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Data for the Assessment of the Shrimp (*Pandalus borealis*) Stock in Denmark Strait/off East Greenland, 2003

by

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Abstract

Northern shrimp (*Pandalus borealis*) occurs off East Greenland from Cape Farewell to about 70°N in depths down to about 800 m. North of 65°N the stock spans the adjacent Greenlandic and Icelandic economic zones. The stock is assessed as a single population by evaluation of fishery dependent data only. The stock is managed by catch quotas in the Greenlandic zone. There are no management related restrictions on the fishery in the Icelandic zone.

A multinational fleet of large factory trawlers exploits the stock taking annual catches close to 12 500 tons through the recent 15-year period. During the same period a biomass index indicate that the stock declined until 1993 and increased again thereafter. Fishing mortality indices have in the most recent year been the lowest of the time series. Since 1993 the geographical distribution of the fishery seems to have been stable. The available biological samples since 1991 do not indicate any demographic imbalances of stock size composition.

Introduction

Northern shrimp (*Pandalus borealis*) occurs off East Greenland in ICES Div. XIVb and Va. The stock is distributed from Cap Farewell, up through the Denmark Strait to about 70°N in depths down to around 800 meters (Fig. 1). The highest concentrations occur from 150-600 m. There is no evidence of distinct sub-populations and the stock is assessed as a single population. The assessment is based on fishery dependent data only and is largely done by evaluation of trends in biomass indices and size distributions in response to catch levels.

The exploitation of this stock began in the late-1970s initiated by Icelandic trawlers. It soon became a multinational fishery with annual catches increasing rapidly to more than 15 000 tons during the following 10-year period. Since then catches have fluctuated between 9 000-13 000 tons (Fig. 2A). The fishery was originally conducted north of 65°N in the Dohrnbank-Stredebank area on both sides of the territorial midline between Greenland and Iceland and on the slopes of Storfjord Deep (Fig.1A). However, in 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell (Fig. 1B). At any time access to fishing grounds depends on ice conditions.

During the recent ten years fleets from Greenland, Denmark, the Faroe Islands and Norway have participated in the fishery in the Greenlandic zone. Annual catches in this area accounts for around 70-98% of the total and the fishery is managed by a Total Allowable Catch (TAC). Icelandic vessels operate exclusively in the Icelandic EEZ and the fishery is unrestricted by management initiatives. Vessels taking part in the fishery on both sides of the national midline are large factory trawlers in the range of 1 000-4 000 GRT.

This paper presents and analyses data from the shrimp fishery in Denmark Strait/off East Greenland to provide a basis for the

assessment of the shrimp stock in this area i.e. time series of catch, fishing effort, geographical distribution, size composition of the catch and catch-per-unit-effort based biomass indices and indices of harvest rate.

Materials and Methods

Raw data

Logbooks from Greenland, Norway, Iceland, Faroe Islands and EU-Denmark since 1980 and from EU-France for the years 1980 to 1991 supplied data on catch and effort (hours fished) on a by haul basis. The catches in the Greenland EEZ were corrected according to Hvingel 2003. The catches in the Icelandic EEZ were corrected by 1.2 based on discussions in STACFISH. Catches and corresponding effort were compiled by year and by areas north and south of 65°N. Catch-Per-Unit-Effort (CPUE) was calculated and applied to the total catch of the year to estimate the total annual effort. The distribution of the fishery was shown by plotting the geographical positions of the individual hauls.

Catch rate indices

Three standardised CPUE indices were constructed: one for each of the areas north and south of 65°N and a combined index series representing the total area. The indices were based on logbook data from Greenlandic, Faeroese and Danish vessels, operating exclusively in the Greenlandic zone and from the Icelandic fleet fishing exclusively in the Icelandic zone (north of 65°N).

For the indices of the northern areas and the total areas this involved a two-step process. In the first step multiplicative General Linear Modelling (GLM) techniques were used to standardise the CPUE data from the Greenlandic and Icelandic zones separately. There is no area overlap between the vessels fishing in the two zones. Therefore annual CPUE indices cannot be derived from a single GLM-run as such a model will not be able to estimate the relative fishing power of the vessels. The "first step" was performed following the method described in Hvingel *et al.* (2000). The multiplicative models, included the following variables: (1) individual vessel fishing power, (2) seasonal availability of shrimp, (3) spatial availability of shrimp and (4) annual mean CPUE. Input data were mean CPUE by vessel, area, month and year. The calculations were done using the SAS statistical software (Anon., 1988). The main effects model was represented in logarithmic form:

$$\ln\left(CPUE_{mjki}\right) = \ln(u) + \ln\left(A_m\right) + \ln\left(S_j\right) + \ln\left(V_k\right) + \ln\left(Y_i\right) + e_{mjki}$$

Where $CPUE_{ijki}$ is the mean CPUE for vessel k, fishing in area m in month j during year i (k = 1,...,n; m = 1,…,a; j = 1,…,s; i = 1,…,y); ln(u) is overall mean ln($CPUE$); A_m is effect of the mth area; S_j is the effect of the jth month; V_k is the effect of the kth vessel; Y_i is the effect of the ith year; e_{mjki} is the error term assumed to be normally distributed N(0,σ^2/n) where n is the number of observations in the cell. The standardised CPUE indices are the antilog of the year coefficient.

Parameter estimates of the vessel, month and area variable from a first run of the model were compared. Levels within each variable were combined in subsequent analyses if the parameter estimates did not differ by more than 5%. This was done to reduce the number of empty cells in the models.

For the model pertaining to the Greenlandic zone 52 of 67 vessels met the criteria for inclusion in the analysis (at least three years of fishing in the area), i.e. 37 Greenlandic, 9 Faeroese and 6 Danish vessels. Based on an exploratory run of the main effects model the vessel effect was collapsed into 16 groups consisting of 4-8 vessels with similar fishing power. The month effect was reduced to 5 levels by grouping months with similar indices of relative shrimp availability. The area effect had two levels - one for each of the fishing areas north and south of 65°N. The year*area cross-effect was calculated to give separate indices for the northern and southern areas.

In the Icelandic zone 126 different Icelandic vessels had been registered in the area since 1987. The 61 vessels qualifying for the index were collapsed into 12 groups consisting of 1-8 vessels of equal fishing power. The month effect was reduced to 9 levels. No area effect was included. A two level trawl effect was introduced to account for the effect of twin trawling.

The index of the area south of 65°N

From this first step of calculations the biomass index for the areas south of 65°N came directly as the 'year-area south' cross effect of the Greenlandic zone model (see appendix 1).

The combined index of the area north of 65°N

In the second calculation step the biomass index for the areas north of 65°N was derived by combining the year coefficients of the Icelandic zone model (appendix 2) and the year effects for the northern areas in the Greenlandic zone model (i.e. the 'year-area north' cross effect, see appendix 1). A Monte Carlo Markov Chain (MCMC) sampling process was used to construct distributions of likelihoods of possible values of the combined index. This was done within the programming framework WinBUGS v.1.3, (www.mrc-bsu.cam.ac.uk/bugs; Gilks *et al.*, 1994; Spiegelhalter *et al.*, 2000). The individual CPUE series for the p^{th} fleet, μ_{pi}, was assumed to reflect an overall biomass series, Y_i, and a constant fleet coefficient, v_p, so that:

$$\mu_{pi} = v_p Y_i \exp(e_{pi})$$

The error, e_{pi}, were considered to be distributed with mean zero and variance σ_{pi}^2. The error term was assumed that e_{pi}, have variances inversely proportional to the area of fishing ground, a_p, covered by fleet p. The factor, a_p, was taken to be the area of sea bottom between 150-600 m. Hence, σ_{pi}^2 was calculated by:

$$\sigma_{pi}^2 = \frac{cv_{pi}^2}{a_p}$$

Where cv_{pi} is the annual fleet specific coefficient of variation as calculated in the GLM-run. The area weighting factors, a_p, for the Greenlandic area north of 65 and the Icelandic zone were estimated to 0.8 and 0.2, respectively.

The combined index of the total area

In a similar second calculation step a single combined index of the development of the population biomass in the whole area was derived by aggregating the overall year coefficients from the Greenlandic zone model and the year coefficients from the Icelandic zone model. This was also done by the method described above using an area-weighting factor of 0.875 for the Greenlandic zone data and thus 0.125 for the Icelandic zone data.

Harvest rate indices

Indices of harvest rate were calculated by dividing total annual catch of the area by the respective standardised CPUE indices.

Length distributions

For some years annual size compositions of shrimp catches were obtained from samples taken before processing by fisheries observers onboard vessels fishing in the Greenlandic zone. Onboard the vessel or later in the laboratory samples were sorted by sexual characteristics (McCrary, 1971) and measured to the nearest 0.1 mm carapace length. The data were then pooled in 0.5 mm length groups and adjusted by ratio of weight to the number caught in the set. Numbers from all sets for the month were totalled and adjusted by weight to the monthly catch reported in vessel logs. The numbers from all months were totalled and adjusted by weight to the total catch of the year in the respective areas. Sex specific indices of abundance were calculated by dividing the numbers caught of each sex by the standardised effort.

In years with sparse sampling the samples were pooled and presented without weighing them up to total annual catches.

Results and Discussion

Geographical distribution of the fishery

The fishery was originally conducted north of 65°N in the Dohrnbank-Stredebank area on both sides of the territorial midline between Greenland and Iceland and on the slopes of Storfjord Deep (Fig. 1A). In 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell (Fig. 1B). The fishery was generally distributed in accordance with this "new" fishing pattern in 2002 and 2003 (Fig. 1C).

Catch

As the fishery developed, catches increased rapidly to more than 15 000 tons in 1987-88, but declined thereafter to about 9 000 tons in 1992-93. Following the area expansion of the fishery south of 65°N catches increased again reaching 13 500 tons in 1997 (Fig. 2A, Table 1and 2). In recent years annual catches have been between 11-14000 tons and is for the current year projected to be close to 13 500 tons (projected from September) of which about 30% will originate from the northern areas.

Compared to 1988 when catches peaked the amount caught in the area north of 65°N has declined by about 75%, i.e. from 15 000 to about 2 000 tons in 2002 (Fig. 2A). According to Greenlandic skippers the reduced effort spent was due to reduced catch rates of large shrimp, which was the primary target of the Greenlandic fishery. Fishing opportunities elsewhere, i.e. at Flemish Cap, and the discovery of the new fishing ground south of 65°N may also have contributed this development. For the northern areas catches in 2003 are projected to be around 3 700 tons.

Catches in the southern area increased from 1 900 tons in 1993 - the first year of fishery in this area - to about 9 300 tons in 1997 (Fig. 2A). They then decreased somewhat to about 6-7 000 tons in 1998-2000. In 2001 catches reached 11 700 tons declined to 9 000 tons the year after and are expected to be around 10 000 tons in 2003.

Fishing effort

The high increase in catches during the first ten-year period was mainly driven by increased fishing effort (Fig. 2B, Table 2). Between 1981 and 1989, total effort increased from about 20 000 hr's to a peak of more than 117 000 hr's and then declined again to about 20 000 hr's in 2002. The expected value for 2003 is at this level (Fig. 2B).

The historic development of fishing effort spent in the northern areas follow closely the one described for the total area. However, for 2001 effort in the northern areas was down instead of up. In the southern area, effort increased from about 10 000 hours in 1993 to 21 000 hours in 1997. In 1999 it reached a low of 7 500 hr's but increased again to 27 000 hr's in 2001. For 2002 effort in the southern areas was approx. 11 000 hr's. The 2003 value is expected to end up around this level (Fig. 2B, Table 2).

Catch rate

Catch rates (total area) decreased from 282 kg/hr to 111 kg/hr in the period 1980-1989, but has shown an increasing trend since then reaching about 585 kg/hr in 2002 (Fig. 2C, Table 2). The preliminary catch rates for 2003 are 612 kg/hr.

In the southern areas CPUE increased from 204 kg/hr in 1993 to 898 kg per hour in 1999. During the following two years the mean CPUE obtained in this area was halved reaching 432 kg/hr in 2001. However CPUE was back at 780 kg/hr in 2002 and 870kg/hr in 2003 (registered until September).

Catch rates in the northern area follow the same trend as the overall figures until 1993 as the fishery in the southern areas had not yet been initiated. From 1994-2001, CPUEs have fluctuated around 225 kg/hr except for an extreme of 145 kg/hr in 1996. An increase is registered for 2002 and 2003 giving 331 kg/hr and 340 kg/hr respectively.

Standardised catch rate indices

Results of the two multiple regression analysis to standardise catch rates showed that all main effects were highly significant

($p<0.01$). The r-squared of the models were 71% and 84%, respectively. The model-diagnostical outputs (see appendix) indicate that the model and error structures were correct. All first-order interactions between the effects of YEAR, MONTH and VESSEL were also highly significant, suggesting that the effect of YEAR on CPUE differ from month to month and from vessel to vessel. The contributions of these interactions to the variability within the data set however were small compared to that of the main effects. Thus, the basic model without interactions was considered a good descriptor of the data.

The CPUE index series of the northern areas (Fig. 3) declined from 1987 to 1993 thereafter an increasing trend was observed and by the turn of the century the index values had reached the level seen at the offset of the time series. The CPUE index series of the southern area (Fig. 3) increased until 1999 and thereafter fluctuated without trend.

The combined index for the total area (Fig. 3) indicated that the stock was more than halved during the period 1987-1993. After that it has been rebuilding at a corresponding rate reaching the level of 1987 in the late-1990s. The index values indicate that the stock biomass have stayed at or around this level since then.

The addition of new data for 2002 and 2003, and a re-evaluation and correction of the existing logbook data have only caused minor changes in the CPUE index series as compared to the corresponding series resulting from last years analyses (Hvingel, 2002). However, the perception of the 2002 value was changed in a positive direction for the southern and overall area indices.

The standardisation method used accounts for the increase in efficiency from renewal of the fleet but does not account for the technological improvements, which results from the upgrading of older vessels. The standardised effort may therefore be underestimated in which case the standardised CPUE time series interpreted as a biomass index is expected to give a slightly optimistic view of the stock development (for further discussion of the CPUE index as a stock indicator see Hvingel *et al.*, 2000).

Indices of harvest rate

The Standardised effort, i.e. the index of harvest rate, showed a decreasing trend since 1993 for the total area (Fig. 4). The separate indices for the northern and southern areas are also shown in Fig. 4. As mentioned in the previous section the development in the harvest rate indices might be to optimistic. Furthermore, the index of 2003 also depends on the precision with which the catch is projected to the end of the year.

Length distributions

Some biological samples were available from the fishery in the Greenlandic zone (Table 5, Fig. 5). Generally the catches consisted of relatively large shrimp. On average a shrimp caught at East Greenland since 1991 is about 50% larger than one caught at West Greenland and at least twice the weight of one from the fishery at Flemish Cap (Div. 3M). Shrimp caught north of 65°N are the largest (Table 4). More detailed interpretations of the samples with respect to age composition was not attempted due to incomplete coverage over time and areas.

For 2002 and 2003 only few samples were available (Fig. 5C and 5D). These length frequency distributions indicate a demographic healthy stock composition with a wide distribution of the sizes normally present in this fishery.

Conclusions

Catches have been relatively stable in the recent 5-10 year period its size dictated mainly by the catch quotas set for the Greenlandic zone (Table 1). However, an areal redistribution has taken place, i.e. catches in the northern areas have declined in favour of catches in areas south of 65°N.

Since the mid-1990s 53-84 % of the total catch has been taken in the southern areas and the geographical distribution of the fishery seems to have been stable during this period (Fig. 1B, C).

Since 1993 overall catch rates have been continuously improving except for a decline from 2000 to 2001. This positive development was mainly driven by the CPUEs obtained in the southern areas whereas the CPUE in the northern areas showed much less variation during in the same period (Fig. 2C).

Available information on stock size composition does not indicate any demographic imbalances.

The CPUE based biomass index (Fig. 3C) indicates that the stock size is back at the levels of the mid-1980s. Stock biomass seems to have been stable during the recent years.

Indices of harvest rate have shown a decreasing trend since 1993. The 2003 value is close to the lowest of the time series (Fig. 4C).

References

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Table 1. Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland 1978 to September 2003. Values for the fishery in the Greenland EEZ by EU-Denmark, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel (2003).

Area/Nation	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997[1]	1998[1]	1999[1]	2000[1]	2001[1]	2002[1]	2003[1,2]
North of 65°N																										
Denmark	-	0	878	727	926	255	554	442	626	703	554	454	476	450	199	138	250	302	26	85	401	793	459	72	238	496
Faroe Islands	-	0	5296	892	922	554	836	843	910	754	847	738	1029	1265	1355	689	462	931	995	635	1268	867	956	214	308	789
France	-	0	63	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	-	0	250	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	1771	1326	2390	359	105	646	614	115	650	152	77
Iceland	436	582	911	150	0	52	890	2153	1380	1596	1717	1591	337	558	2100	3064	1817	1381	679	3427	1705	923	158	12	1477	844
Norway	-	1001	3079	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	1831	2180	2402	1544	797	1628	1783	2759	1291	383	1158
Total	436	1583	10477	5989	6133	5221	8383	10055	13658	15339	15600	13264	12536	10850	9251	7492	6034	7406	3604	5049	5648	4980	4447	2239	2558	3363
South of 65°N																										
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	613	731	1167	1657	1300	1095	1900	2473	2310	1413
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	280	974	295	402	656	138	453	340	2402	1014	505
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1141	3603	2667	5295	4701	3950	4966	5235	4943	4333	4483
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	424	1011	720	1590	2261	670	378	157	1855	1359	1811
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1904	6201	4412	8453	9276	6057	6893	7632	11674	9016	8211
Total area																										
Denmark	-	0	878	727	926	255	554	442	626	703	554	454	476	450	199	198	863	1033	1193	1742	1701	1888	2358	2545	2548	1909
Faroe Islands	-	0	5296	892	922	554	836	843	910	754	847	738	1029	1265	1355	968	1436	1225	1397	1292	1406	1321	1296	2616	1322	1294
France	-	0	63	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	-	0	250	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	2912	4929	5057	5655	4806	4595	5581	5349	5593	4484	4560
Iceland	436	582	911	150	0	52	890	2153	1380	1596	1717	1591	337	558	2100	3064	1817	1381	679	3427	1705	923	158	12	1231	703
Norway	-	1001	3079	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	2255	3190	3122	3133	3059	2298	2160	2917	3147	1743	2968
Total	436	1583	10477	5989	6133	5221	8383	10055	13658	15339	15600	13264	12536	10850	9251	9396	12235	11818	12057	14325	11706	11873	12079	13913	11329	11434
Total all areas	436	1583	10477	5989	6133	5221	8383	10055	13658	15339	15600	13264	12536	10850	9251	9396	12235	11818	12057	14325	11706	11873	12079	13913	11329	11434
Advised TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	10000[3]	10000[3]	10000[3]	8000	5000	5000	5000	5000	5000	5000	9600	9600	9600	9600	9600
Effective TAC[4]	-	-	-	8000	4500	5725	5245	6090	7525[5]	7525[5]	8725[5]	9025[5]	14100	14500	13000	9563	9563	9563	9563	9563	9563	10600	12600	10600	10600	10600

[1]Provisional

[2]Catch in 2002 per Nov. 1.

[3]Advised for a few years as a precautionary measure

[4]For Greenland zone only

[5]Not including Greenland fishery north of 66°30'N

Table 2. Catch (tons), effort (hr's) and Catch-Per-Unit-Effort (kg/hr) by trawlers fishing in Denmark Strait/off East Greenland in areas north and south of 65°N.

	Area north			Area south			Total area		
Year	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
1980	10477	37198	282				10477	37198	282
1981	5989	19986	300				5989	19986	300
1982	6133	23081	266				6133	23081	266
1983	5221	23855	219				5221	23855	219
1984	8383	34983	240				8383	34983	240
1985	10055	62911	160				10055	62911	160
1986	13658	61863	221				13658	61863	221
1987	15339	79881	192				15339	79881	192
1988	15600	109455	143				15600	109455	143
1989	13264	119629	111				13264	119629	111
1990	12536	72776	172				12536	72776	172
1991	10850	78444	138				10850	78444	138
1992	9251	67291	137				9251	67291	137
1993	7492	50942	147	1904	9335	204	9396	59836	157
1994	6034	24842	243	6201	16361	379	12235	39545	309
1995	7406	33571	221	4412	11328	389	11818	43347	273
1996	3604	23563	153	8453	21097	401	12057	40616	297
1997	5049	19079	265	9276	18994	488	14325	37973	377
1998	5648	21201	266	6057	10560	574	11706	30022	390
1999	4980	20979	237	6893	7679	898	11873	25768	461
2000	4447	19646	226	7632	10758	709	12079	23535	513
2001	2239	10353	216	11674	27043	432	13913	35029	397
2002	2454	6624	370	8875	11372	780	11329	18530	611
2003*	3282	9075	362	8152	9367	870	11434	18360	623

*until Nov.

Table 3. Means and standard errors (se) of standardized CPUE and effort index values based on logbook information from trawlers fishing in Denmark Strait/off East Greenland in areas north and south of 65°N and total area until September 2002.

	Area north				Area south				Total			
	Std.CPUE		Std. Effort		Std.CPUE		Std. Effort		Std.CPUE		Std. Effort	
Year	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se
1987	1.00	-	1.00	-					1.00	-	1.00	-
1988	0.86	0.09	1.18	0.13					0.84	0.07	1.21	0.09
1989	0.61	0.07	1.40	0.16					0.59	0.05	1.47	0.12
1990	0.61	0.07	1.35	0.15					0.59	0.05	1.41	0.12
1991	0.52	0.06	1.36	0.16					0.49	0.04	1.46	0.12
1992	0.41	0.05	1.44	0.16					0.39	0.03	1.53	0.13
1993	0.36	0.04	1.30	0.16	1.00	-	1.00	-	0.31	0.03	1.89	0.16
1994	0.80	0.10	0.47	0.06	2.52	0.24	1.29	0.12	0.69	0.06	1.15	0.10
1995	0.66	0.08	0.72	0.09	2.45	0.25	0.95	0.09	0.62	0.06	1.24	0.11
1996	0.58	0.09	0.40	0.06	3.10	0.30	1.43	0.13	0.71	0.07	1.11	0.11
1997	0.79	0.12	0.38	0.06	3.06	0.30	1.59	0.15	0.76	0.07	1.21	0.12
1998	0.95	0.14	0.37	0.05	3.49	0.39	0.91	0.10	0.87	0.09	0.87	0.09
1999	0.75	0.13	0.43	0.07	5.80	0.77	0.62	0.08	1.08	0.12	0.72	0.08
2000	0.98	0.18	0.30	0.06	4.85	0.58	0.83	0.09	1.13	0.13	0.71	0.08
2001	0.85	0.30	0.17	0.06	3.78	0.43	1.62	0.17	0.94	0.11	0.98	0.11
2002	1.15	0.24	0.13	0.03	5.36	0.80	0.88	0.12	1.31	0.14	0.57	0.06
2003	1.14	0.18	0.19	0.03	4.30	0.50	0.99	0.11	1.08	0.12	0.70	0.07

Table 4. Mean shrimp size, numbers caught and estimated abundance calculated from logbook data and catch samples from the Greenlandic fishery in Denmark Strait north and south of 65°N 1991-2001. The sign '-' denotes missing data.

Area north

Mean size

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cpl (mm)	27.0	26.5	26.7	26.0	26.2	-	-	27.6	27.4	26.7
Weight (g)	12.2	12.6	13.2	12.1	12.7	-	-	13.9	14.4	9.2
Count (no/kg)	82	79	76	83	79	-	-	72	70	109

Proportion of total catch

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Males	-	-	-	29%	51%	-	-	36%	41%	57%
Primi	-	-	-	48%	7%	-	-	8%	-	-
Multi	-	-	-	23%	41%	-	-	55%	-	-
Females total	-	-	-	71%	49%	-	-	64%	59%	43%

Number caught (millions)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<=16mm	0.12	0.01	0.01	0.01	0.06	-	-	0.00	0.00	0.06
Males	-	-	-	25	77	-	-	13	14	6
Primi	-	-	-	42	11	-	-	3	-	-
Multi	-	-	-	20	62	-	-	20	-	-
Females Total	-	-	-	62	73	-	-	23	20	4
Total	344	159	108	87	151	-	-	36	34	10

Abundance index

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Males	-	-	-	4.5	6.1	-	-	2.8	2.9	3.2
Primi	-	-	-	7.5	0.9	-	-	0.6	-	-
Multi	-	-	-	3.6	4.9	-	-	4.2	-	-
Females total	-	-	-	11.1	5.8	-	-	4.8	4.1	2.5

Area south

Mean size

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cpl (mm)	26.0	26.5	-	24.8	23.6	22.8	22.7	22.6	24.6
Weight (g)	11.5	12.7	-	9.1	9.6	6.5	7.3	7.5	8.0
Count (no/kg)	87	78	-	109	104	154	137	134	124

Proportion of total catch

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Males	-	32%	-	55%	74%	77%	78%	78%	72%
Primi	-	15%	-	11%	2%	4%	-	-	-
Multi	-	54%	-	34%	24%	18%	-	-	-
Females total	-	68%	-	45%	26%	23%	22%	22%	28%

Number caught (millions)

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
<=16mm	0.0	0.0	-	0.2	0.3	0.3	0.3	0.2	0.1
Males	-	72	-	258	293	339	423	431	275
Primi	-	33	-	52	6	18	-	-	-
Multi	-	120	-	156	95	81	-	-	-
Females Total	-	153	-	208	101	99	119	125	106
Total	80	225	-	466	395	439	542	556	381

Abundance index

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Males	-	2.0	-	6.2	7.8	13.9	13.4	13.1	9.0
Primi	-	0.9	-	1.3	0.2	0.7	-	-	-
Multi	-	3.4	-	3.8	2.5	3.3	-	-	-
Females total	-	4.4	-	5.0	2.7	4.1	3.8	3.8	3.5

Table 5. Biological samples from catches taken in the Greenlandic zone north and south of 65°N.

North

Year	Month	Number of samples	Sample weight	Numbers measured	Sample represent catch (kg)
91	1	30	184.6	12041	21898
91	2	28	235.4	16196	15250
91	3	42	211.5	16147	30367
91	4	74	318.8	24067	52571
91	5	32	142.0	9861	18707
92	2	20	63.4	1502	9437
93	2	55	203.3	5014	21953
94	2	19	79.9	6682	14025
95	1	13	42.1	3505	11098
95	3	15	67.3	6124	31757
96	10	10	28.4	2643	4861
98	1	10	25.7	1875	11300
98	2	19	75.9	5485	19775
98	10	10	35.2	2412	5153
98	11	18	53.4	4082	5554
98	12	16	37.3	2665	14610
99	5	6	11.9	823	6517
99	6	3	6.2	435	9304
0	3	3	9.8	873	7092
0	4	3	9.7	759	5609
0	5	9	37.5	2474	9304
	Total	435	1879	125665	326142

South

Year	Month	Number of samples	Sample weight	Numbers measured	Sample represent catch (kg)
93	3	10	58.6	6323	7758
93	4	37	355.5	27169	76376
94	1	30	134.3	9957	61702
94	2	8	41.0	2712	10137
94	3	14	52.7	3916	8288
94	4	11	62.0	5115	14623
96	4	10	38.3	4973	16717
96	5	7	33.9	2571	2222
96	8	12	39.9	4405	11257
96	11	24	72.3	6444	31013
97	7	3	10.3	1214	13252
97	11	6	14.0	1951	5705
97	12	9	31.6	2982	10388
98	2	12	40.6	3951	14551
98	3	34	101.2	11618	47672
98	10	15	44.2	5313	21344
98	11	19	40.9	5317	25422
98	12	8	15.8	2224	10128
99	4	1	1.8	181	2796
99	6	5	9.6	1073	9932
99	8	13	23.0	3336	57346
99	10	12	35.5	4076	27714
99	11	30	111.1	13959	53996
99	12	1	4.5	664	1035
0	1	2	6.7	650	2711
0	3	4	10.0	1199	17611
0	4	1	3.0	414	5104.5
0	5	3	10.0	1369	6183
0	6	14	49.9	6197	32804
0	8	7	12.8	1890	15081
0	9	1	4.4	601	2548
1	3	8	17.1	1813	25450
1	4	7	14.7	1263	16041
	Total	378	1501	146840	664907

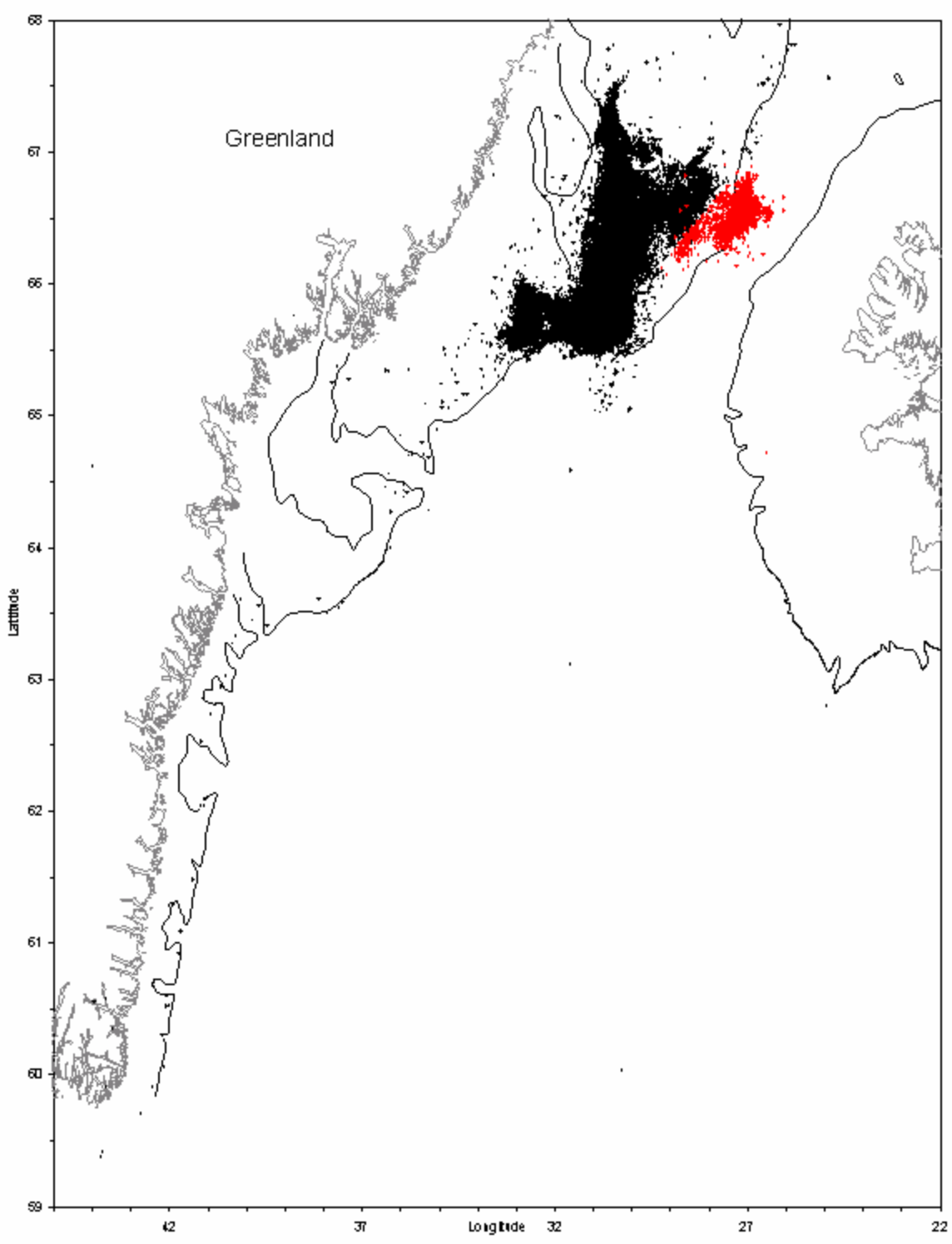


Fig. 1A. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 1987-1992 (black dots) and Icelandic trawlers 1990-1992 (red dots). 400 meters depth curve are shown as a solid line.

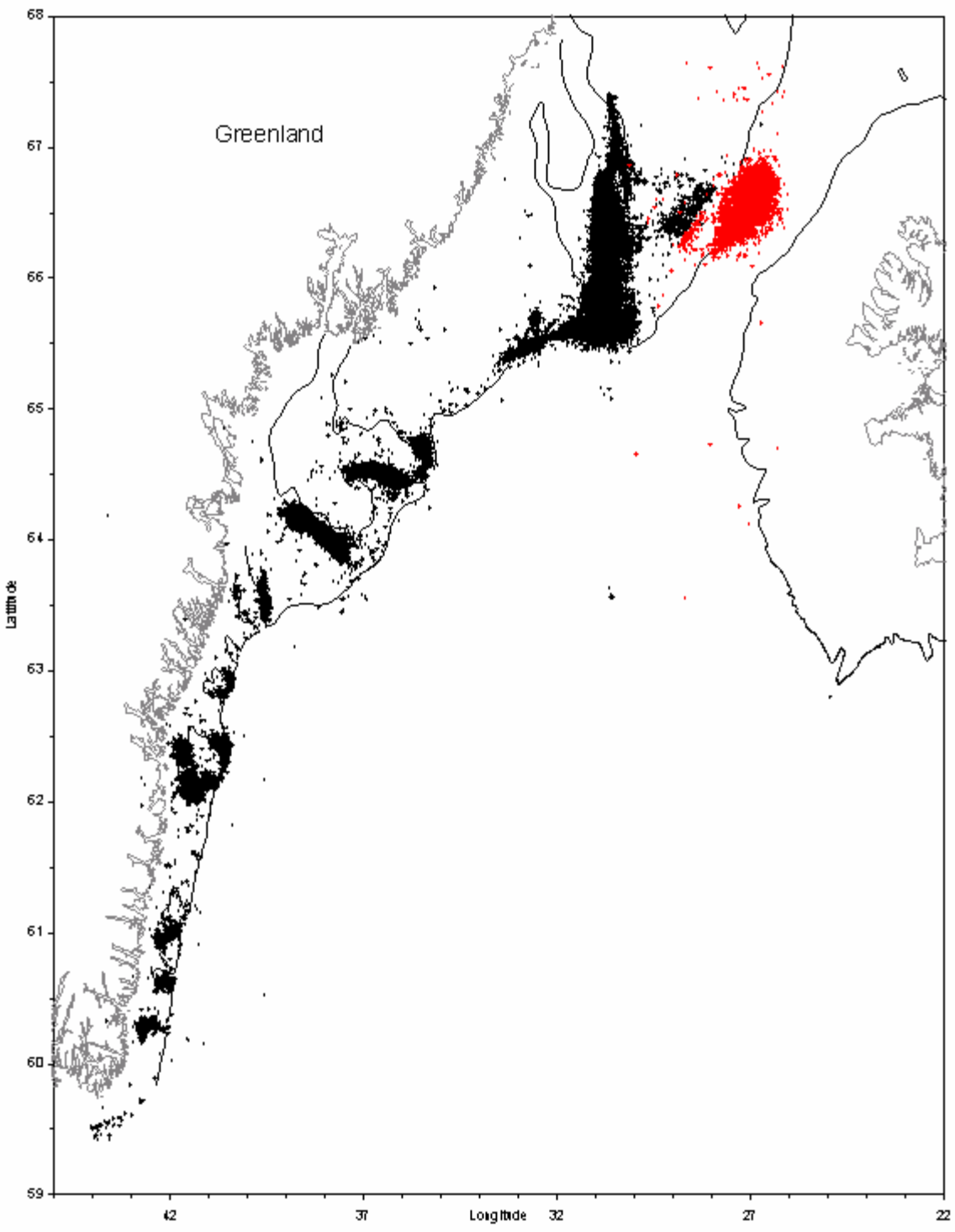


Fig. 1B. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland 1993-2001 by Greenlandic, Faeroese and Danish trawlers (black dots) and Icelandic trawlers (red dots). 400 meters depth curve are shown as a solid line.

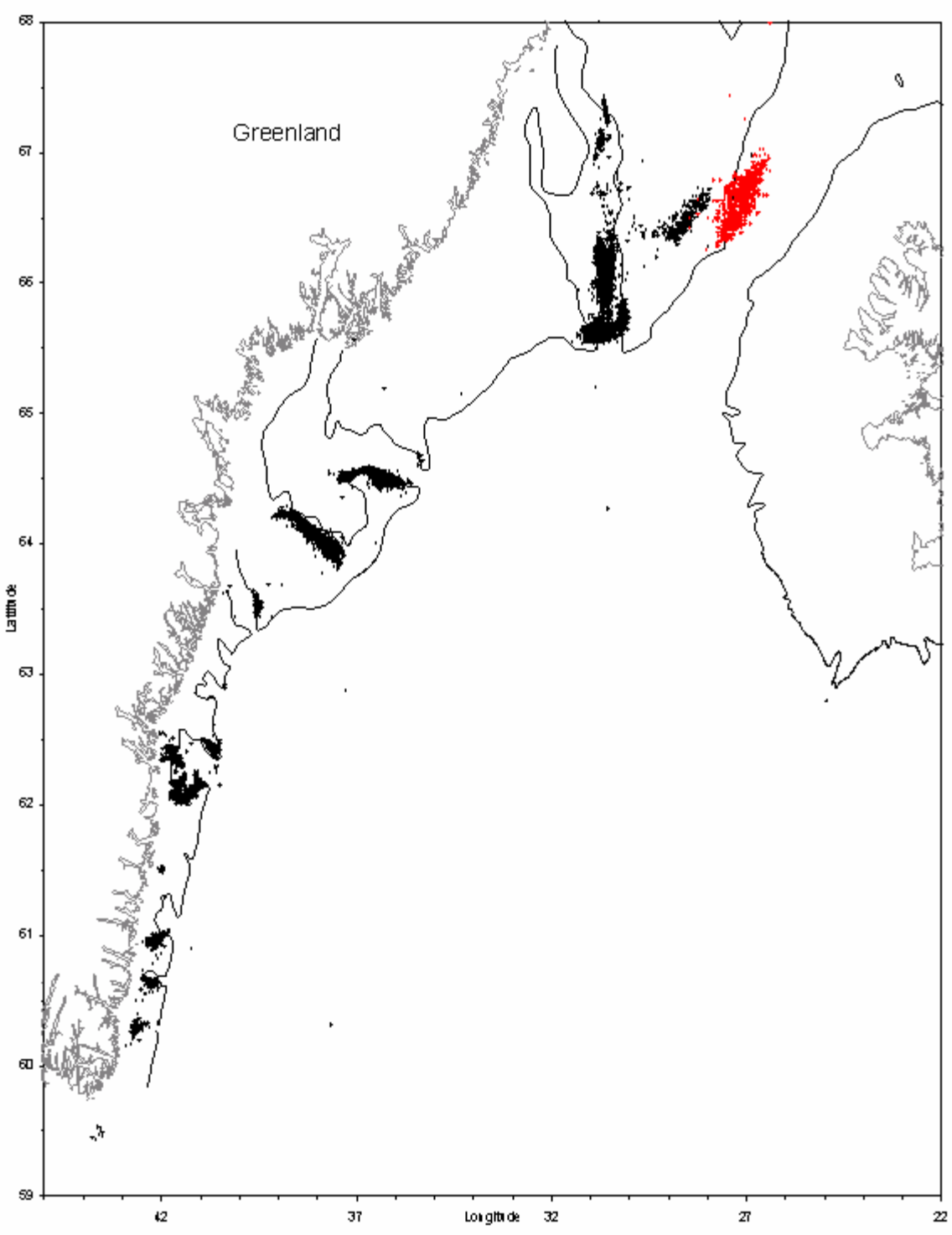


Fig. 1C. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland 2002-September 2003 by Greenlandic, Faeroese and Danish trawlers (black dots) and Icelandic trawlers (red dots). 400 meters depth curve are shown as a solid line.

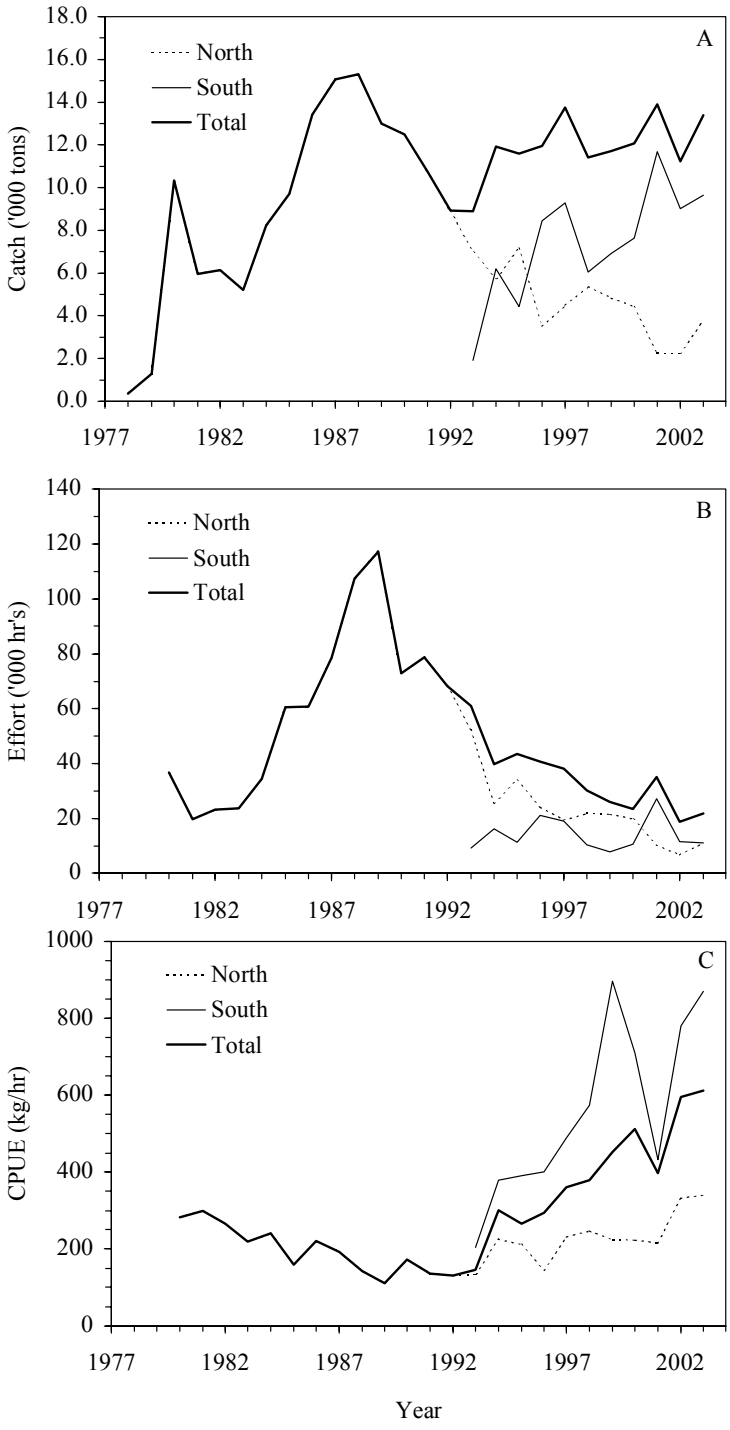


Fig. 2. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65ºN and overall. Data for 2003 are projected from September to the end of the year.

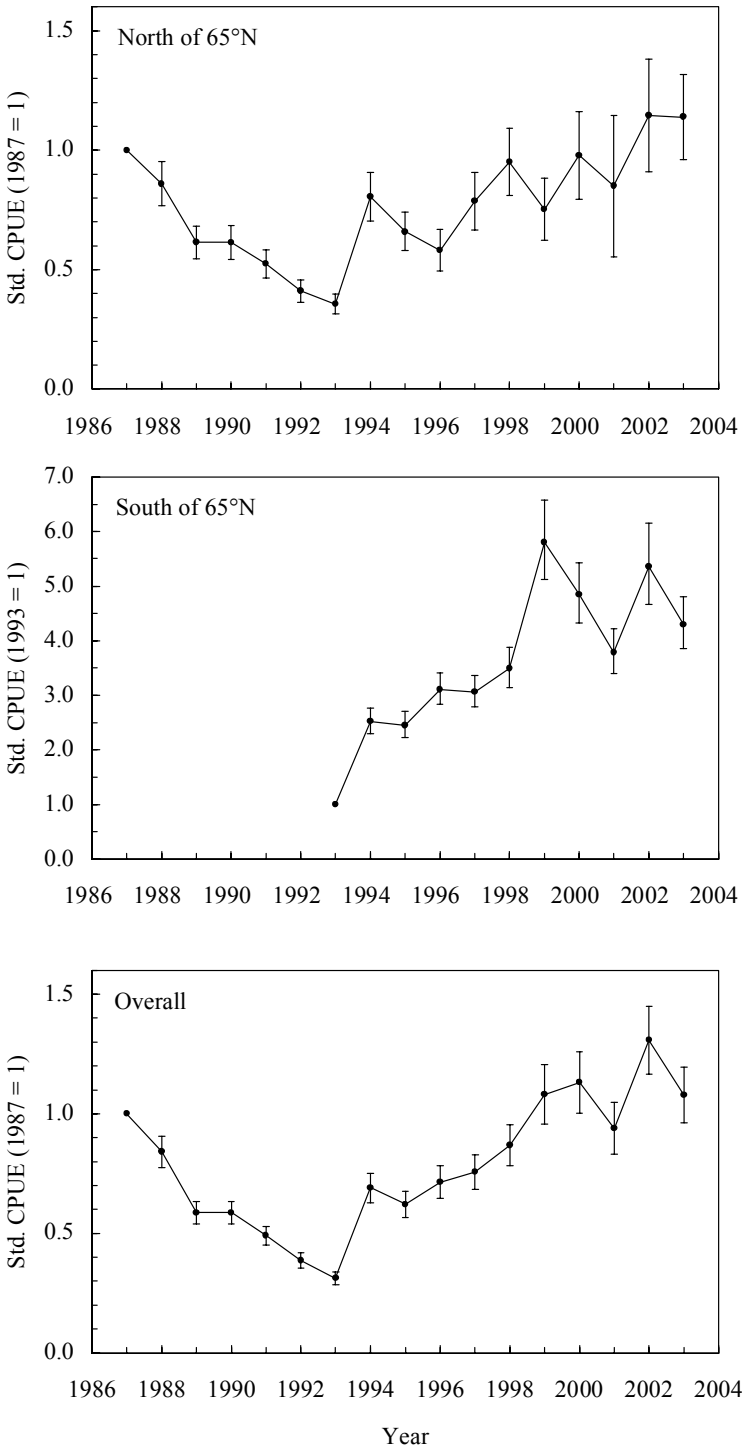


Fig. 3. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65ºN, south of 65ºN and overall. Estimates are based on data until September 2003.

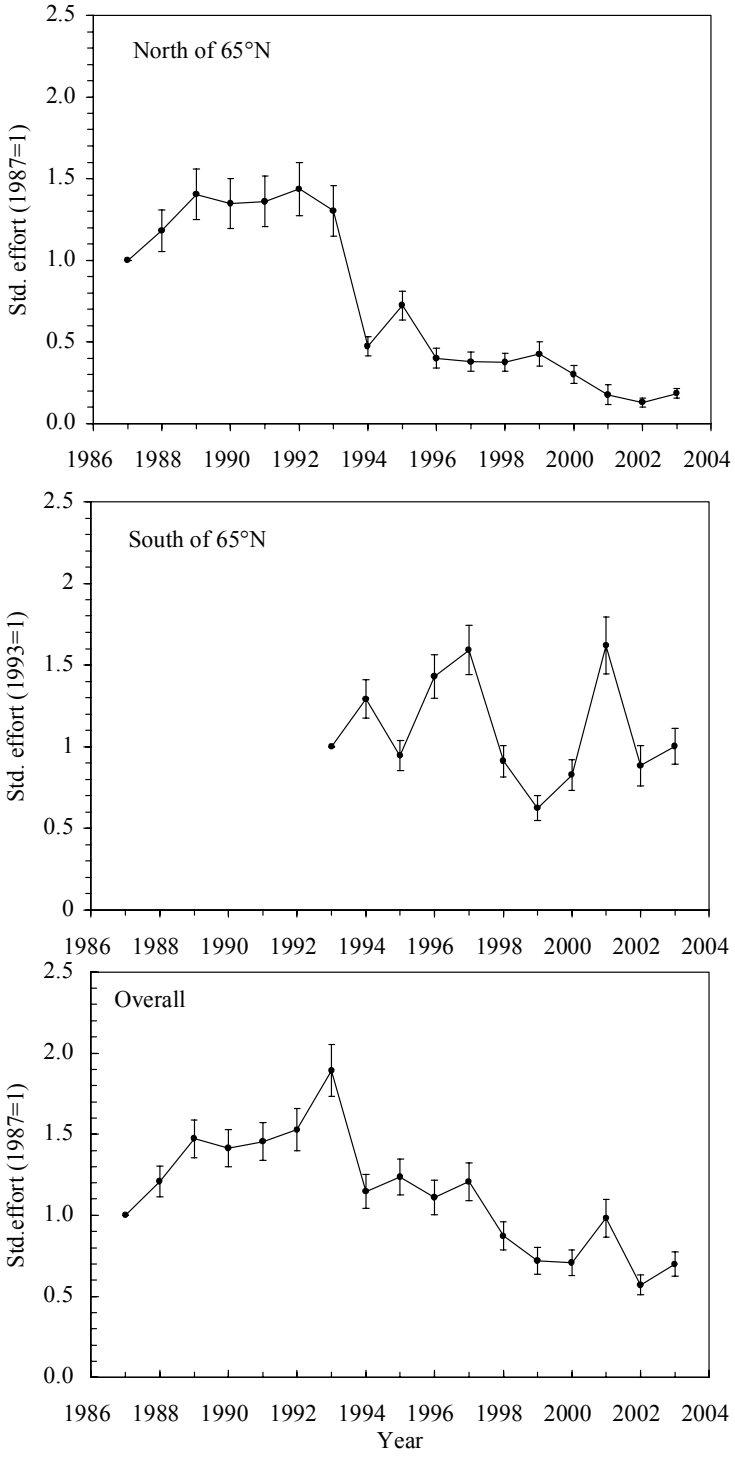


Fig. 4. Standardized effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65ºN, south of 65ºN and overall. Estimates are based on data until September 2003.

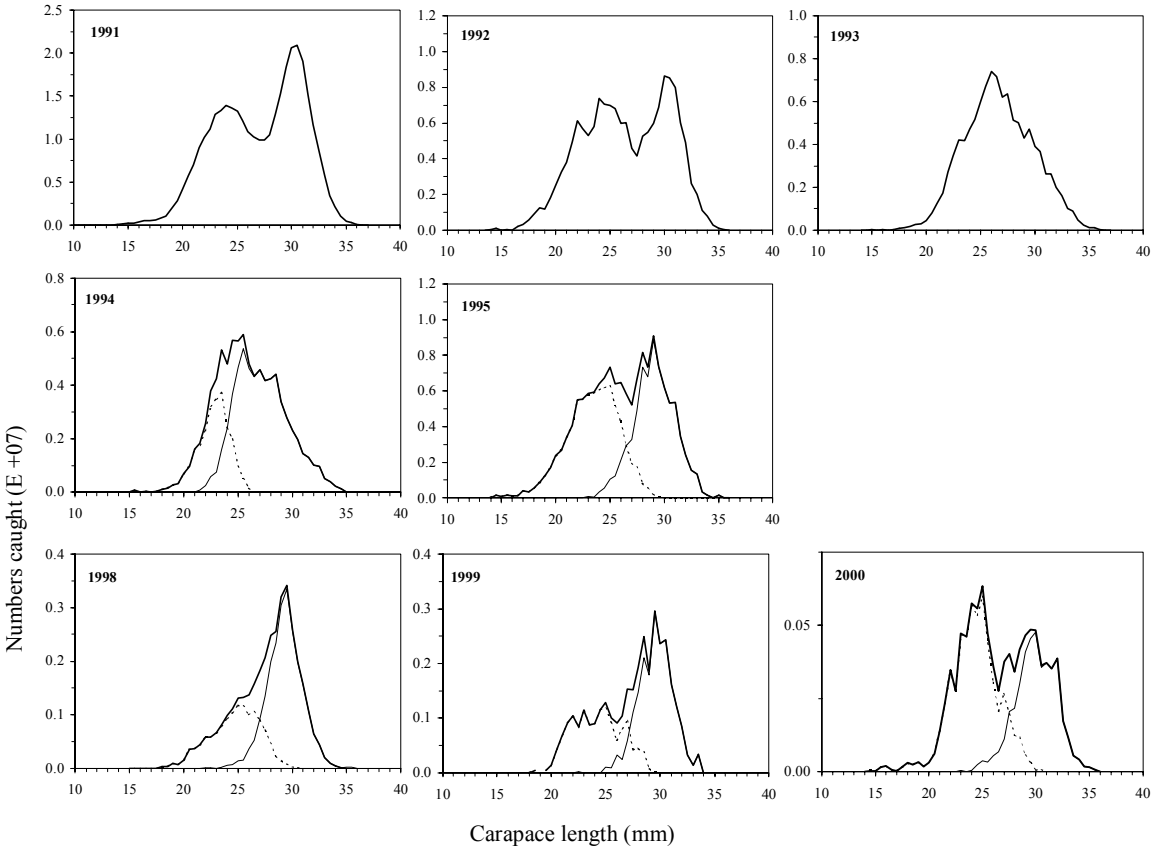


Fig. 5A. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland north of 65°N, 1991-2000 (no data available for 1996-1997 and 2001-2001). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.

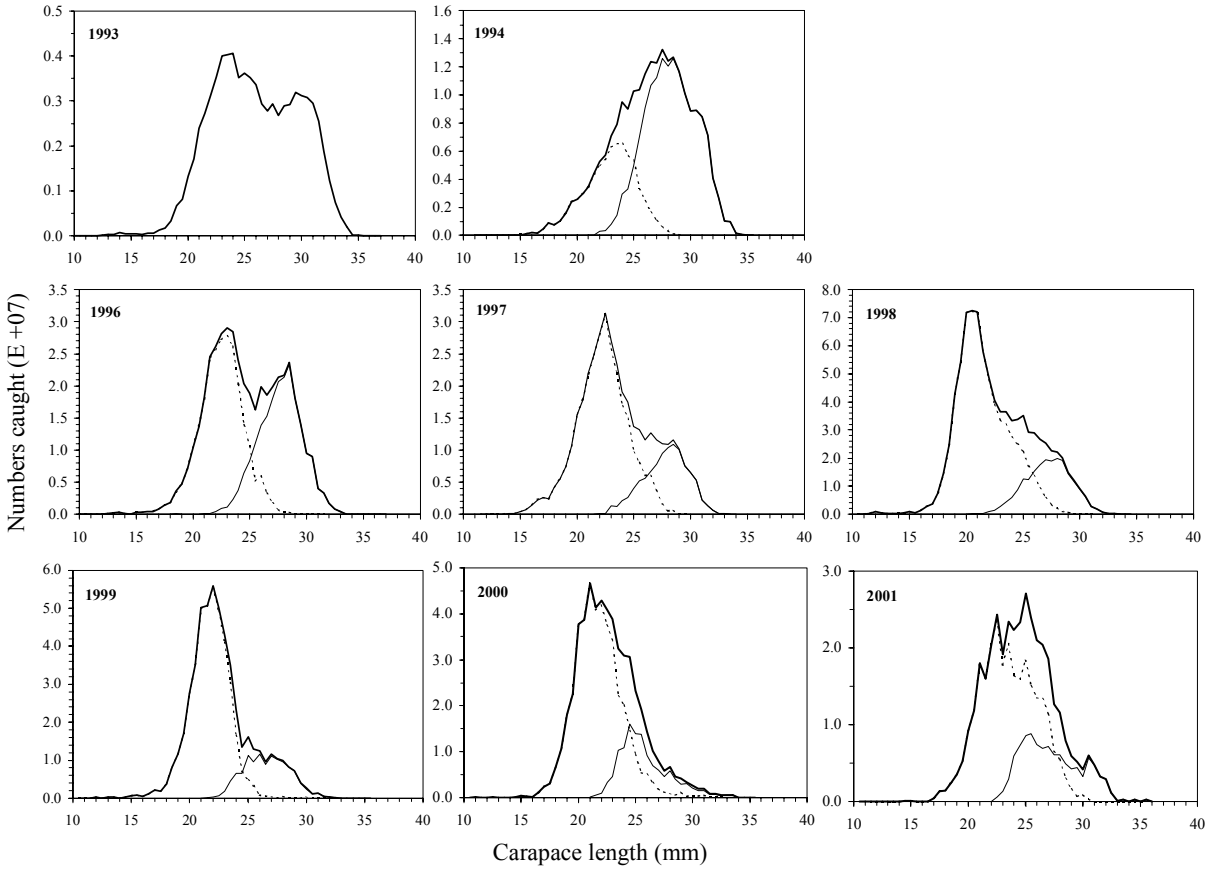


Fig. 5B. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland south of 65°N, 1993-2001 (no data available for 1995 and 2002). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.

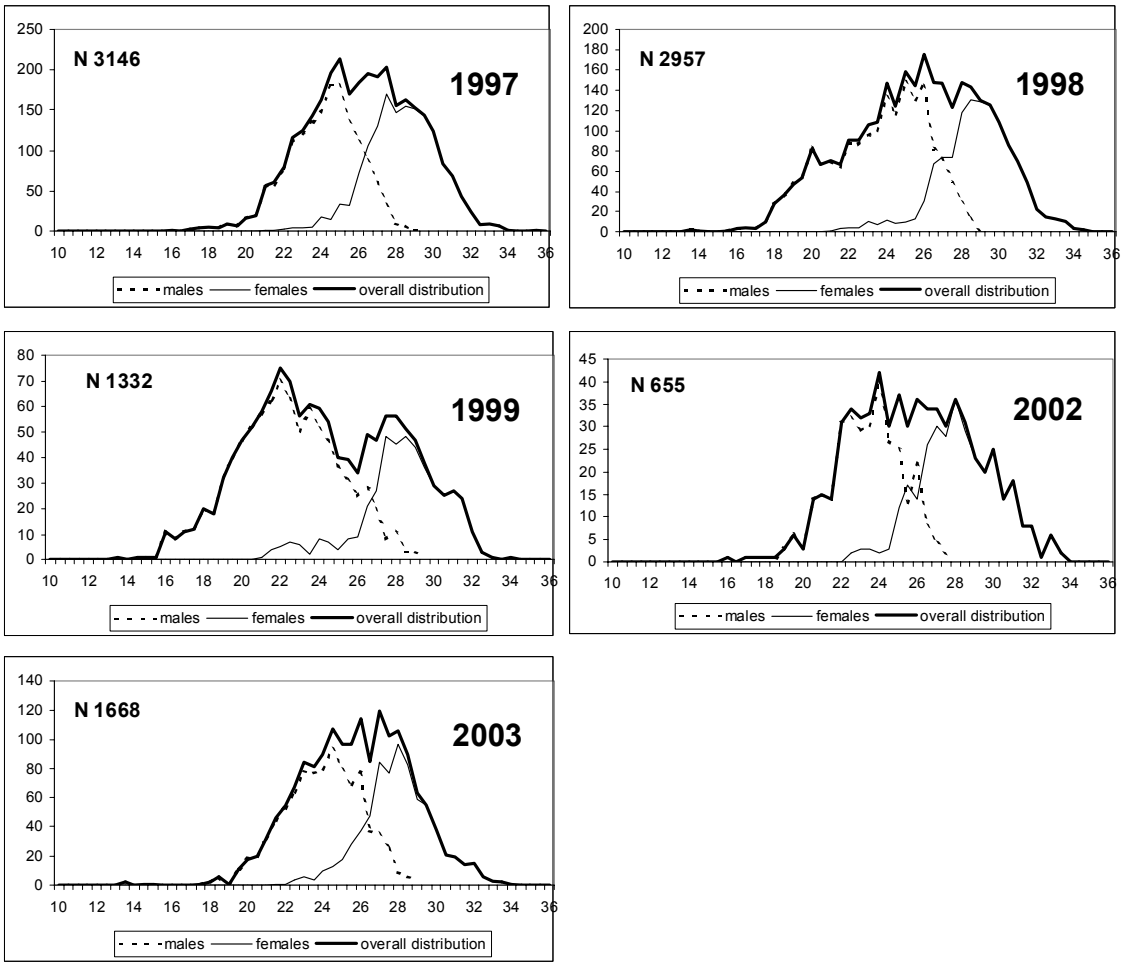


Fig 5C. Length-frequency distributions of pooled samples taken in the Icelandic fishery in the area north of 65°N 1997-1999 and 2002-2003 (data from U. Skulatottir). N is number measured.

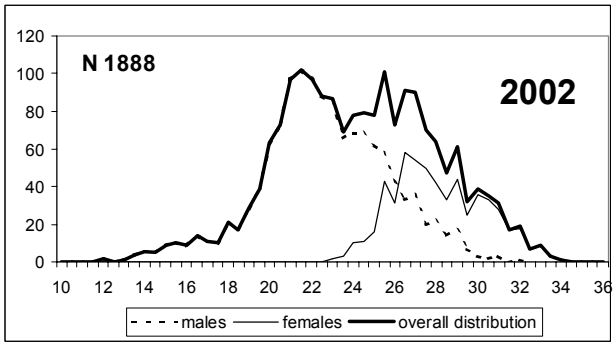


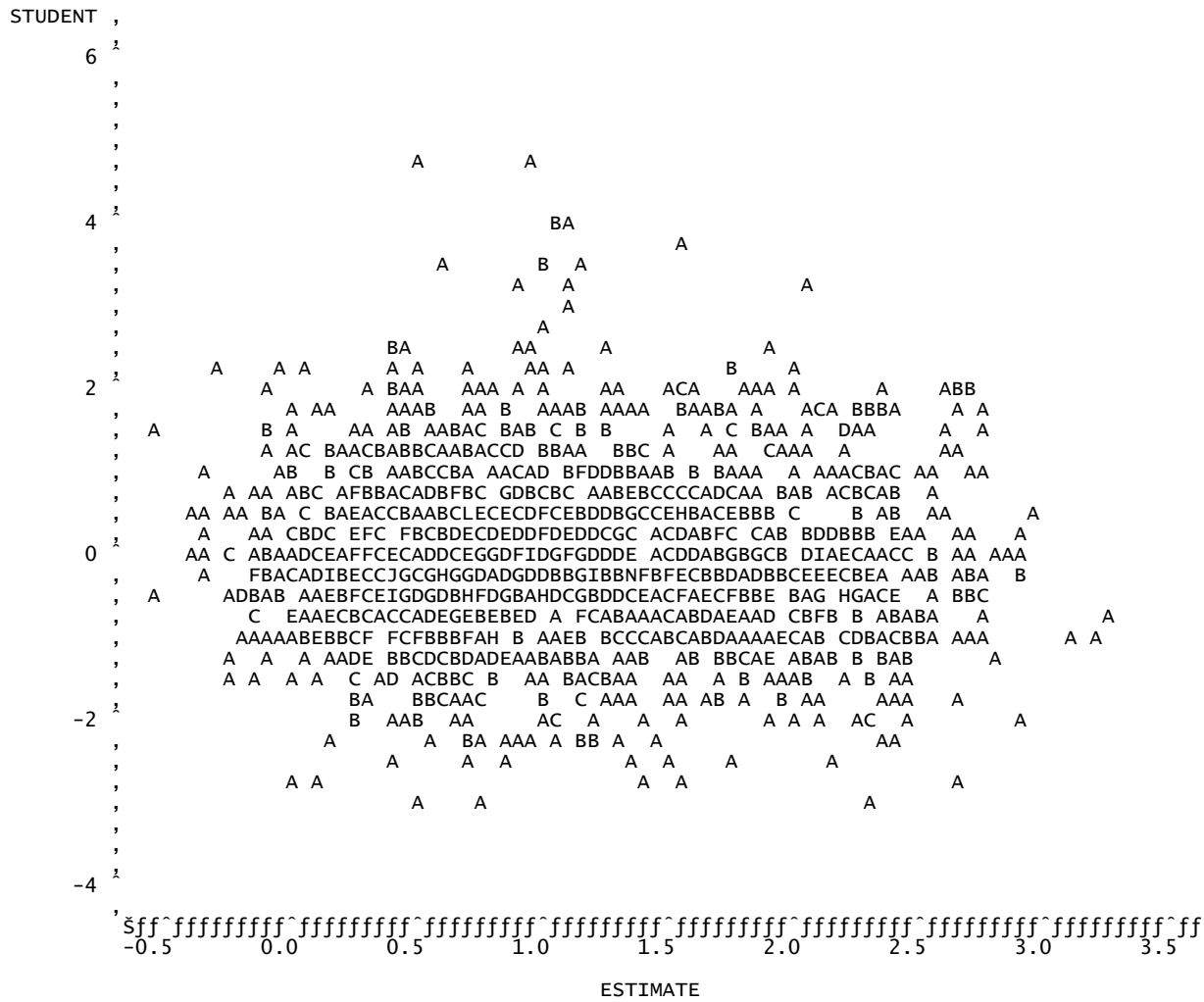
Fig 5D. Length-frequency distribution of 12 pooled samples taken in the Greenlandic fishery in the area south of 65°N in 2003. N is number measured.

Appendix 1. Diagnostical outputs from GLM run of model for standardising CPUE in Greenlandic zone. Data from Greenlandic, Faeroese and Danish vessels.

```
                          Class Level Information
VESSEL          16  AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH IIII JJJJ KKKK LLLL MMMM OWWP
                    OZHJ OZMA
YEAR            17  87 88 89 90 91 92 94 95 96 97 98 99 100 101 102 103 111
MONTH            5  1 3 5 6 12
AREA             2  21 22

                               Number of observations    1864

Dependent Variable: LNCPUE
Weight: HAULS
                                          Sum of
      Source                     DF         Squares     Mean Square    F Value    Pr > F
      Model                      46     46979.52624      1021.29405      98.23    <.0001
      Error                    1817     18892.24658        10.39749
      Corrected Total          1863     65871.77282

                    R-Square     Coeff Var      Root MSE    LNCPUE Mean
                    0.713197      308.2507      3.224515       1.046069

      Source                     DF       Type I SS     Mean Square    F Value    Pr > F
      VESSEL                     15     22111.72560      1474.11504     141.78    <.0001
      YEAR*AREA                  27     21398.29349       792.52939      76.22    <.0001
      MONTH                       4      3469.50715       867.37679      83.42    <.0001
      AREA                        0         0.00000               .          .         .

      Source                     DF     Type III SS     Mean Square    F Value    Pr > F
      VESSEL                     15      7562.35584       504.15706      48.49    <.0001
      YEAR*AREA                  26     11676.78255       449.10702      43.19    <.0001
      MONTH                       4      3469.50715       867.37679      83.42    <.0001
      AREA                        1      5687.44936      5687.44936     547.00    <.0001

                                                          Standard
     Parameter                    Estimate                  Error    t Value    Pr > |t|
     Intercept                0.895830082 B          0.15616207       5.74      <.0001
     VESSEL    AAAA          -0.957272214 B          0.14800884      -6.47      <.0001
     VESSEL    BBBB          -0.826705444 B          0.14097134      -5.86      <.0001
     VESSEL    CCCC          -0.691026948 B          0.13878433      -4.98      <.0001
     VESSEL    DDDD          -0.512026355 B          0.15264372      -3.35      0.0008
     VESSEL    EEEE          -0.560170321 B          0.13852287      -4.04      <.0001
     VESSEL    FFFF          -0.474571441 B          0.13709009      -3.46      0.0005
     VESSEL    GGGG          -0.382337428 B          0.13654241      -2.80      0.0052
     VESSEL    HHHH          -0.337862244 B          0.13612629      -2.48      0.0132
     VESSEL    IIII          -0.176076919 B          0.13631958      -1.29      0.1966
     VESSEL    JJJJ          -0.150076073 B          0.14138303      -1.06      0.2886
     VESSEL    KKKK          -0.013036491 B          0.13810046      -0.09      0.9248
     VESSEL    LLLL           0.031920864 B          0.13525747       0.24      0.8135
     VESSEL    MMMM           0.084824203 B          0.13825826       0.61      0.5396
     VESSEL    OWWP          -0.078751016 B          0.14461014      -0.54      0.5861
     VESSEL    OZHJ           0.382040129 B          0.16101097       2.37      0.0178
     VESSEL    OZMA           0.000000000 B                   .          .         .
     YEAR*AREA 87 21          0.691730297 B          0.08589244       8.05      <.0001
     YEAR*AREA 88 21          0.515177392 B          0.08095068       6.36      <.0001
     YEAR*AREA 89 21          0.106503724 B          0.07951520       1.34      0.1806
     YEAR*AREA 90 21          0.100624495 B          0.07956110       1.26      0.2061
     YEAR*AREA 91 21         -0.108525960 B          0.07841556      -1.38      0.1665
     YEAR*AREA 92 21         -0.350999291 B          0.08194164      -4.28      <.0001
     YEAR*AREA 94 21          0.326752265 B          0.10297357       3.17      0.0015
     YEAR*AREA 94 22          0.924879117 B          0.09063000      10.20      <.0001
     YEAR*AREA 95 21          0.143588591 B          0.09366168       1.53      0.1254
     YEAR*AREA 95 22          0.896754997 B          0.09767962       9.18      <.0001
     YEAR*AREA 96 21          0.007200844 B          0.12879696       0.06      0.9554
     YEAR*AREA 96 22          1.132509003 B          0.09176289      12.34      <.0001
     YEAR*AREA 97 21          0.378235883 B          0.14332347       2.64      0.0084
     YEAR*AREA 97 22          1.118111239 B          0.09357513      11.95      <.0001
     YEAR*AREA 98 21          0.689320276 B          0.12917229       5.34      <.0001
     YEAR*AREA 98 22          1.249663052 B          0.10496724      11.91      <.0001
     YEAR*AREA 99 21          0.378137269 B          0.16280626       2.32      0.0203
     YEAR*AREA 99 22          1.758016723 B          0.12388447      14.19      <.0001
     YEAR*AREA 100 21         0.579201866 B          0.17334529       3.34      0.0009
     YEAR*AREA 100 22         1.577996566 B          0.11121118      14.19      <.0001
     YEAR*AREA 101 21         0.336286964 B          0.32099168       1.05      0.2949
     YEAR*AREA 101 22         1.330965088 B          0.10661825      12.48      <.0001
     YEAR*AREA 102 21         0.548924148 B          0.23421090       2.34      0.0192
     YEAR*AREA 102 22         1.678348983 B          0.10666468      15.73      <.0001
     YEAR*AREA 103 21         0.780089745 B          0.13709584       5.69      <.0001
     YEAR*AREA 103 22         1.458393945 B          0.11075756      13.17      <.0001
```

YEAR*AREA	111	21	-0.532872055	B	0.08627982	-6.18	<.0001
YEAR*AREA	111	22	0.000000000	B	.	.	.
MONTH	1		0.294774265	B	0.03425851	8.60	<.0001
MONTH	3		0.117988353	B	0.03709454	3.18	0.0015
MONTH	5		0.060728598	B	0.05641424	1.08	0.2819
MONTH	6		-0.256295066	B	0.03729409	-6.87	<.0001
MONTH	12		0.000000000	B	.	.	.
AREA	21		0.000000000	B	.	.	.
AREA	22		0.000000000	B	.	.	.

Plot of STUDENT*ESTIMATE. Legend: A = 1 obs, B = 2 obs, etc.



Appendix 2. Results and diagnostical outputs from GLM run of model for standardising CPUE data from in Icelandic zone. Data are from Icelandic vessels only.

Class Level Information

Class	Levels	Values
YEAR	17	1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 19870
MONTH	9	1 3 4 5 6 9 10 11 12
SHIP	12	1046 1753 2061 2204 3100 3200 3300 3400 3500 3600 3700 3800
T	2	1 2

Number of observations 902

Dependent Variable: LNCPUE
Weight: EFFORT EFFORT

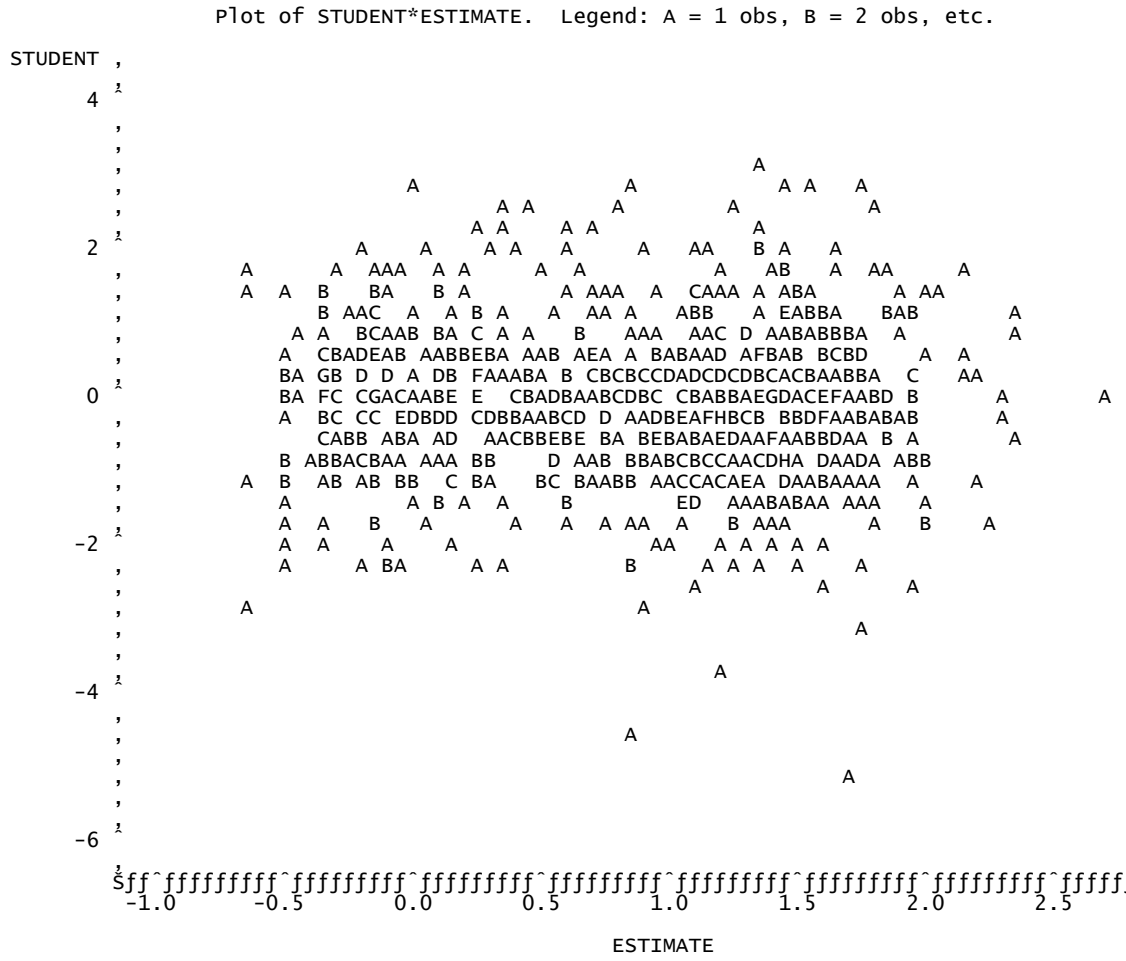
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	36	2972341.292	82565.036	122.60	<.0001
Error	865	582535.541	673.451		
Corrected Total	901	3554876.834			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.836131	3798.833	25.95094	0.683129

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MONTH	8	2414488.501	301811.063	448.16	<.0001
SHIP	11	273785.014	24889.547	36.96	<.0001
YEAR	16	279036.335	17439.771	25.90	<.0001
T	1	5031.442	5031.442	7.47	0.0064

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	8	434011.2776	54251.4097	80.56	<.0001
SHIP	11	242448.6492	22040.7863	32.73	<.0001
YEAR	16	282785.1924	17674.0745	26.24	<.0001
T	1	5031.4424	5031.4424	7.47	0.0064

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		1.633555262	B	0.14878349	10.98	<.0001
MONTH	1	-0.449357417	B	0.30204691	-1.49	0.1372
MONTH	3	0.780057942	B	0.12054838	6.47	<.0001
MONTH	4	0.855442381	B	0.12130112	7.05	<.0001
MONTH	5	0.429524855	B	0.12101889	3.55	0.0004
MONTH	6	-0.103664819	B	0.12758242	-0.81	0.4167
MONTH	9	-0.596006661	B	0.12408714	-4.80	<.0001
MONTH	10	-0.758071609	B	0.12734046	-5.95	<.0001
MONTH	11	-0.930114957	B	0.14392228	-6.46	<.0001
MONTH	12	0.000000000	B	.	.	.
SHIP	1046	0.122092812	B	0.57531117	0.21	0.8320
SHIP	1753	0.210448001	B	0.27147501	0.78	0.4384
SHIP	2061	0.065088370	B	0.09937267	0.65	0.5126
SHIP	2204	-1.280090713	B	0.24924208	-5.14	<.0001
SHIP	3100	-0.951940725	B	0.11535314	-8.25	<.0001
SHIP	3200	-0.733607898	B	0.08413799	-8.72	<.0001
SHIP	3300	-0.586041232	B	0.07325886	-8.00	<.0001
SHIP	3400	-0.434465867	B	0.07299727	-5.95	<.0001
SHIP	3500	-0.303063994	B	0.07428285	-4.08	<.0001
SHIP	3600	-0.178720261	B	0.08052575	-2.22	0.0267
SHIP	3700	-0.096596965	B	0.07493008	-1.29	0.1977
SHIP	3800	0.000000000	B	.	.	.
YEAR	1988	-0.425376583	B	0.04291931	-9.91	<.0001
YEAR	1989	-0.606534051	B	0.04885512	-12.41	<.0001
YEAR	1990	-0.612225593	B	0.08022506	-7.63	<.0001
YEAR	1991	-0.188910938	B	0.08746562	-2.16	0.0311
YEAR	1992	-0.541627731	B	0.07795031	-6.95	<.0001
YEAR	1993	-0.688198794	B	0.07435973	-9.25	<.0001
YEAR	1994	-0.111694033	B	0.08093205	-1.38	0.1679
YEAR	1995	-0.288416029	B	0.10087123	-2.86	0.0043
YEAR	1996	-0.523362124	B	0.10855469	-4.82	<.0001
YEAR	1997	-0.487584459	B	0.08072764	-6.04	<.0001
YEAR	1998	-0.724743115	B	0.08059974	-8.99	<.0001
YEAR	1999	-0.777228567	B	0.09598070	-8.10	<.0001
YEAR	2000	-0.550119903	B	0.15670302	-3.51	0.0005
YEAR	2001	-1.197973670	B	0.38439272	-3.12	0.0019
YEAR	2002	0.167282276	B	0.08993106	1.86	0.0632
YEAR	2003	-0.365644775	B	0.09864824	-3.71	0.0002
YEAR	19870	0.000000000	B	.	.	.
T	1	-0.185589142	B	0.06789839	-2.73	0.0064
T	2	0.000000000	B	.	.	.


Plot of STUDENT*ESTIMATE. Legend: A = 1 obs, B = 2 obs, etc.
STUDENT
4
2
0
-2
-4
-6
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
ESTIMATE