Northwest Atlantic Fisheries Organization

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Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 + Div. 1A offshore + Div. 1B-1F

by

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1. TAC, description of the fishery and nominal catches.

Between 1979 and 1994 a TAC has been set at 25,000 tons for SA 0+1, including Div. 1A inshore. In 1994 it was decided to make separate assessments for the inshore area in Div. 1A and SA 0 + Div. 1A offshore + Div.1B-1F. From 1995-1998 a TAC for this area was set at 11,000 tons.

In the period 1982-1989 nominal catches of Greenland halibut in SA 0 + Div. 1A offshore + Div.1B-1F fluctuated between 300 and 4,500 tons. Catches increased from 2,200 in 1989 tons to 10,500 in 1990. Catches stayed at that level in 1991 but increased again in 1992 to 18,100, the highest in the time series. Since then catches have been about 11,000 tons. In 1997 catches were 10,540 compared to 10,430 tons in 1996. The increase in catches from 1989 to 1990 was mainly due to a new trawl fishery by Canada and Norway in Div. 0B, while the increase from 1991 to 1992 was due to the introduction of a trawl fishery by Russia in Div. 0B and an increase in fishing activity in SA 1.

In 1983 annual catches in Div. 0B were about 4,500 tons. Catches then dropped to a level of 1,000 tons or lower, where they remained until they increased from 907 tons in 1989 to 9,498 tons in 1990. Catches decreased in 1991 to 8,606 tons, to increase again in 1992 to 12,358 tons. Catches then decreased gradually to 4,321 tons in 1994, but increased again to 5,519 tons in 1996 via 5,299 tons in 1995. The catch in 1997 was 5,740 tons (Table 1).

Canadian catches were mainly taken by gillnets and longlines and amounted to 1,700 tons of which 66 tons were taken inshore in Cumberland sound. Foreign trawlers (not reported) took about 4,000 tons. An exploratory trawl fishery in Div. 0A by Canada yielded 240 tons.

The catches in Subarea 1 (Div. offshore 1A Div. + 1B-1F) were below 1,600 tons during the period 1982-1990. In 1991 catches increased to 2,376 tons and were

around 5,500 tons in the period 1992-1995, but decreased to 4,556 in 1996. In 1997 total catches in offshore Div. 1A + Div. 1B-1F increased slightly to 4,800 tons, of which 4,793 tons were taken offshore, almost exclusively in Div. 1D. Longliners from Greenland and Norway caught 1,090 tons, while 3,575 tons were caught by trawlers from Greenland, EU and Norway. Non-reported catches amounted to 128 tons, taken by trawl. Inshore catches amounted to 7 tons (Table 2).

2. Input data

2.1 Research trawl survey

In 1997 a stratified random trawl survey for Greenland halibut was conducted in September-October (SCR 98/25). The survey covered NAFO Division 1CD between the 3-nm line or the midline to Canada at depths between 400 and 1500 m. The biomass and abundance was estimated at 56,260 tons and $53.613*10^6$ specimens. Most of the biomass and abundance was found in Div. 1D at depths > 1000 m. The over all length distribution was dominated by a single mode around 50 cm. In 1995 the biomass and abundance was estimated to 38,079 tons and $33.025*10^6$ specimens in the joint Japan/Greenland survey. The survey was, however, conducted a month earlier and with another vessel and gear. The mode in the length distributions in the joint surveys has been around 47-50 cm during the years 1987-1995 (SCR 98/25).

Since 1988 annual trawl surveys with a shrimp trawl have been conducted off West Greenland in July-September. The survey covers the area between 59°N and 72°30'N (Div. 1A-1F), from the 3-mile limit to the 600 m depth contour line.

Estimated total trawlable biomass of Greenland halibut in the offshore areas was about 9,000 tons in 1992 and 1993 and increased to 11,000 tons in 1994. After a drop in 1995 to 6,800 tons the total offshore biomass increased to 14,772 tons in 1996 to decline again to 9,631 tons in 1997. The catches were almost exclusively comprised of one and two year old fish. The abundance was estimated to 115 mill, which is the lowest observed in the time series. The promising 1995 year class appears to be at an average level at age 2, while it appears even stronger in the inshore area Disko Bay in 1997 compared to 1996. In the Disko Bay the biomass was estimated at 7,772 tons and the abundance at 126 mill (SCR 98/40).

The biomass in the nursery area (1AS and 1B) was estimated to 4,229 tons compared to 7,753 tons 1996. The abundance was estimated to 67 mill compared to 342 mill in 1996.The estimates from 1997 are at the same low level as seen in 1990 and 1991, and below the 1992-1995 level (200 mill).

A recruitment index was provided from the shrimp trawl survey. By means of the Petersen-method ages 1, 2 and 3 were separated in the survey catches in the nursery area during the period 1988 to 1997. Catches were standardized as catch in number per hour as described in Bech (1995). Data were plotted by year classes to visualize the relative year class strength and development in relative abundance (Fig. 1).

The recruitment has been declining since the presumably large 1991 year-class, but the recruitment has been above the level in the 1980'ies. The 1995 year class seems, however, to be the largest on record. The 1996 year class is at the low level of the 1990 year-class. The mean catch of one year old fish in 1997 was 132 specimens per hour compared to 649 specimens in 1996. The large 1995 year class has at age 2 been reduced markedly offshore and is now at an average level for the 1990'ies. In Disko Bay in 1997 catches of one year old fish was about average for the 1990'ies (215 specimens per hour). The 1995 year class was also the highest on record as age 1 (465 specimens per hour) in the Disko Bay. As age 2 this year class seems even stronger (635 specimens per hour).

The relation between the spawning stock in numbers (ages 10-18) in Div. 1CD from the joint Japan/Greenland survey) and recruitment, given as the number of

fish age 1 in the nursery area (Div. 1AS and Div. 1B) estimated from the Greenland shrimp trawl survey is given in Fig 2.

The by-catch of Greenland halibut in the offshore West Greenland shrimp fishery in July-August was estimated at 288 tons and 3.3 mill specimens based on data from the Greenland shrimp trawl survey. The by-catch was mainly taken in the northern part of Div. 1B and in Div. 1C. In Div. 1BN the by-catch almost exclusively comprised of fish between 10 and 20 cm. In Div. 1C the by-catch mainly comprised of 15-30 cm fish (SCR 98/41).

An exploratory trawl fishery for Greenland halibut was conducted in Div. 0A in 40 days by 3 otter trawlers. The catch was 240 tons. The length distribution ranged from 23 cm to 89 cm with a clear mode around 50 cm (Fig.3)

2.3 Commercial fishery data.

Length and age distribution
Length frequency samples from the offshore fishery were obtained from a trawler in Div. 1D (SCS 98/7) and a length frequency sample was available from Cumberland Sound (Fig. 4)

Canadian catch-at-age was updated for the period 1988-1997 (SCR 98/39). The catch-at-age in the trawl fishery in SA1 was calculated using a Canadian age length key from Div. 0B. The longline catches from SA1 was added to the combined gillnet-longline catch-at-age-data from 0B. Table 3 and 4 shows catch-at-age and weight-at-age, respectively. The age distributions for trawl and longline + gillnets are given in Fig.5.

Ages 7 and 8 are the most dominant yearclass in the trawl fishery, age 7 being most dominant in 0B and age 8 most dominant in 1CD. The ages 8 and 9 was dominant in gillnet catches. The estimation of the combined gillnet-longline age distribution was based on few data. The longline catches from SA1, which normally are dominated by fish between 12 and 16 years, was added to this combined sample as no better was available. This is probably the reason why the amount of old fish has declined in the overall catches compared to previous years (Table 3).

Mean weight at age
Mean weight at age for the ages 7-12 in the commercial offshore fishery in Div. 0B has been stable for the last thee years (SCR 98/39).

Catch rates
Standardized catch rate series for the offshore trawl fishery were calculated based on observer data in SA0 (Div. 0B) for the period 1990-1997 and for the offshore trawl fishery in SA1 (1CD) for the period 1987-1997 based on available logbook data and CPUE data from Norwegian and German trawlers (SCR 98/39).

Average catch rates were available from the Norwegian trawl fishery in Div. 1CD in the period 1991-1997 (Table 5).

Catch rates form an EU (German) trawler were available for 1996 and 1997 (SCS 98/7).

Unstandardized catch rates from the trawl fishery Div. 1CD are shown in Fig.6 (Japan s: small trawlers, Japan l: one large trawler).

Further, catch rates from one offshore longliner were available for the period 1994-1997.

The standardized catch rate series from 0B showed rather stable catch rates during the period with a weak, but not statistically significant, increasing

tendency and the catch rates seems to be near the highest observed level in 1997 (Fig 7). The standardized catch rates in SA 1 fluctuated in the period 1987-1992, declined in 1993 and 1994 to the lowest observed. Since then the CPUE has increased gradually and is 1997 near the average level for the period 1987-1997 (Fig. 7, Appendix 1, and SCR 98/39. The increase in the catch rate in SA1 was mainly caused by an increase in Greenland catch rates (Fig 6).

Norwegian catch rates in SA 1 have shown a decreasing trend in the period 1991-1995, but have stabilized since then, however with a small decrease from 1996 to 1997(Table 5, Fig. 6).

The catch rates from the longline fishery in Div. 1CD increased from 137 kg/hr in 1994 to 181 kg/hr in 1995, but decreased again in 1996 to 112 kg/hr and further to 84 kg/hr in 1997.

3. Assessment.

3.1 Yield per Recruit Analysis.

The level of total mortality has in the previous three years been estimated by means of catch-curves using data from the offshore longline fishery in Div. 1D. Z was estimated from regression on age 15-21. A relative F-at-age was derived from the catch curve analysis, where the trawl, longline and gillnet catches were weighed and scaled to the estimated stock composition. In all three years STACFIS considered that the estimation of Z was based on too limited samples and represented too small a part of the fishery and that the outcome of the catch curve analysis were too uncertain to be used in the yield per recruit analysis. No longline data from 1997 were available for catch curve analysis this year.

3.2 XSA.

An XSA has been run unsuccessful several times during the 1990'ies, the latest in 1996. STAFIS considered the XSA's unsuitable for an analytic assessment due to high log-catchability residuals and S.E.'s and systematic shift in the residuals by year. Further, a retrospective plot of F_{bar} showed poor convergence. Preliminary XSA analyses have been made in 1997 and 1998 (not presented) but the outcome of the analysis has not improved.

3.3 Spawning stock/recruitment relations.

A spawning stock/recruitment plot based on the 7 available observations is shown in Fig. 2. No further analysis of spawning stock recruitment relationships have been made due to few observations, poor estimate of spawning stock biomass (survey trawl only take a small proportion of the mature fish, the survey covers only a restricted part of the area covered by the assessment, further, knife edge maturity ogive was applied), poor estimate of age of the recruits (the Petersen method), poor estimates of the numbers of recruits (data from Div. 1AS and 1B only, but the recruits occurs in an larger area especially when the yearclass is good).

3.4 ASPIC

ASPIC was run with standardized CPUE data and a biomass index as inputs. The two CPUE series covered 0B during the period 1990-1997 and 1CD during the period 1987-1997. The biomass index was from 1CD and covered the period 1987-1995. Several runs showed that the CPUE series from 1CD fitted the total catch data best. Runs with biomass alone gave relatively good fits in terms of "total objective function" and r^2 but MSY, K and r were unrealistic low, the modeled population trajectory declining drastically over the period. Runs with the CPUE series from 0B gave unrealistic high B_{msy} and very low r. All three indices combined showed negative r^2 for the 0B CPUE series. The fit of the 1CD Biomass and CPUE series combined was not as good as the 1CD CPUE series alone. This latter run showed, however, that sensitivity analysis should be run, because

"the B1-ratio constraint term contributed to loss". Several runs with different realistic values for the constraint did not solve the problem. Further, the coverage index and nearness index was equal in all runs. (This was also the case when the series were run in combination. In some case, however, when a series was run alone there were different values for the two indices). Despite this the 1CD was considered to fit the catch data best. To get measures of variance the series was bootstrapped. Inputs and outputs are given in Appendix 2.

Part of the difference in the results of model runs with the biomass index data alone and including the fishery CPUE data is due to the difference in the periods covered. The CPUE series is longer by two years, and the last two years in the series had increasing CPUE values while the catches were stable. Including them increased the estimate of the stock's natural rate of increase (r), and consequently of the MSY.

For the reasons given above, it was decided to stay with an assessment model based only on one data series, the CPUE from SA1 only. Results from this model (Appendix 2) show that estimated fishing moralities 1987--1997 have been less than the (bias-reduced) estimate of F_{msy} (0.17) except for one year (1992).

Using only CPUE series as indices of biomass decreases modelling precision, owing to the added uncertainty of unknown catchability factors that must be estimated. To verify the precision of the results, the bootstrap mode of ASPIC was used (500 resamplings). The results are shown in Appendix 2. A number of essential parameters are quite imprecisely estimated (r, q, F_{msy}), and STACFIS considered that the estimates of MSY and F_{msy} were not precise enough to be used.

4. Prognosis

Since catches peaked with 18.000 tons in 1992 they have been stable at around 10.500 tons. The age composition in the catches seems stable. Standardized catch rates in both 0B and 1CD have increased from 1996 to 1997. The catch rates seem to be at a high level in 0B and around average in 1CD. An unstandardized longline CPUE index showed a decrease from 1995 to 1997.

Survey biomass showed an increasing trend between a survey in 1995 and a survey in 1997 although the surveys were conducted with different vessel and gear. The length distribution in the survey 1997 peaked around 50 cm, where the peak usually was at 47-50 cm in previous year's surveys. The recruitment has declined markedly compared to the large 1995 year class and the 1996 yearclass seems to be below average for the period 1988-1997.

5. Biological reference points.

Yield per recruit analysis or other age based methods are not available, for estimating biological reference points. Biomass indices and CPUE series are relative short and show little variability and are not useful for estimating reference points.

6. References

Bech, G. 1995. Recruitment of Greenland halibut at West Greenland. NAFO SCR Doc. 95/19.

Brodie W. and W.R. Bowering. 1998. Data from the commercial fishery for Greenland halibut in Subarea 0. NAFO SCR Doc. 98/39.

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Table 1. Greenland halibut catches (metric tons) by year and country for Subarea 0 from 1987 to 1997.

	Year										
Country	87	88	89	90	91	92	93	94[a]	95[a]	96[a]	97[a]
CAN	-	2	-	589	256	2194	883	-	1366	2349[d]	1700
EST	-	-	-	-	-	-	631	-	-	-	-
FRO	388	963	596	2252	2401	463	1038	-	-	-	-
JAP	-	-	-	113	232	337	252	600	1031	500	-
LAV	-	-	-	-	-	-	83	-	-	-	-
NOR	-	-	282	5016[f]	3959	-	373	-	-	-	-
RUS	-	59	29	1528	1758	9364	4229[b]	3721	261	-	-
TOTAL	388	1024	907	9498	8606	12358	7489	4321	5299[c]	5519[e]	5740[g]

[a] Provisional data.
[b] The russian catch is reported as area unknown, but has peviously been reported from 0B
[c] Including 2641 tons non-reported.
[d] Including 60 tons from Cumberland Sound and 295 tons from an exploratory fishery in 0A.
[e] Including 3025 tons non-reported
[f] Dobbel reported as 10031 tons
[g] Including 4000 tons non-reported

Table 2. Greenland halibut catches (metric tons) by year and country for Subarea 1 from 1987 to 1997.

	Year										
Country	87	88	89	90	91	92	93	94[a]	95[a]	96[a]	97[a]
GRL (excl. 1A inshore)	-	-	-	-	965	227	213	885	1407	1886	2312
FRO	-	-	-	54	123	151	128	-	-	-	-
JPN	907	1581	1300	988	677	2902	1198	820	337	-	-
NOR	-	-	-	-	611	2432	2344	3166	2377	1856	1912
RUS	-	-	-	-	-	-	5	-	269	229	-
EU	-	-	-	-	-	-	46	266	528	457	448
1A-F (excl. 1A inshore)	907	1581	1300	1042	2376	5712	3934	5917[b]	5585[c]	4556[d]	4800[e]

[a] Provisional data.
[b] Including 780 tons non-reported.
[c] Including 667 tons non-reported.
[d] Including 128 tons non-reported.
[e] Including 128 tons non-reported.

Table 3. Catch numbers at age

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
AGE											
5	2	1	1	4	20	53	241	257	96	160	60
6	31	29	36	87	318	678	651	870	472	571	429
7	182	190	244	592	1742	2967	2422	2497	1980	1990	1954
8	296	354	409	1711	2679	4311	2356	1709	1178	1711	2408
9	193	245	212	1356	1418	2604	1048	963	737	720	1155
10	77	115	75	711	533	951	590	298	369	336	483
11	40	80	47	359	221	398	224	185	322	174	256
12	18	61	48	195	144	231	130	161	282	136	127
13	10	58	44	189	108	158	72	126	155	68	100
14	9	46	42	115	60	85	59	58	107	59	22
15	6	35	26	67	36	45	37	55	118	40	13
16	3	15	12	17	6	23	26	34	51	37	12
17	4	4	1	3	2	1	4	10	26	14	0
+gp	2	1	0	0	0	0	2	7	12	22	0
TOT.NUM	873	1234	1197	5406	7287	12505	7862	7230	5905	6038	7019
TONS	1295	2605	2207	10640	10982	18070	11423	10238	10884	10430	10540

Table 4. Catch weights at age (kg)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
AGE											
5	0.29	0.29	0.29	0.33	0.34	0.33	0.58	0.43	0.47	0.52	0.36
6	0.51	0.51	0.51	0.54	0.54	0.56	0.72	0.62	0.64	0.68	0.55
7	0.74	0.74	0.74	0.79	0.79	0.80	0.96	0.91	0.93	0.94	0.86
8	1.08	1.08	1.08	1.10	1.12	1.13	1.26	1.26	1.33	1.38	1.27
9	1.41	1.42	1.42	1.52	1.57	1.59	1.80	1.72	1.81	1.90	1.83
10	1.97	2.05	2.00	2.11	2.27	2.28	1.43	2.19	2.40	2.48	2.37
11	2.58	2.80	2.68	2.94	3.22	3.02	3.25	2.73	2.93	3.18	3.01
12	3.52	3.88	3.73	3.90	4.24	4.02	4.10	3.43	3.65	4.04	3.84
13	4.64	5.01	4.87	4.96	5.50	5.33	5.26	4.48	4.48	5.05	4.93
14	5.79	6.16	6.20	6.26	6.82	6.76	6.17	5.75	5.67	5.95	5.70
15	6.61	7.44	7.65	7.96	8.33	7.76	7.42	6.58	6.66	7.33	6.79
16	7.99	8.88	9.36	9.90	9.89	8.58	8.04	7.36	7.74	8.64	8.00
17	9.56	9.86	9.56	11.86	9.56	11.95	9.24	9.42	10.28	9.17	
+gp		11.33					10.25	11.15	11.00	11.10	

Table 5. CPUE in Divs. 1C+1D by Norwegian factory trawlers 1991-1997.

DIVISION		1991	1992	1993	1994	1995	1996	1997
1C Norwegian Trawlers	min	12,279	19,702	20,222	1,077	43,8376		750
	catch(t)	176	243	182	7	234		1
	CPUE	0.86	0.74	0.54	0.39	0.32		0.08
1D Norwegian Trawlers	min	42,495	207,802	238,500	321,457	286,468	196,000	237,512
	catch(t)	687	2,459	2,226	3,161	2,2244	1,568	1,624
	CPUE	0.97	0.71	0.56	0.59	0.47	0.48	0.41

Appendix 1. Standardized CPUE SA 1

15:16 Wednesday, June 10, 1998

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YR	11	87 88 89 90 91 92 93 94 95 96 97
CGT	6	3 5 6 7 8 9

Number of observations in data set = 86

General Linear Models Procedure

Dependent Variable: LCPH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	13.2284373	0.8818958	18.20	0.0001
Error	70	3.3926706	0.0484667		
Corrected Total	85	16.6211079			

R-Square	C.V.	Root MSE	LCPH Mean
0.795882	-3.034352	0.22015	-7.25531

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YR	10	9.71042674	0.97104267	20.04	0.0001
CGT	5	3.51801061	0.70360212	14.52	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	10	1.57358535	0.15735854	3.25	0.0017
CGT	5	3.51801061	0.70360212	14.52	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-7.433839111 B	-79.53	0.0001	0.09346911
YR	87	0.423828390 B	1.64	0.1052	0.25823618
	88	0.268501664 B	1.75	0.0849	0.15363721
	89	0.307042243 B	1.94	0.0569	0.15856550
	90	-0.034056198 B	-0.20	0.8455	0.17417199
	91	0.182332120 B	1.22	0.2267	0.14951183
	92	0.228924810 B	1.58	0.1191	0.14506980
	93	0.067014700 B	0.41	0.6824	0.16306546
	94	-0.156007147 B	-1.20	0.2359	0.13048248
	95	-0.105847731 B	-0.75	0.4561	0.14122313
	96	-0.094732744 B	-0.87	0.3860	0.10859560
	97	0.000000000 B	.	.	.
CGT	3	-0.088334698 B	-0.72	0.4769	0.12350925
	5	-0.278812109 B	-1.77	0.0804	0.15714986
	6	-0.169088928 B	-0.71	0.4819	0.23917190
	7	0.395655083 B	3.03	0.0034	0.13052985
	8	-0.360047918 B	-3.30	0.0015	0.10913689
	9	0.000000000 B	.	.	.

General Linear Models Procedure

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

The variables division and month were removed from the model because they ver insignificant

CGT. 3: Norway, 5: Small Japan trawlers, 6: Faroe trawler, 7: Large Japan trawler, 8: German tawlers, 9: Greenland trawlers.

Appendix 2. Input for ASPIC run.

```
'BOT'                    ## Mode (FIT, IRF, BOT)
'NAFO Subarea 0-1 Greenland halibut -- ASPIC 3.6x -- One Indices'   ## Title for run
'EFF'                    ## Error type ('EFF' = condition on yield)
2                        ## Verbosity (0 to 4)
500                      ## Number of bootstrap trials, <= 1000
1 50000                  ## Monte Carlo search enable (0,1,2), N trials
1d-6                     ## Convergence crit. for simplex
3d-8                     ## Convergence crit. for restarts
1.0d-4                   ## Convergence crit. for estimating effort
3.0                      ## Maximum F when estimating effort
1.0                      ## Statistical weight for B1 > K as residual
1                        ## Number of data series (fisheries)
1.0                      ## Statistical weights for fisheries
2.5                      ## B1-ratio (starting guess)
8000                     ## MSY (starting guess)
0.2                      ## r (starting guess)
1.0d-4 1.0 1.0d-4        ## q (starting guess)
1 1 1 1                  ## Flags to estimate parameters
1000 40000               ## Min and max allowable MSY
0.1  2.0                 ## Min and max allowable r
1872085                  ## Random number seed
11                       ## Number of years of data.
'Standardized CPUE SA1'       ## Title for first series
'CC'                          ## Type of series ('CC' = CPUE, catch)
1987    0.903  1295
1988    0.773  2605
1989    0.803  2207
1990    0.571 10640
1991    0.709 10982
1992    0.743 18070
1993    0.632 10957
1994    0.506 10238
1995    0.532 10884
1996    0.538 10430
1997    0.590 10540
```

Appendix 2 (Cont.). Output of bootstrapped ASPIC run.

NAFO Subarea 0-1 Greenland halibut -- ASPIC 3.6x -- One Indices — Page 1
15 Jun 1998 at 19:59

ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.65) — BOT Mode

Author: Michael H. Prager
National Marine Fisheries Service
Southwest Fisheries Science Center
3150 Paradise Drive
Tiburon, California 94920 USA

CONTROL PARAMETERS USED (FROM INPUT FILE)

Number of years analyzed:	11	Number of bootstrap trials:	500
Number of data series:	1	Lower bound on MSY:	1.000E+03
Objective function computed:	in EFFORT	Upper bound on MSY:	4.000E+04
Relative conv. criterion (simplex):	1.000E-06	Lower bound on r:	1.000E-01
Relative conv. criterion (restart):	3.000E-08	Upper bound on r:	2.000E+00
Relative conv. criterion (effort):	1.000E-04	Random number seed:	1872085
Maximum F allowed in fitting:	3.000	Monte Carlo search trials:	50000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS) — code 0

Normal convergence.

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title		Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1)	SSE in yield	0.000E+00					
Loss(0)	Penalty for B1R > 2	2.764E-03	1	N/A	1.000E+00	N/A	
Loss(1)	Standardized CPUE SA1	1.380E-01	11	1.533E-02	1.000E+00	1.000E+00	0.645

TOTAL OBJECTIVE FUNCTION: 1.40761030E-01

NOTE: B1-ratio constraint term contributing to loss. Sensitivity analysis advised.

Number of restarts required for convergence:	3
Est. B-ratio coverage index (0 worst, 2 best):	0.5795
Est. B-ratio nearness index (0 worst, 1 best):	0.5795

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Starting guess	Estimated	User guess
B1R	Starting biomass ratio, year 1987	2.108E+00	2.500E+00	1	1
MSY	Maximum sustainable yield	1.095E+04	8.000E+03	1	1
r	Intrinsic rate of increase	3.393E-01	2.000E-01	1	1
.....	Catchability coefficients by fishery:				
q(1)	Standardized CPUE SA1	5.986E-06	1.000E-04	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	
MSY	Maximum sustainable yield	1.095E+04	Kr/4	
K	Maximum stock biomass	1.291E+05		
Bmsy	Stock biomass at MSY	6.457E+04	K/2	
Fmsy	Fishing mortality at MSY	1.696E-01	r/2	
F(0.1)	Management benchmark	1.527E-01	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.084E+04	0.99*MSY	
B-ratio	Ratio of B(1998) to Bmsy	1.399E+00		
F-ratio	Ratio of F(1997) to Fmsy	6.828E-01		
Y-ratio	Proportion of MSY avail in 1998	8.411E-01	2*Br-Br^2	Ye(1998) = 9.213E+03
.....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	Standardized CPUE SA1	2.834E+04	r/2q(1)	f(0.1) = 2.550E+04

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1987	0.010	1.361E+05	1.344E+05	1.295E+03	1.295E+03	-1.872E+03	5.678E-02	2.108E+00
2	1988	0.020	1.330E+05	1.312E+05	2.605E+03	2.605E+03	-7.083E+02	1.170E-01	2.059E+00
3	1989	0.017	1.296E+05	1.286E+05	2.207E+03	2.207E+03	1.933E+02	1.012E-01	2.008E+00
4	1990	0.086	1.276E+05	1.230E+05	1.064E+04	1.064E+04	1.970E+03	5.099E-01	1.976E+00
5	1991	0.095	1.190E+05	1.153E+05	1.098E+04	1.098E+04	4.175E+03	5.612E-01	1.842E+00
6	1992	0.171	1.122E+05	1.060E+05	1.807E+04	1.807E+04	6.432E+03	1.005E+00	1.737E+00
7	1993	0.111	1.005E+05	9.889E+04	1.096E+04	1.096E+04	7.865E+03	6.531E-01	1.557E+00
8	1994	0.106	9.742E+04	9.641E+04	1.024E+04	1.024E+04	8.299E+03	6.260E-01	1.509E+00
9	1995	0.115	9.548E+04	9.431E+04	1.088E+04	1.088E+04	8.638E+03	6.803E-01	1.479E+00
10	1996	0.113	9.324E+04	9.245E+04	1.043E+04	1.043E+04	8.920E+03	6.650E-01	1.444E+00
11	1997	0.116	9.173E+04	9.099E+04	1.054E+04	1.054E+04	9.129E+03	6.828E-01	1.421E+00
12	1998		9.032E+04						1.399E+00

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Standardized CPUE SA1

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed yield	Model yield	Resid in log effort	Resid in yield
1	1987	1.434E+03	1.609E+03	0.0096	1.295E+03	1.295E+03	-0.11527	0.000E+00
2	1988	3.370E+03	3.317E+03	0.0199	2.605E+03	2.605E+03	0.01576	0.000E+00
3	1989	2.748E+03	2.868E+03	0.0172	2.207E+03	2.207E+03	-0.04250	0.000E+00
4	1990	1.863E+04	1.445E+04	0.0865	1.064E+04	1.064E+04	0.25421	0.000E+00
5	1991	1.549E+04	1.591E+04	0.0952	1.098E+04	1.098E+04	-0.02655	0.000E+00
6	1992	2.432E+04	2.849E+04	0.1705	1.807E+04	1.807E+04	-0.15832	0.000E+00
7	1993	1.734E+04	1.851E+04	0.1108	1.096E+04	1.096E+04	-0.06551	0.000E+00
8	1994	2.023E+04	1.774E+04	0.1062	1.024E+04	1.024E+04	0.13139	0.000E+00
9	1995	2.046E+04	1.928E+04	0.1154	1.088E+04	1.088E+04	0.05927	0.000E+00
10	1996	1.939E+04	1.885E+04	0.1128	1.043E+04	1.043E+04	0.02814	0.000E+00
11	1997	1.786E+04	1.935E+04	0.1158	1.054E+04	1.054E+04	-0.08001	0.000E+00

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1

Year	Residual	-1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1
1987	-0.1153	=====|
1988	0.0158	|=
1989	-0.0425	==|
1990	0.2542	|==========
1991	-0.0265	=|
1992	-0.1583	======|
1993	-0.0655	===|
1994	0.1314	|=====
1995	0.0593	|==
1996	0.0281	|=
1997	-0.0800	===|

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	2.224E+00	2.108E+00	-5.20%	2.099E+00	2.305E+00	2.163E+00	2.300E+00	1.370E-01	0.062
K	1.823E+05	1.291E+05	-29.17%	9.754E+04	5.245E+05	1.397E+05	3.258E+05	1.861E+05	1.020
r	9.043E-02	3.393E-01	275.19%	1.000E-01	5.371E-01	1.077E-01	3.354E-01	2.277E-01	2.518
q(1)	6.407E-07	5.986E-06	834.42%	1.687E-06	6.878E-06	1.946E-06	4.756E-06	2.809E-06	4.385
MSY	1.064E+04	1.095E+04	3.00%	7.172E+03	1.377E+04	9.024E+03	1.216E+04	3.134E+03	0.295
Ye(1998)	8.194E+03	9.213E+03	12.43%	4.426E+03	1.040E+04	5.596E+03	9.468E+03	3.872E+03	0.472
Bmsy	9.117E+04	6.457E+04	-29.17%	4.877E+04	2.623E+05	6.984E+04	1.629E+05	9.304E+04	1.020
Fmsy	4.521E-02	1.696E-01	275.19%	5.001E-02	2.685E-01	5.387E-02	1.677E-01	1.138E-01	2.518
fmsy(1)	3.115E+04	2.834E+04	-9.01%	2.238E+04	5.407E+04	2.650E+04	3.849E+04	1.198E+04	0.385
F(0.1)	4.069E-02	1.527E-01	247.67%	4.501E-02	2.417E-01	4.849E-02	1.509E-01	1.024E-01	2.518
Y(0.1)	1.053E+04	1.084E+04	2.97%	7.100E+03	1.364E+04	8.934E+03	1.204E+04	3.103E+03	0.295
B-ratio	1.505E+00	1.399E+00	-7.04%	1.263E+00	1.731E+00	1.374E+00	1.607E+00	2.332E-01	0.155
F-ratio	6.376E-01	6.828E-01	7.10%	3.933E-01	9.944E-01	5.032E-01	7.839E-01	2.807E-01	0.440
Y-ratio	7.739E-01	8.411E-01	8.67%	3.963E-01	9.321E-01	6.060E-01	8.701E-01	2.641E-01	0.341
f0.1(1)	2.803E+04	2.550E+04	-8.11%	2.014E+04	4.866E+04	2.385E+04	3.464E+04	1.079E+04	0.385

NOTES ON BOOTSTRAPPED ESTIMATES:

- The bootstrapped results shown were computed from 500 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- The bias corrections used here are based on medians. This is an accepted statistical procedure, but may estimate nonzero bias for unbiased, skewed estimators.

Trials replaced for lack of convergence: 0
Trials replaced for MSY out-of-bounds: 2
Trials replaced for r out-of-bounds: 126
Residual-adjustment factor: 1.2536

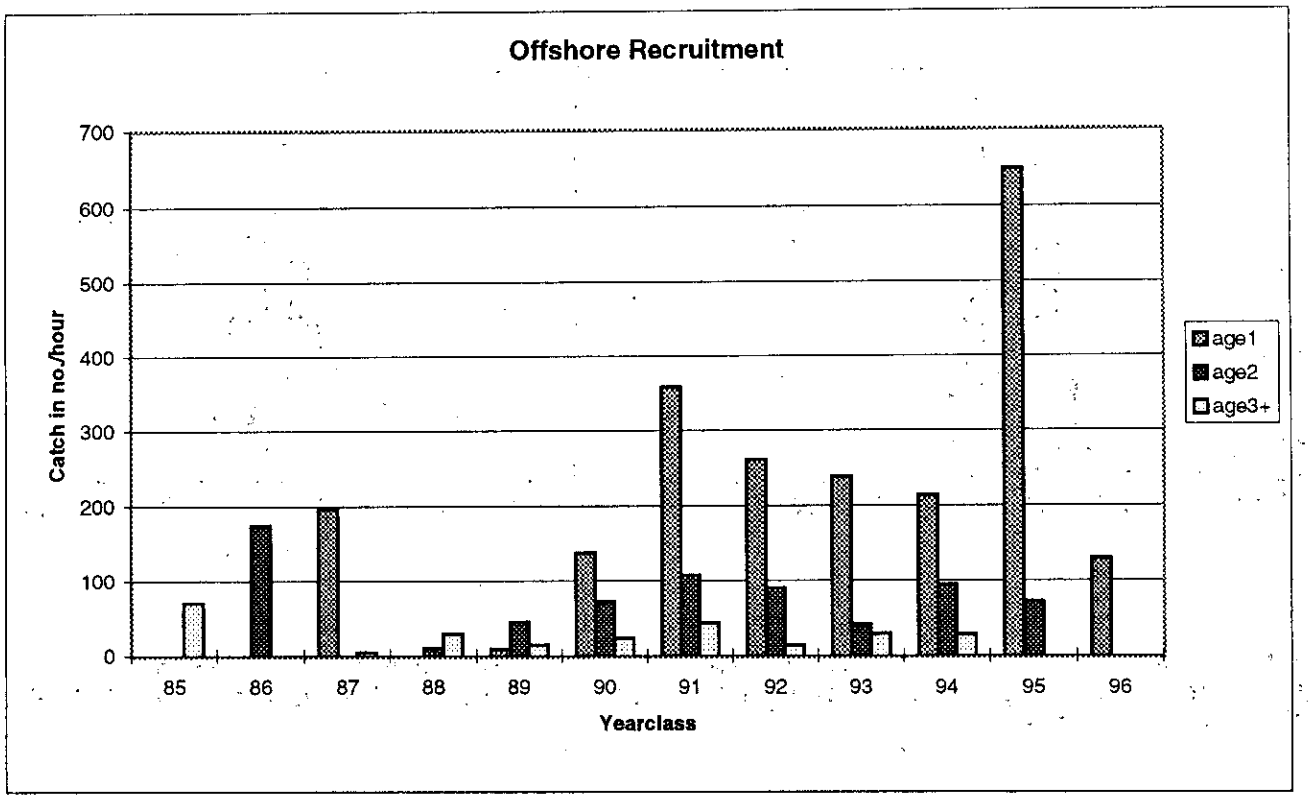


Fig. 1. Year-class strength of Greenland halibut of ages 1-3 in number per hour trawled in the offshore nursery area.

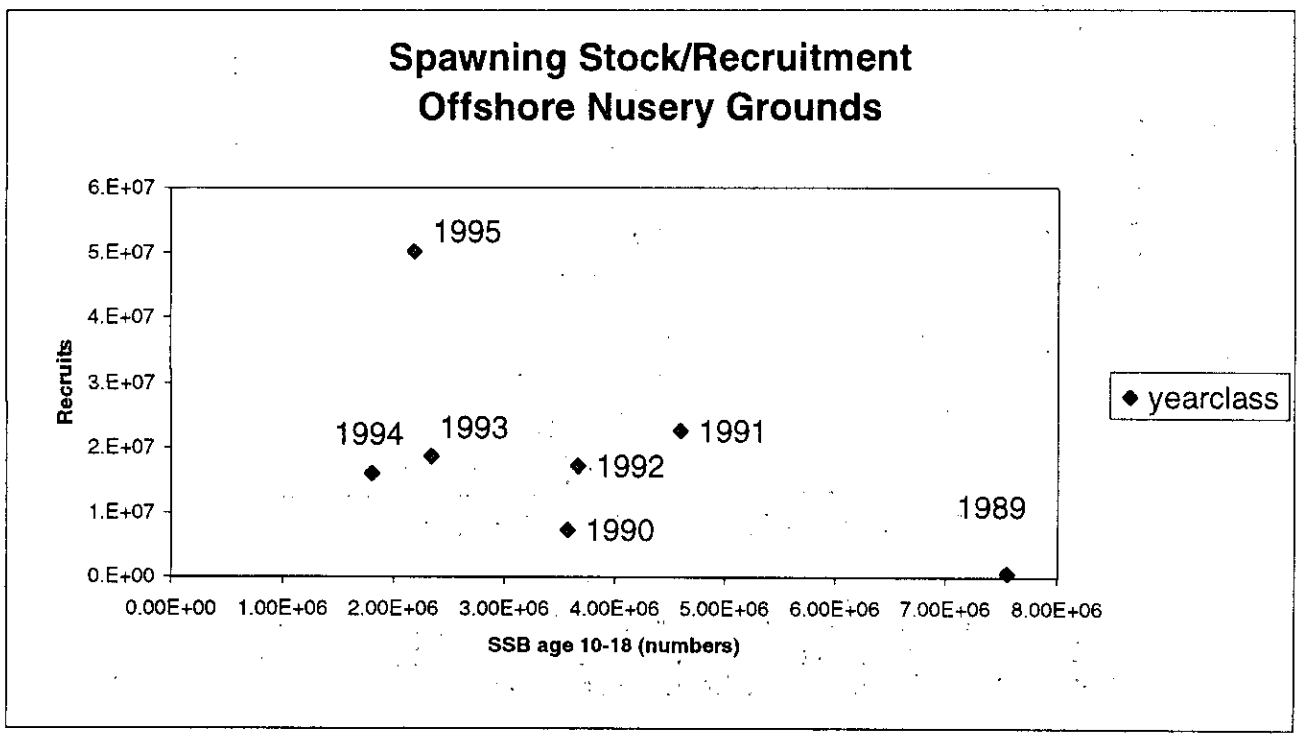


Fig.2. Spawning stock in numbers(ages 10-18 in Div.1CD from the joint Japan/Greenland survey) plotted vs number of fish age 1 in the nusery area (Div. 1AS-1B) the following year estimated from the Greenland shrimp trawl survey.

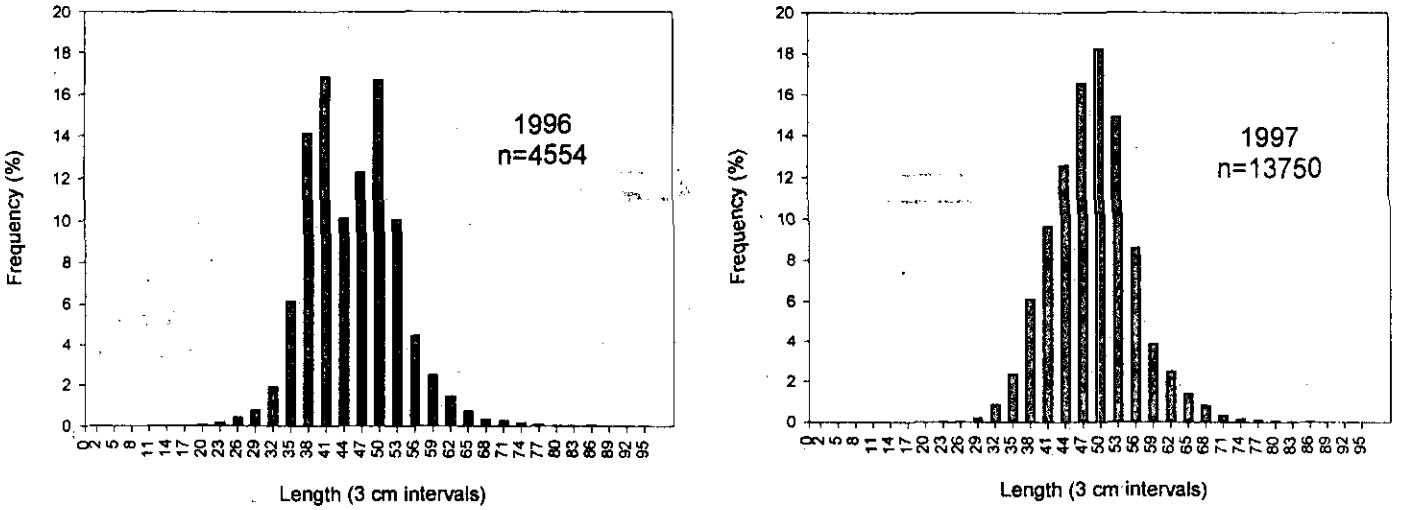


Figure 3. Length frequency of Greenland halibut from NAFO Div. 0A exploratory fishery in 1996 and 1997. The 1997 catch over 40 days by 3 otter trawl vessels was approximately 240 t (Observor data). The 1996 catch totaled 295 t over 30 days.

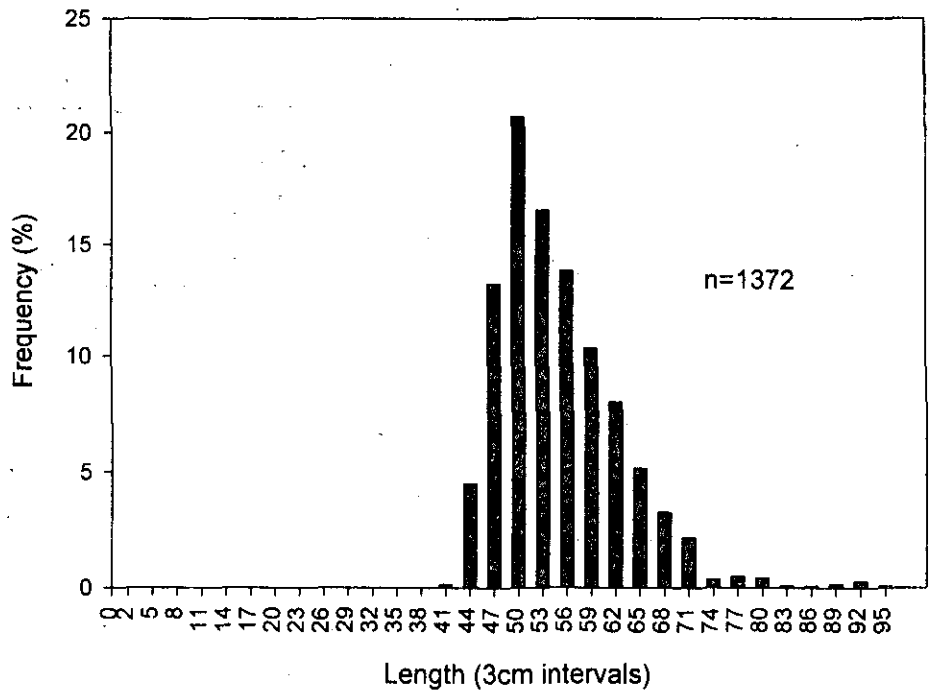
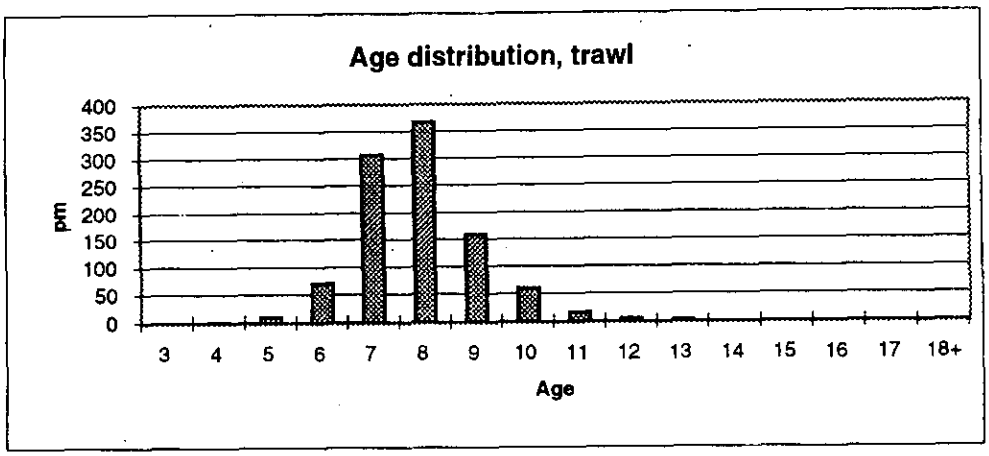


Figure 4. Length frequency of Greenland halibut from the Cumberland Sound winter longline fishery in Division 0B during 1997. Catch by approximately 56 fishermen totaled 66 t over 16 weeks.



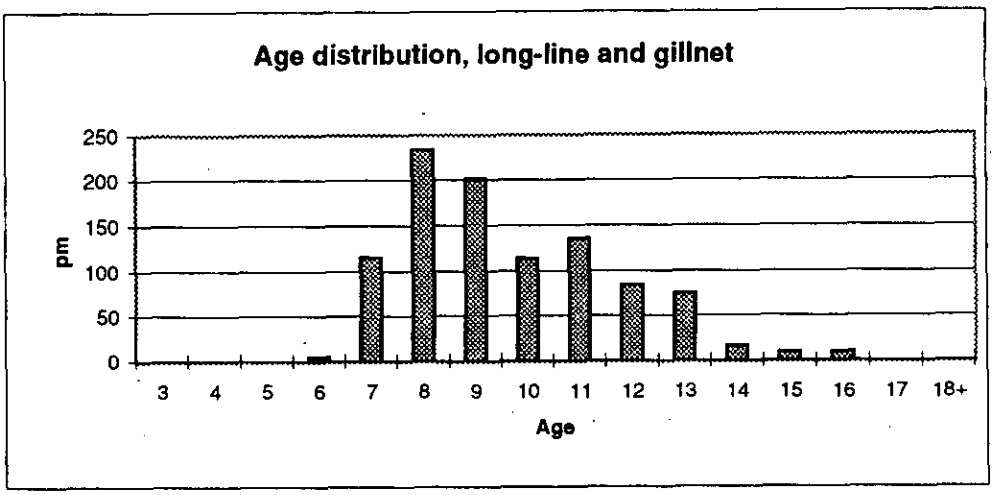


Fig. 5. Age distribution in the offshore trawl and gillnet and longline fishey in SA 0+1 in 1997.

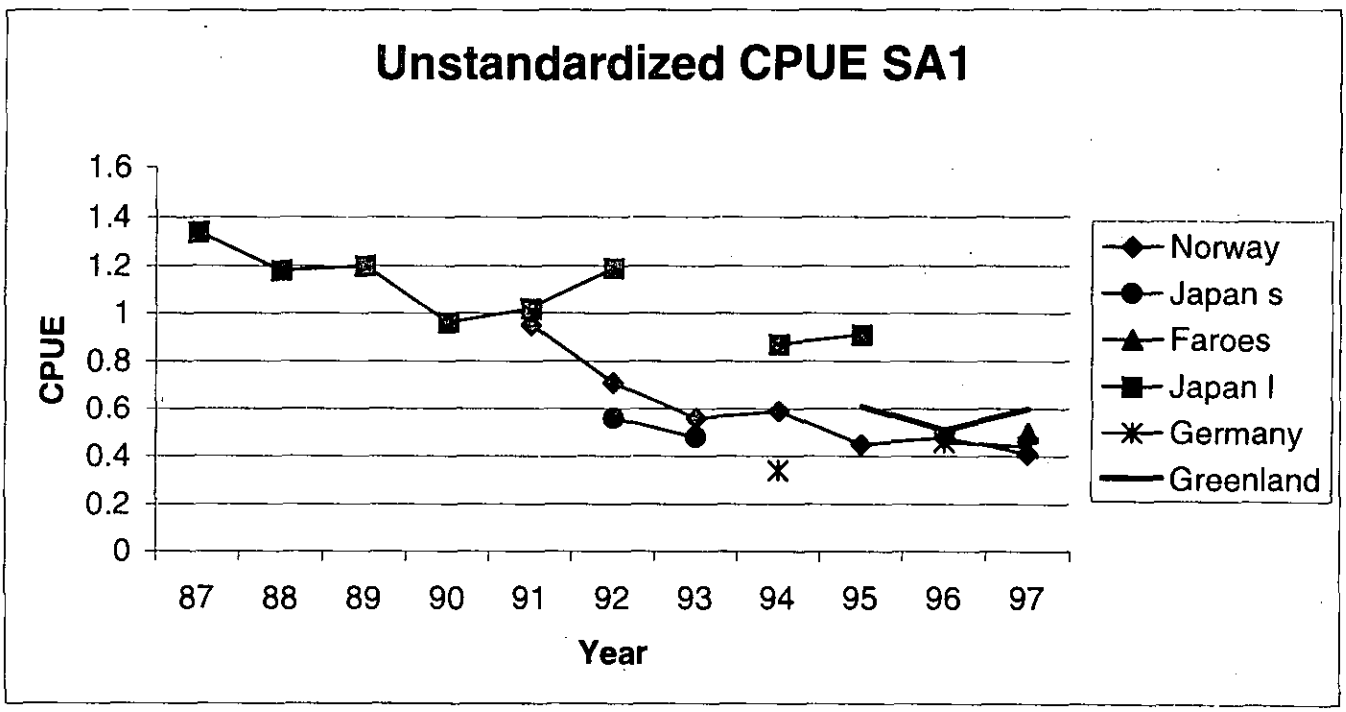


Fig. 6. Unstandardized trawl CPUE series from Div. 1CD.

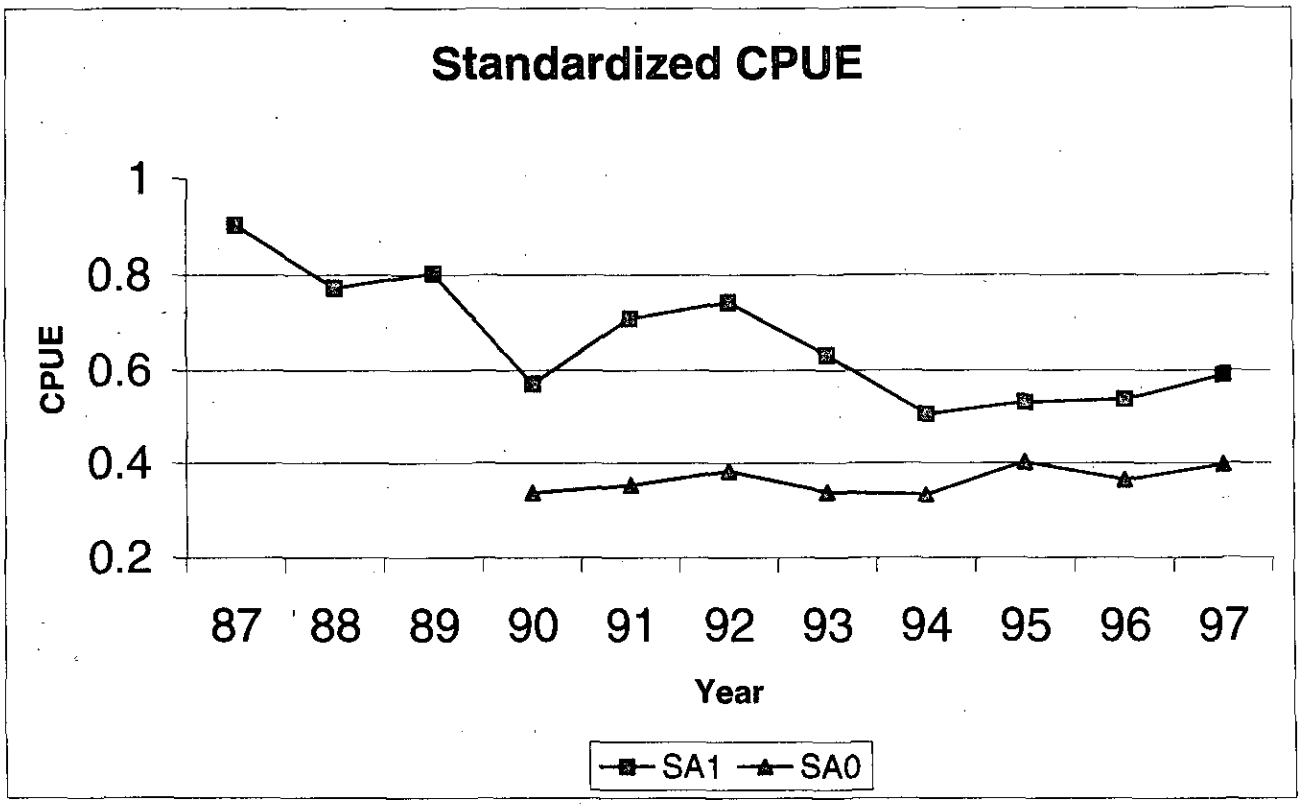


Fig. 7. Standardized trawl CPUE Series from Div. 0B and 1CD. Div. 0B: retansformed to actual figures. Div. 1CD: index, not retransformed.