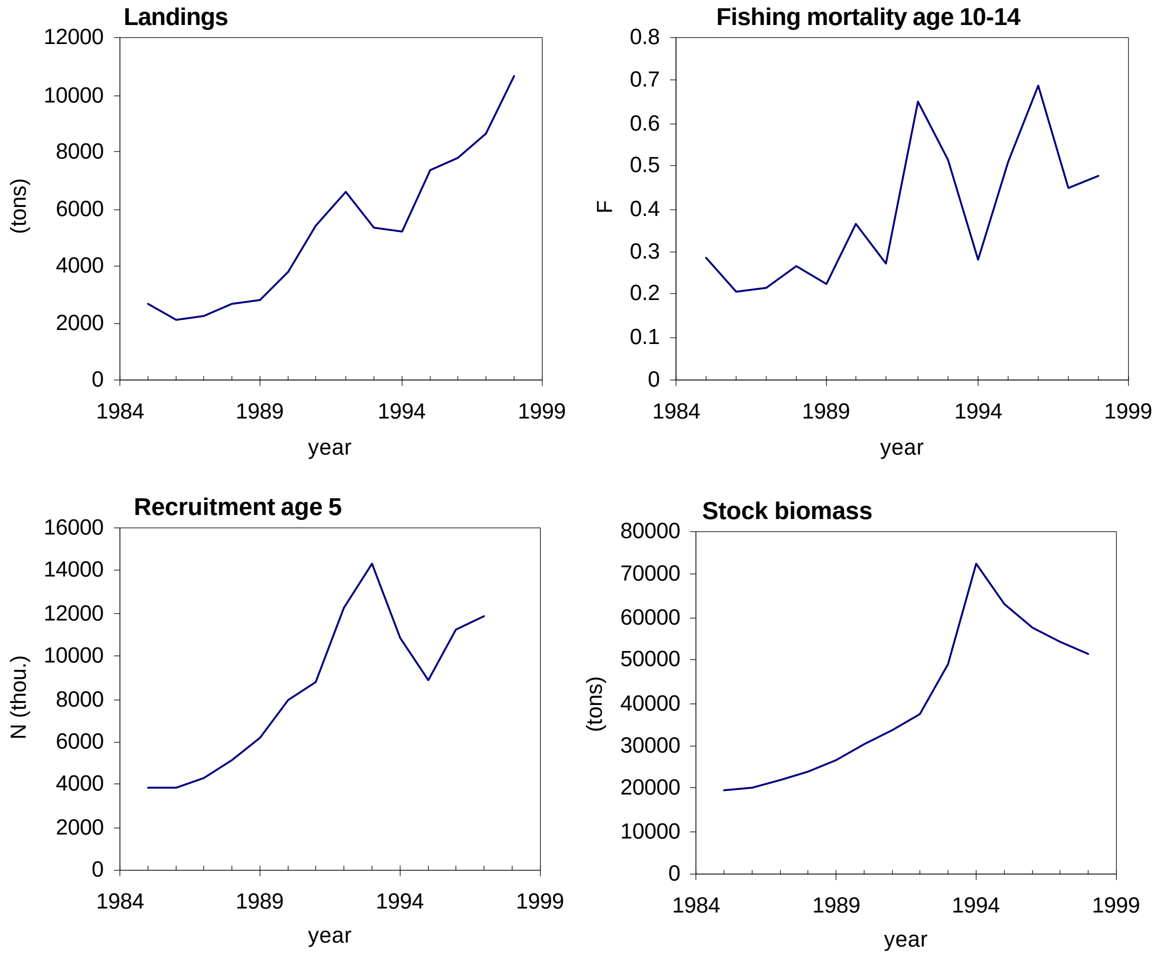


Fig. 3. Summary plots of landings, fishing mortality, recruitment at age 5 and stock biomass derived from cohort analysis (Table 6).