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An Assessment of the Shrimp Stock in Denmark Strait/off East Greenland

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 to a level at or slightly above that seen at the beginning of the time series in 1987. Fishing mortality indices have declined since 1993 and have in the most recent years been fluctuating at the low end of the time series.

Since 1993 the geographical distribution of the fishery seems to have been stable. However, a much larger part of the total effort was allocated to the areas north of 65°N in 2004 then in the previous 8-year period.

Introduction

Northern shrimp (*Pandalus borealis*) occurs off East Greenland in ICES Divisions 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 "overpack" according to Hvingel (2003). The Icelandic catch data series was not corrected for "overpack" as the Icelandic reporting practice does account for this factor.

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 reported 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 m^{th} area; S_j is the effect of the j^{th} month; V_k is the effect of the k^{th} vessel; Y_i is the effect of the i^{th} year; e_{mjki} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ 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.1.4, (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 2003 and 2004 (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 (Fig. 2A, Table 1and 2). Following the area expansion of the fishery south of 65°N catches increased again reaching 13 500 tons in 1997. In recent years annual catches have been between 11-14 000 tons and is for the current year projected to be close to 13 500 tons (projected from October) of which about 67% 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. However in 2004 2/3 of the total catches taken until October originated from the northern areas and the total for the year is projected to be around 9000 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 in 2002-2003. In 2004 catches from the southern area are expected to decline further to about 4 500 tons.

Fishing effort

The high increase in catches during the first ten-year period of the fishery 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 a low of about 20 000 hr's in 2002-2003. The value for 2004 is expected to be of about 35 000 hr's (Fig. 2B).

The historic development of fishing effort spent in the northern areas follow closely the one described for the total area – except for 2001, when a lot of effort shifted to the south. The increase in effort for the total area in 2004 is caused by increased fishing activity north of 65°N where the 2004 value is estimated to 29 000 hr's compared to only 9 000 hr's in 2003.

In the southern areas, 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 2002-2003 effort in the southern areas was down to approx. 11 000 hr's. The 2004 value is expected to decline further to around 8 000 hr's (Fig. 2B, Table 2).

Catch rate

Catch rates (total area) decreased from 278 kg/hr to 109 kg/hr in the period 1980-1989, but has shown an increasing trend since then reaching about 586 kg/hr in 2003 (Fig. 2C, Table 2). The preliminary catch rates for 2004 are down to 380 kg/hr – partly due to the increased effort in the northern areas where density is lower than south of 65°N.

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 2003. For 2004 CPUE is 566 kg/hr (registered until October).

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 CPUE's have fluctuated around 225 kg/hr except for an extreme of 145 kg/hr in 1996. Since 2002 annual mean CPUE was above 300 kg/hr, with 319 kg/hr estimated for 2004.

Standardised catch rate indices

Results of the two multiple regression analysis to standardise catch rates showed that all main effects were highly significant ($p < 0.01$) (see appendix 1 and 2). The r-squared of the models were 70% and 83%, respectively. The model-diagnostical outputs 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 description 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. For the recent three years the mean index values have been varying a little above that of 1987. The CPUE index series of the southern area (Fig. 3) increased until 1999. A slight decreasing trend was seen thereafter with the 2004 value being the lowest at around the mean level of the series.

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 2003 and 2004, 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, 2003).

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 2004 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 to 2004 only few samples were available (Fig. 5C and 5D).

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. 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. However for 2004 this trend seems to be reversed.

Since the mid-1990s 53-84 % of the total catch was taken in the southern areas and the geographical distribution of the fishery seems to have been stable during this period. However for 2004 2/3 of the catches is taken in the northern areas.

Available information on stock size composition is incomplete.

The CPUE based biomass index 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 but the decline may have stopped in recent years.

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Table 1. Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland 1978 to September 2004. 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	1998[1]	1999[1]	2000[1]	2001[1]	2002[1]	2003[1]	2004[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	497	737
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	309	744	974
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	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	292	2338
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1144	635	377
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	679	1920
Total	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	6982	5731	7176	3490	4478	5364	4827	4420	2237	2227	2848	6346
South of 65°N																											
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	613	731	1167	1657	1300	1095	1900	2473	2309	1645	767
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	280	974	295	402	656	138	453	340	2402	1013	621	20
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1141	3603	2667	5295	4701	3950	4966	5235	4943	4333	4597	1778
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	424	1011	720	1590	2261	670	378	157	1855	1359	2380	444
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1904	6201	4412	8453	9276	6057	6893	7632	11674	9015	9243	3009
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	2142	1504
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	1365	994
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	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	4890	4116
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1144	635	377
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	3059	2364
Total	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12091	9355
Total all areas	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12091	9355
Advised TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	10000[3]	10000[3]	10000[3]	8000	5000	5000	5000	5000	5000	5000	9600	9600	9600	9600	9600	12400
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	15043

[1]Provisional

[2]Catch in 2004 per Oct. 1.

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

[4]For Greenland zone only; no restrictions in Iceland zone

[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	10325	37198	278				10325	37198	278
1981	5964	19986	298				5964	19986	298
1982	6133	23081	266				6133	23081	266
1983	5212	23855	219				5212	23855	219
1984	8235	34983	235				8235	34983	235
1985	9696	62911	154				9696	62911	154
1986	13428	61863	217				13428	61863	217
1987	15073	79881	189				15073	79881	189
1988	15313	109455	140				15313	109455	140
1989	12999	119629	109				12999	119629	109
1990	12480	72833	171				12480	72833	171
1991	10757	78789	137				10757	78789	137
1992	8901	68365	130				8901	68365	130
1993	6982	52381	133	1904	9335	204	8886	61003	146
1994	5731	25444	225	6201	16361	379	11932	39725	300
1995	7176	34021	211	4412	11328	389	11588	43574	266
1996	3490	24135	145	8453	21097	401	11944	40712	293
1997	4478	19432	230	9276	18994	488	13754	38178	360
1998	5364	21752	247	6057	10560	574	11422	30211	378
1999	4827	21528	224	6893	7679	898	11719	25925	452
2000	4420	19841	223	7632	10758	709	12053	23550	512
2001	2237	10363	216	11674	27043	432	13911	35030	397
2002	2227	6724	331	9015	11551	780	11242	18887	595
2003	2848	8508	335	9243	11841	781	12091	20640	586
2004*	6346	19869	319	3009	5318	566	9355	24645	380

*until Oct.

Table 3. Means and standard errors (se) of standardised 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 October 2004.

	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	0.85	0.10	1.19	0.13					0.83	0.06	1.22	0.09
1989	0.62	0.07	1.40	0.15					0.58	0.04	1.49	0.11
1990	0.62	0.07	1.34	0.15					0.58	0.04	1.44	0.11
1991	0.52	0.06	1.36	0.16					0.48	0.04	1.49	0.11
1992	0.42	0.05	1.42	0.16					0.38	0.03	1.54	0.12
1993	0.35	0.04	1.31	0.15	1.00	-	1.00	-	0.31	0.02	1.91	0.15
1994	0.80	0.10	0.47	0.06	2.51	0.24	1.30	0.12	0.68	0.06	1.16	0.10
1995	0.67	0.09	0.71	0.09	2.45	0.25	0.95	0.09	0.61	0.05	1.25	0.10
1996	0.57	0.07	0.40	0.05	3.06	0.29	1.45	0.13	0.70	0.06	1.13	0.10
1997	0.81	0.12	0.37	0.05	3.07	0.30	1.59	0.15	0.76	0.07	1.21	0.11
1998	0.95	0.14	0.37	0.06	3.52	0.39	0.90	0.10	0.87	0.08	0.87	0.08
1999	0.78	0.12	0.41	0.06	5.81	0.77	0.62	0.08	1.08	0.12	0.72	0.08
2000	1.00	0.18	0.29	0.05	4.93	0.58	0.81	0.09	1.14	0.12	0.70	0.07
2001	0.80	0.16	0.18	0.04	3.84	0.43	1.60	0.17	0.95	0.11	0.97	0.11
2002	1.18	0.28	0.12	0.03	5.01	0.63	0.94	0.11	1.23	0.14	0.61	0.07
2003	1.04	0.23	0.22	0.05	4.59	0.58	1.00	0.12	1.09	0.12	0.74	0.08
2004	1.13	0.23	0.53	0.11	3.45	0.66	0.66	0.11	1.00	0.12	0.89	0.11

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

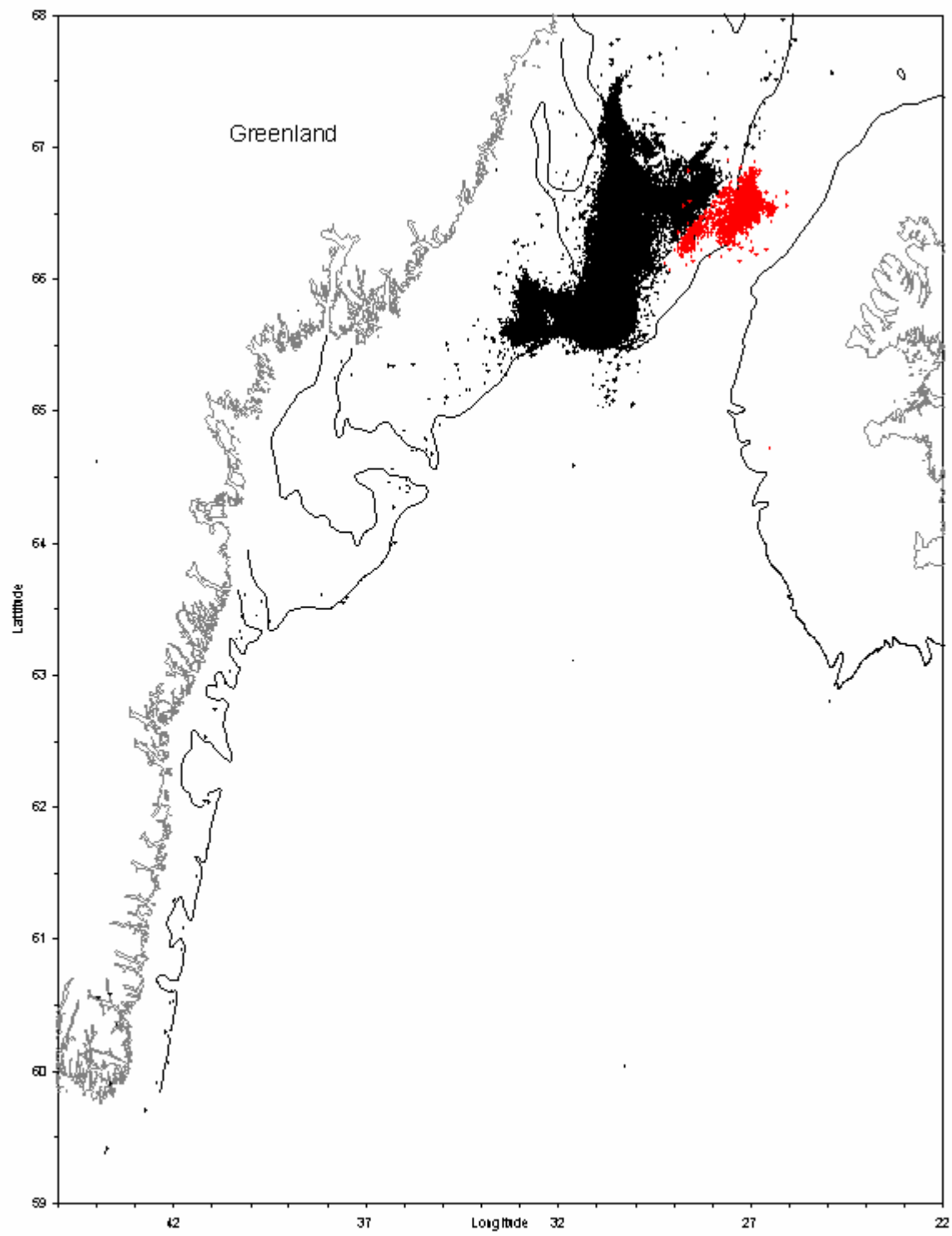


Fig. 1A. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 1987-1992 (black dots) and Icelandic trawlers 1990-1992 (red dots). 400 meters depth curve are shown as a solid line.

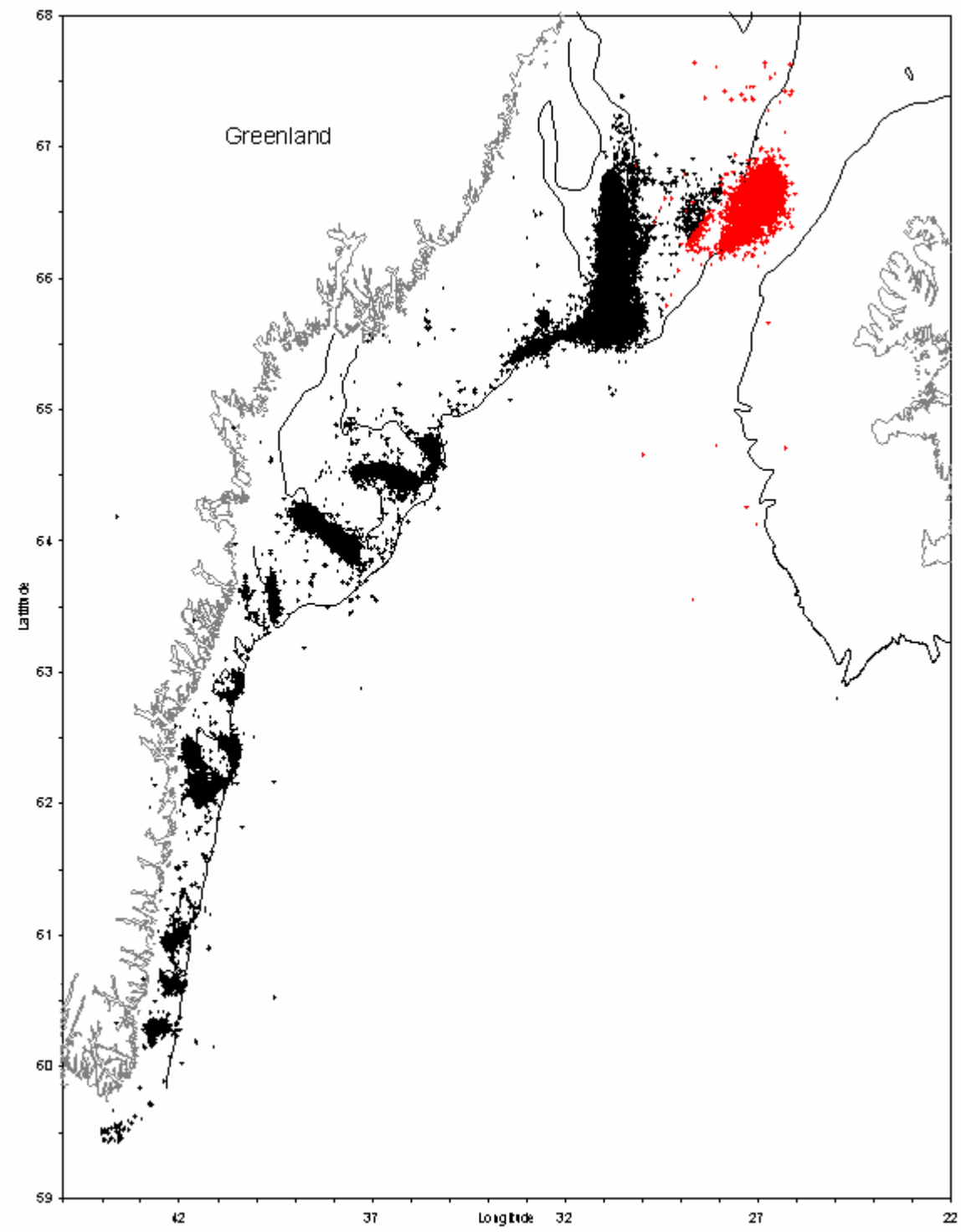


Fig. 1B. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland 1993-2002 by Greenlandic, Faeroese and Danish trawlers (black dots) and Icelandic trawlers (red dots). 400 meters depth curve are shown as a solid line.

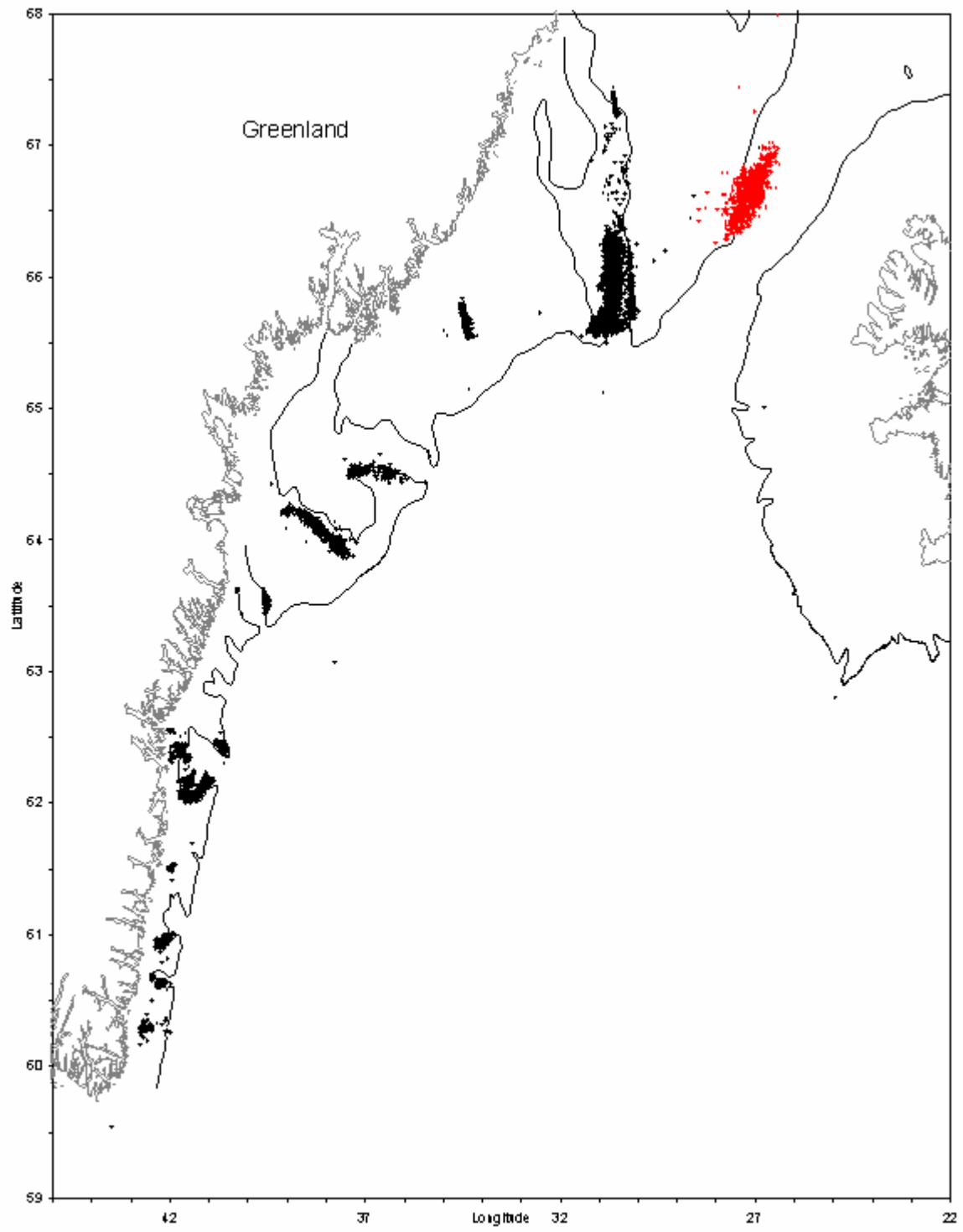


Fig. 1C. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland 2003-October 2004 by Greenlandic, Faeroese and Danish trawlers (black dots) and Icelandic trawlers (red dots). 400 meters depth curve are shown as a solid line.

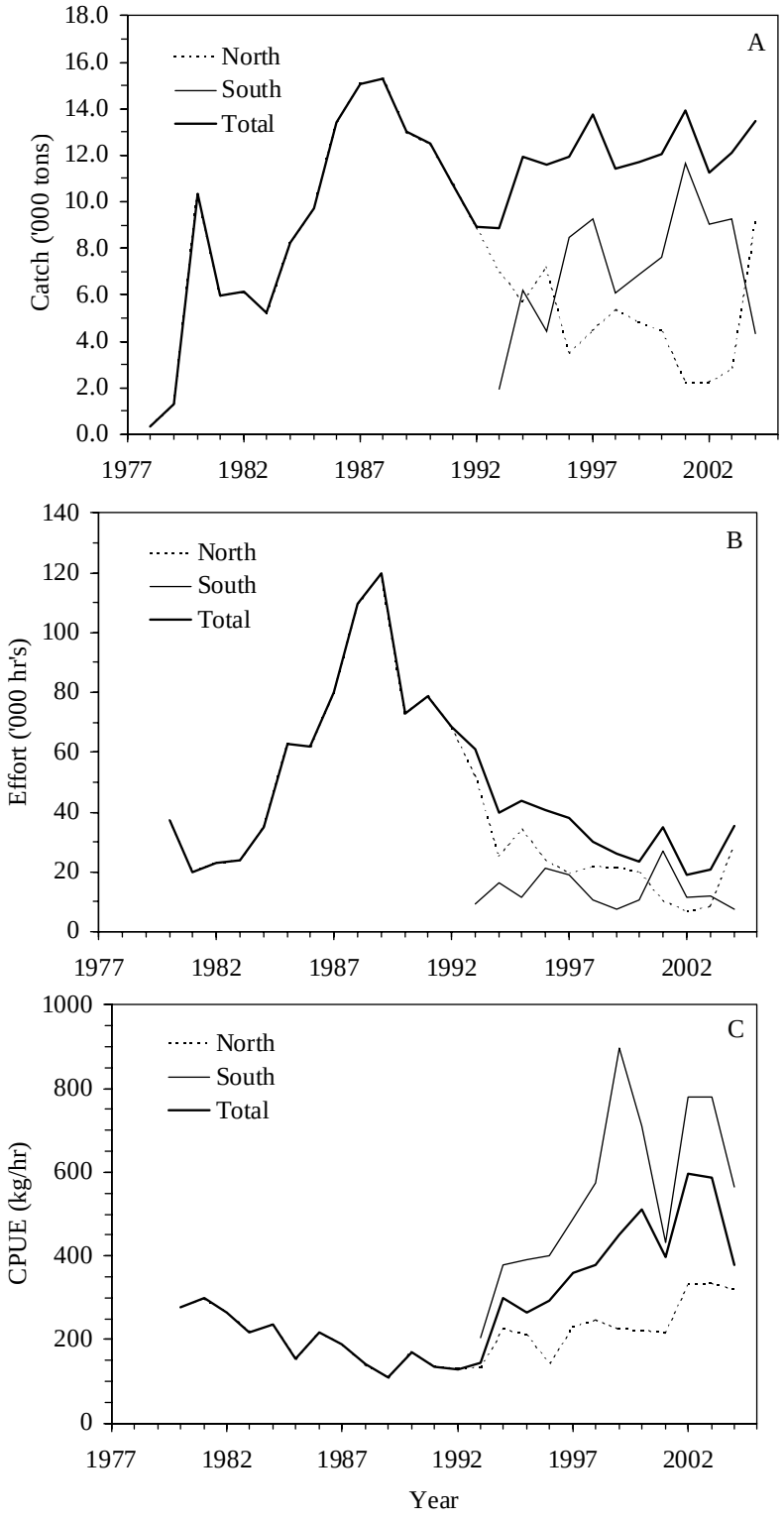


Fig. 2. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall. Data for 2004 are projected from October to the end of the year.

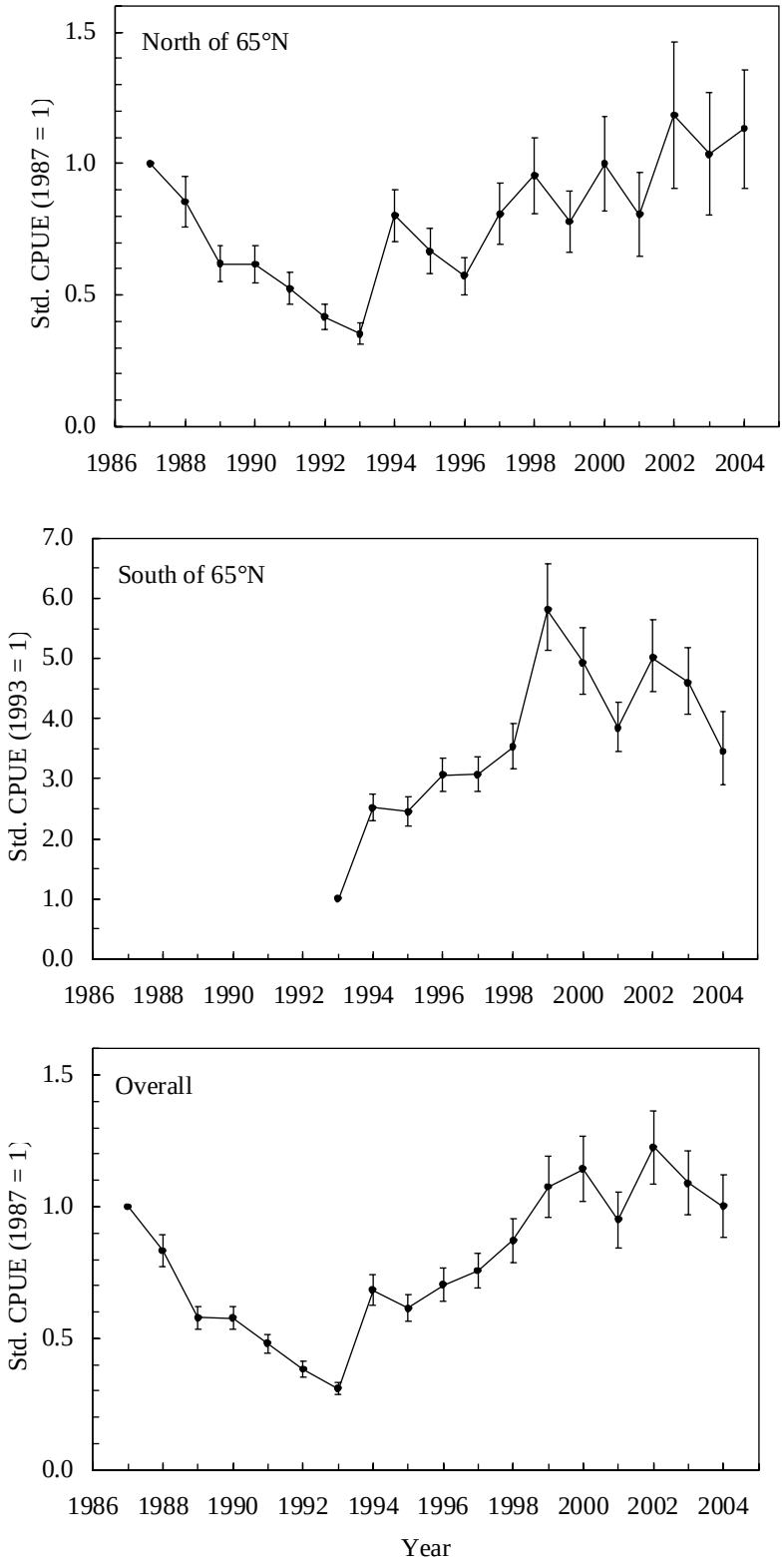


Fig. 3. Standardised Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until October 2004.

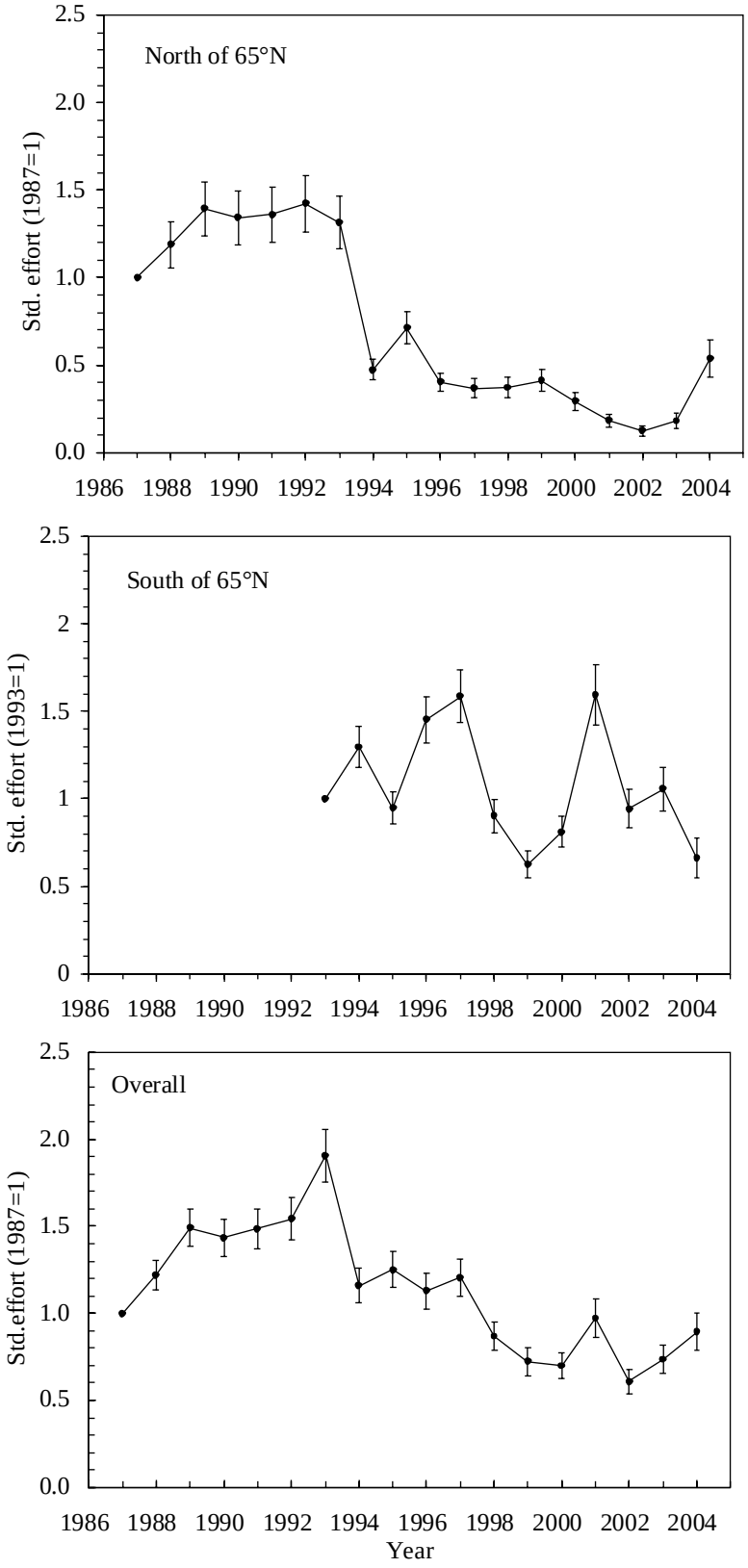


Fig. 4. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until October 2004.

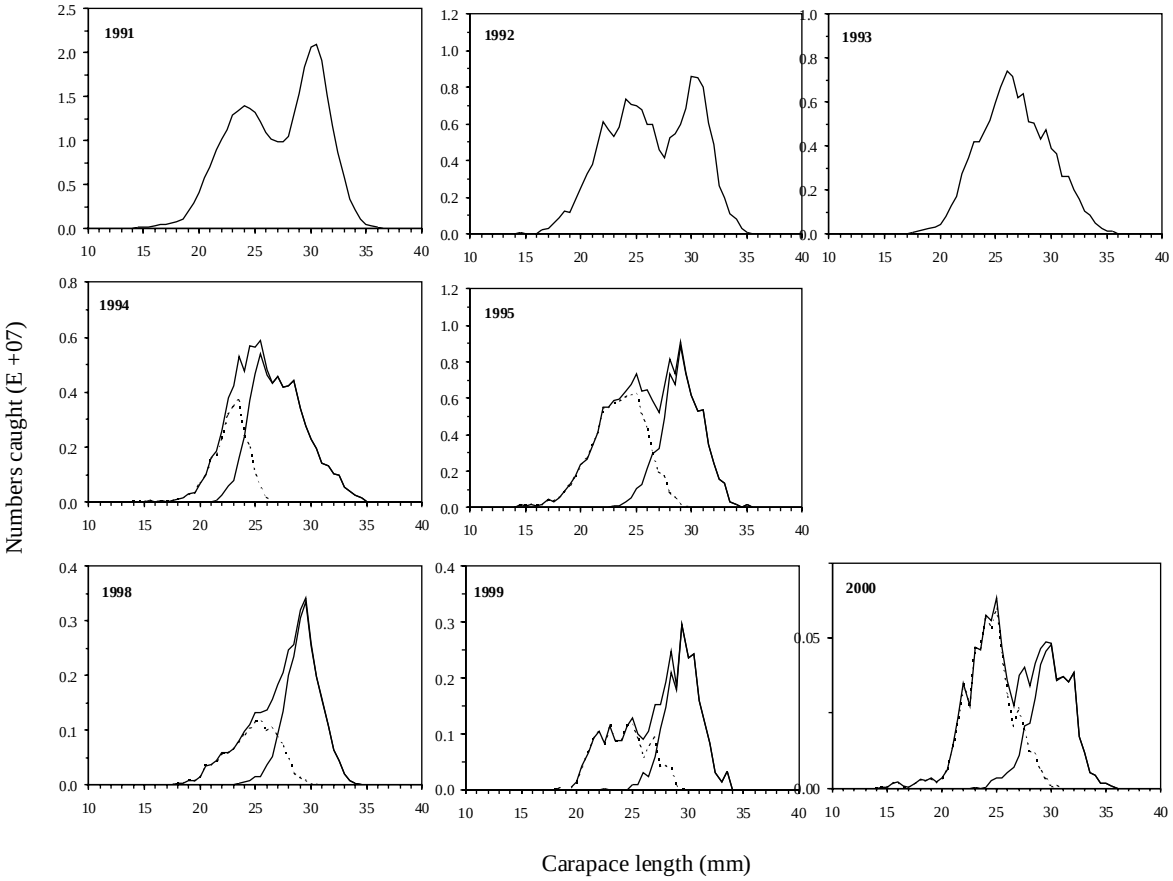


Fig. 5A. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland north of 65°N, 1991 - 2000 (no data available for 1996-1997 and 2001-2001). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.

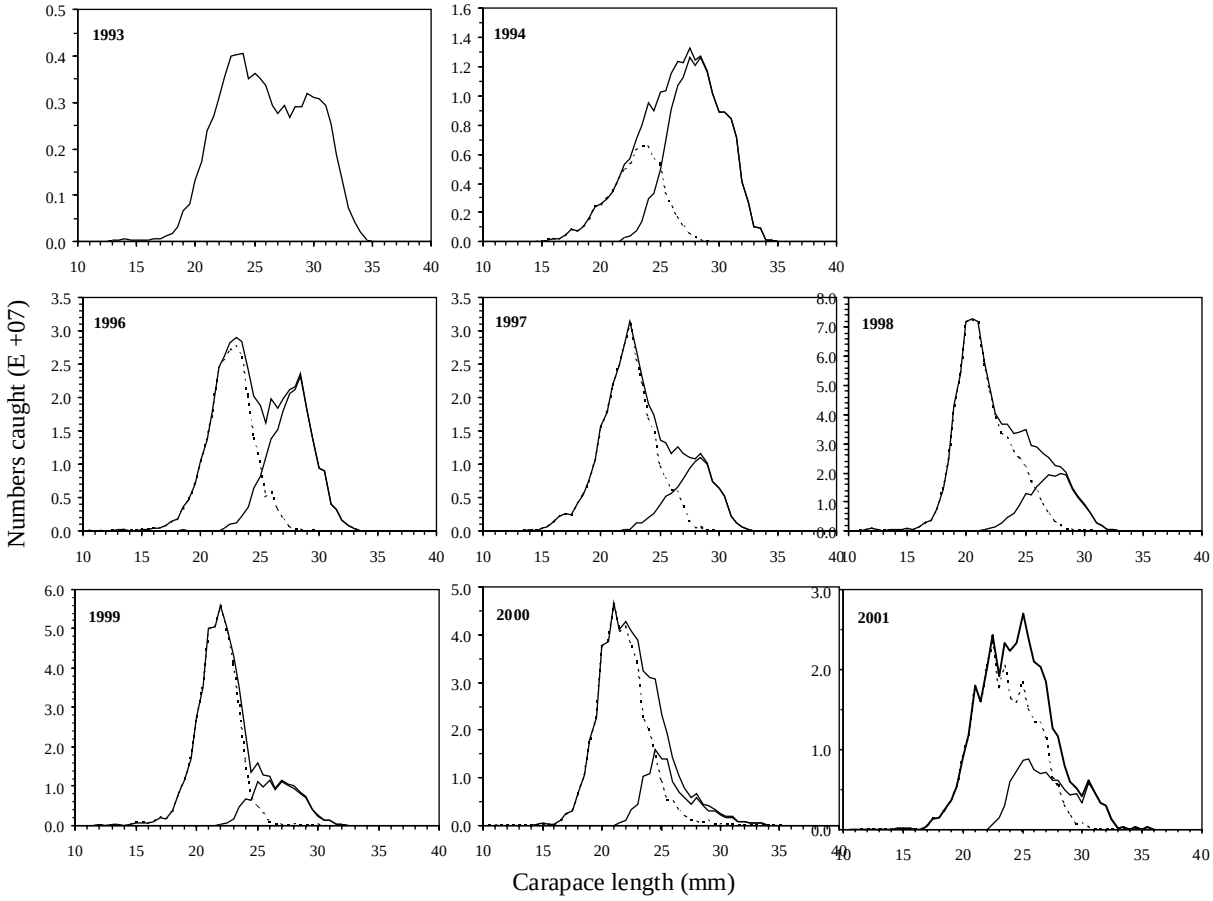


Fig. 5B. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland south of 65°N, 1993-2001 (no data available for 1995 and 2002). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.

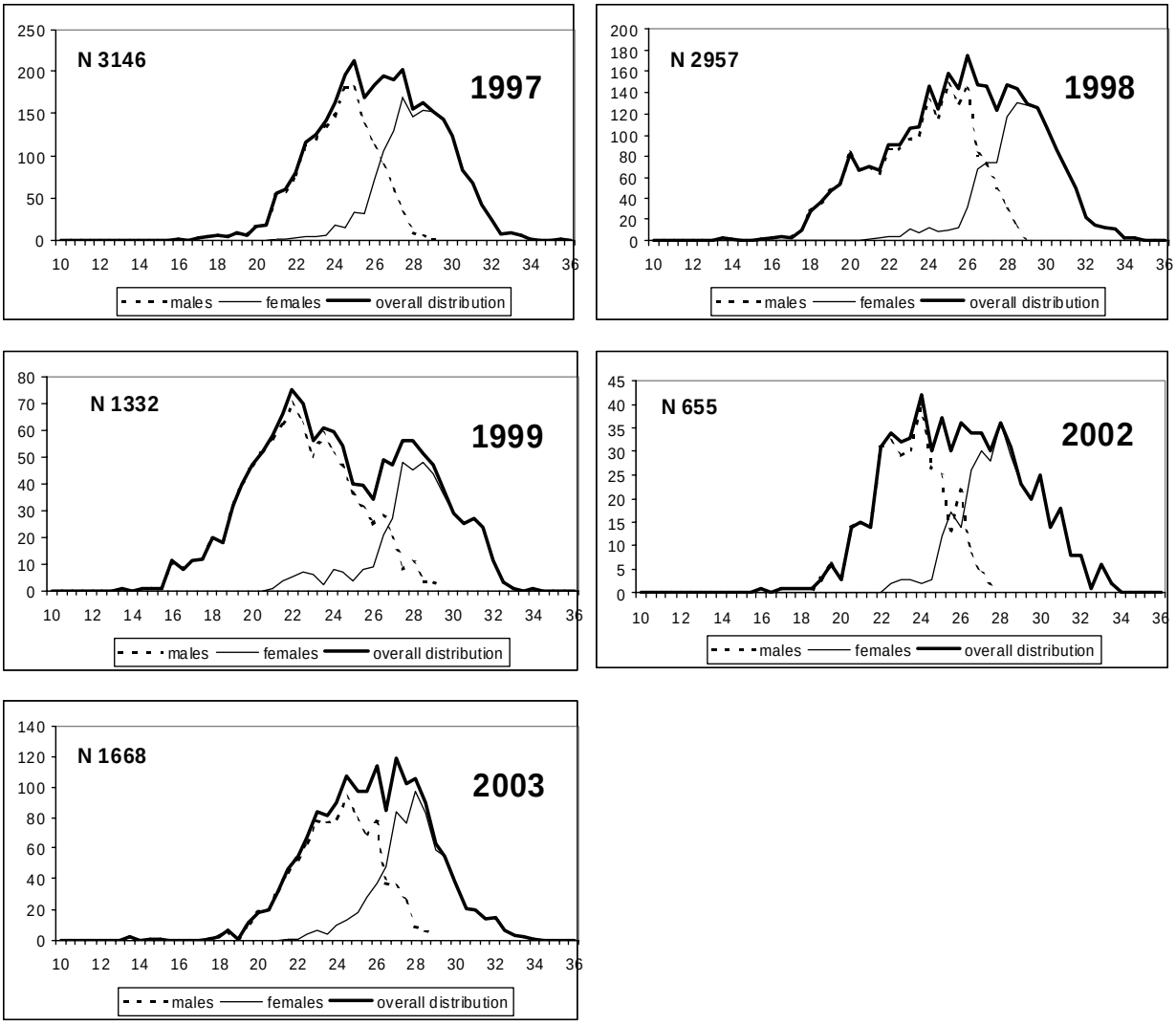


Fig 5C. Length-frequency distributions of pooled samples taken in the Icelandic fishery in the area north of 65°N 1997-1999 and 2002-2003 (data from U. Skulatottir). N is number measured.

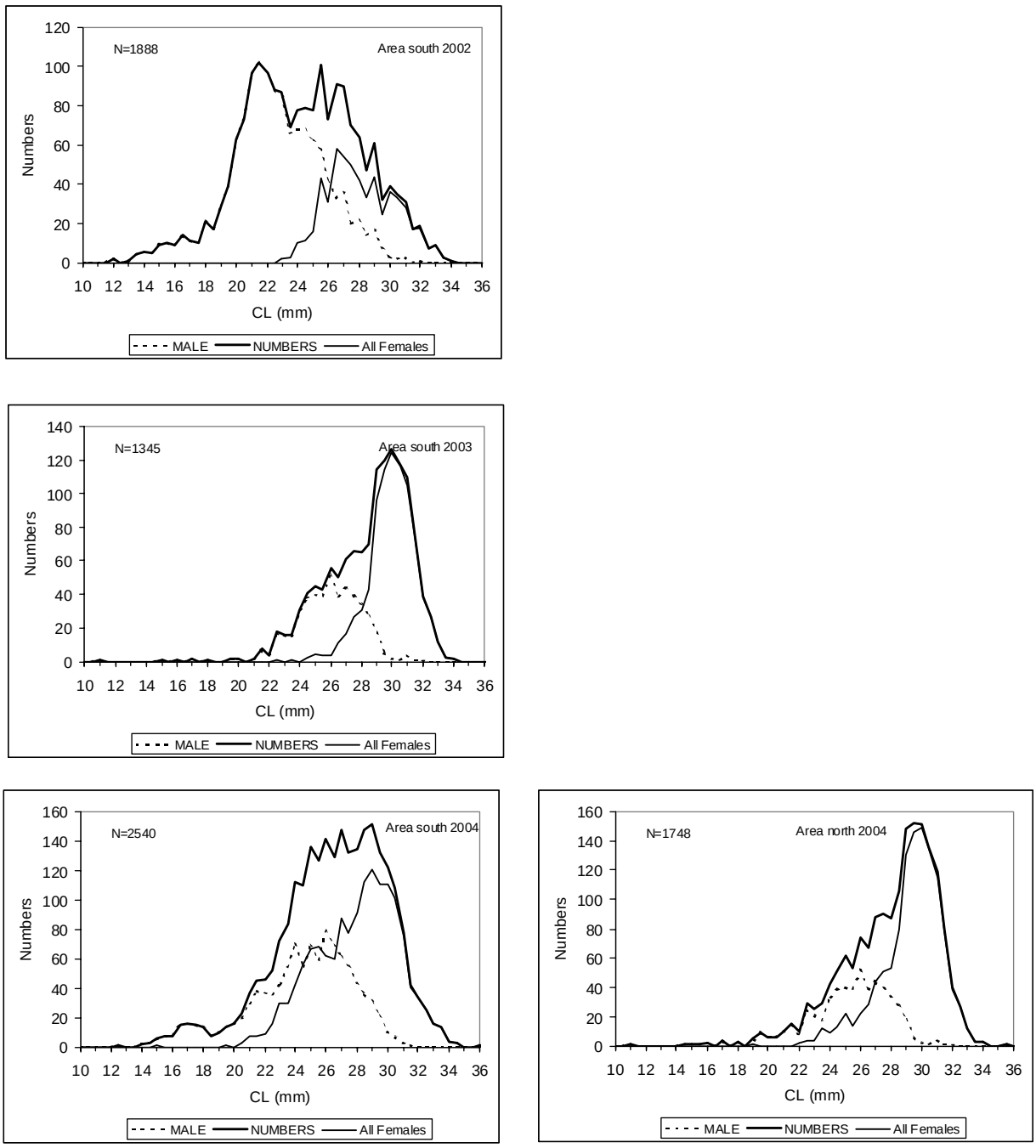


Fig 5D. Length-frequency distribution of pooled samples taken in the Greenlandic fishery in the areas north and south of 65°N in 2002 to 2004. N is number measured.

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

```
Class       Levels  Values
VESSEL          16  AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH IIII JJJJ KKKK LLLL MMMM OWWP
                    OZHJ OZMA
YEAR            18  87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104
SEASON           5  1 3 5 6 12
AREA             2  21 22
                        Number of Observations Read        1868
Dependent Variable: LNCPUE
Weight: HAULS
```

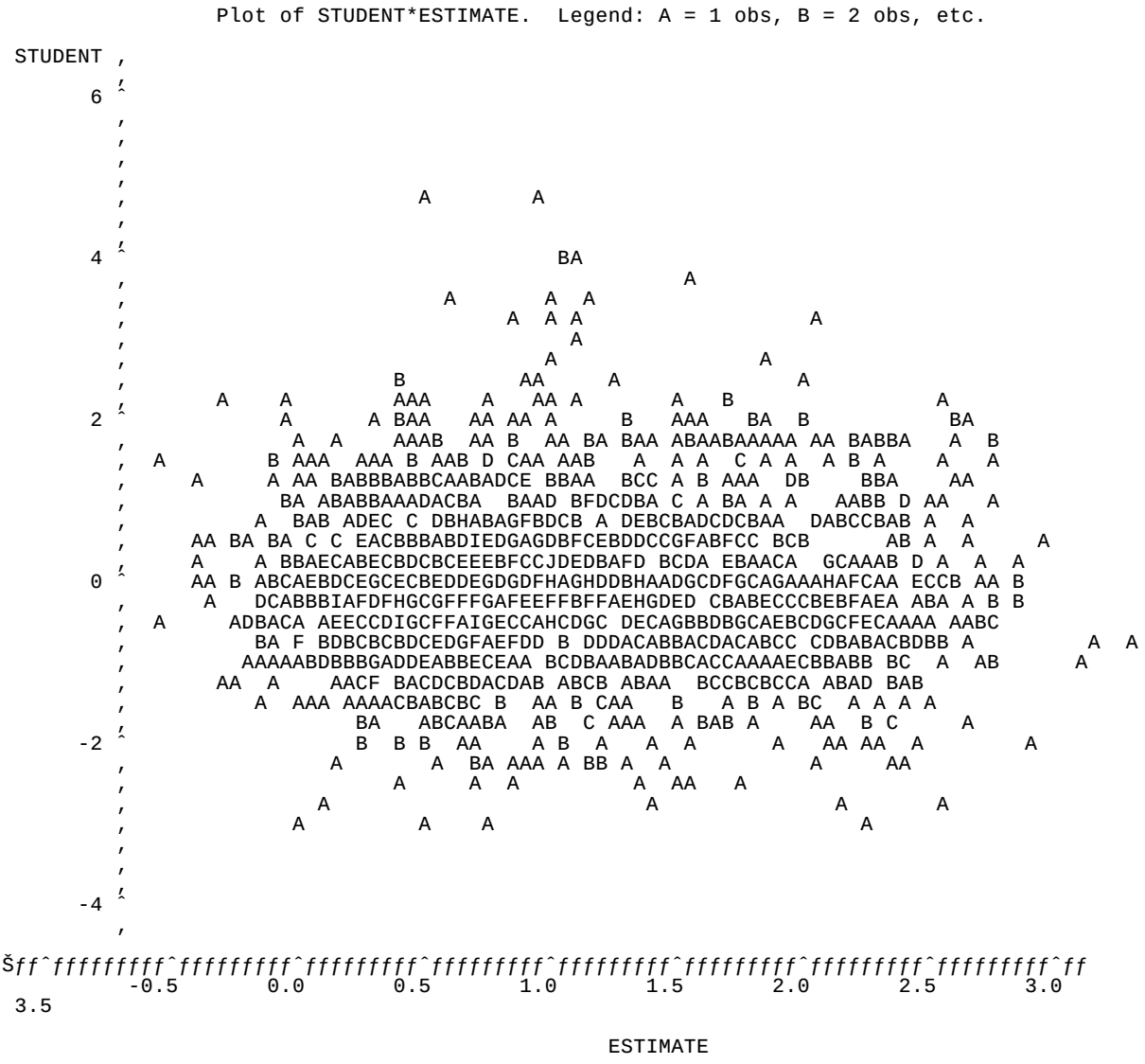
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	48	45097.31358	939.52737	89.94	<.0001
Error	1819	19001.02692	10.44586		
Corrected Total	1867	64098.34049			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.703564	311.1702	3.232006	1.038662

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VESSEL	15	20809.27029	1387.28469	132.81	<.0001
YEAR*AREA	29	20887.18206	720.24766	68.95	<.0001
MONTH	4	3400.86122	850.21531	81.39	<.0001
AREA	0	0.00000	.	.	.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VESSEL	15	7577.98579	505.19905	48.36	<.0001
YEAR*AREA	28	11686.39467	417.37124	39.96	<.0001
MONTH	4	3400.86122	850.21531	81.39	<.0001
AREA	1	4953.28149	4953.28149	474.19	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		0.846914214	B	0.14655586	5.78	<.0001
VESSEL	AAAA	-0.963397410	B	0.14022569	-6.87	<.0001
VESSEL	BBBB	-0.788511572	B	0.13023576	-6.05	<.0001
VESSEL	CCCC	-0.648378871	B	0.12771170	-5.08	<.0001
VESSEL	DDDD	-0.475513121	B	0.14186561	-3.35	0.0008
VESSEL	EEEE	-0.512821117	B	0.12617875	-4.06	<.0001
VESSEL	FFFF	-0.436574775	B	0.12584589	-3.47	0.0005
VESSEL	GGGG	-0.345127035	B	0.12554611	-2.75	0.0060
VESSEL	HHHH	-0.293444903	B	0.12602014	-2.33	0.0200
VESSEL	IIII	-0.186969465	B	0.12593899	-1.48	0.1378
VESSEL	JJJJ	-0.110044464	B	0.13075396	-0.84	0.4001
VESSEL	KKKK	0.038500362	B	0.12717397	0.30	0.7621
VESSEL	LLLL	0.067467667	B	0.12409012	0.54	0.5867
VESSEL	MMMM	0.116912114	B	0.12701060	0.92	0.3574
VESSEL	OWWP	-0.037632259	B	0.13416489	-0.28	0.7791
VESSEL	OZHJ	0.416115631	B	0.15254014	2.73	0.0064
VESSEL	OZMA	0.000000000	B	.	.	.
YEAR*AREA	87 21	0.695198952	B	0.08614684	8.07	<.0001
YEAR*AREA	88 21	0.514593544	B	0.08118735	6.34	<.0001
YEAR*AREA	89 21	0.102791003	B	0.07981296	1.29	0.1979
YEAR*AREA	90 21	0.094676883	B	0.07980852	1.19	0.2357
YEAR*AREA	91 21	-0.119609640	B	0.07869952	-1.52	0.1287
YEAR*AREA	92 21	-0.353264124	B	0.08214235	-4.30	<.0001
YEAR*AREA	94 21	0.321905584	B	0.10322102	3.12	0.0018
YEAR*AREA	94 22	0.920760587	B	0.09085733	10.13	<.0001
YEAR*AREA	95 21	0.138595996	B	0.09389262	1.48	0.1401
YEAR*AREA	95 22	0.894844383	B	0.09792927	9.14	<.0001
YEAR*AREA	96 21	0.004321064	B	0.12910192	0.03	0.9733
YEAR*AREA	96 22	1.117247474	B	0.09198072	12.15	<.0001
YEAR*AREA	97 21	0.393627255	B	0.14400151	2.73	0.0063
YEAR*AREA	97 22	1.122631955	B	0.09384100	11.96	<.0001
YEAR*AREA	98 21	0.701307858	B	0.12968917	5.41	<.0001
YEAR*AREA	98 22	1.259188453	B	0.10524093	11.96	<.0001
YEAR*AREA	99 21	0.386664243	B	0.16313076	2.37	0.0179
YEAR*AREA	99 22	1.759275753	B	0.12411150	14.17	<.0001
YEAR*AREA	100 21	0.590429926	B	0.17369088	3.40	0.0007
YEAR*AREA	100 22	1.595979317	B	0.11145647	14.32	<.0001
YEAR*AREA	101 21	0.337598617	B	0.32173070	1.05	0.2942
YEAR*AREA	101 22	1.345866944	B	0.10689045	12.59	<.0001
YEAR*AREA	102 21	0.454778829	B	0.25939366	1.75	0.0797
YEAR*AREA	102 22	1.611955515	B	0.11823572	13.63	<.0001
YEAR*AREA	103 21	0.733397624	B	0.19474627	3.77	0.0002
YEAR*AREA	103 22	1.524652656	B	0.11899969	12.81	<.0001
YEAR*AREA	104 21	0.712699158	B	0.13588251	5.24	<.0001
YEAR*AREA	104 22	1.238827572	B	0.17470721	7.09	<.0001
YEAR*AREA	111 21	-0.535808124	B	0.08650242	-6.19	<.0001
YEAR*AREA	111 22	0.000000000	B	.	.	.
MONTH	1	0.308973875	B	0.03456478	8.94	<.0001
MONTH	3	0.129735487	B	0.03749303	3.46	0.0006
MONTH	5	0.071843184	B	0.05639342	1.27	0.2028
MONTH	6	-0.236693478	B	0.03772637	-6.27	<.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.
STUDENT
6
4
2
0
-2
-4
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ESTIMATE

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	Levels	Values
YEAR	18	1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
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 Read 910

Dependent Variable: LNCPUE
Weight: EFFORT EFFORT

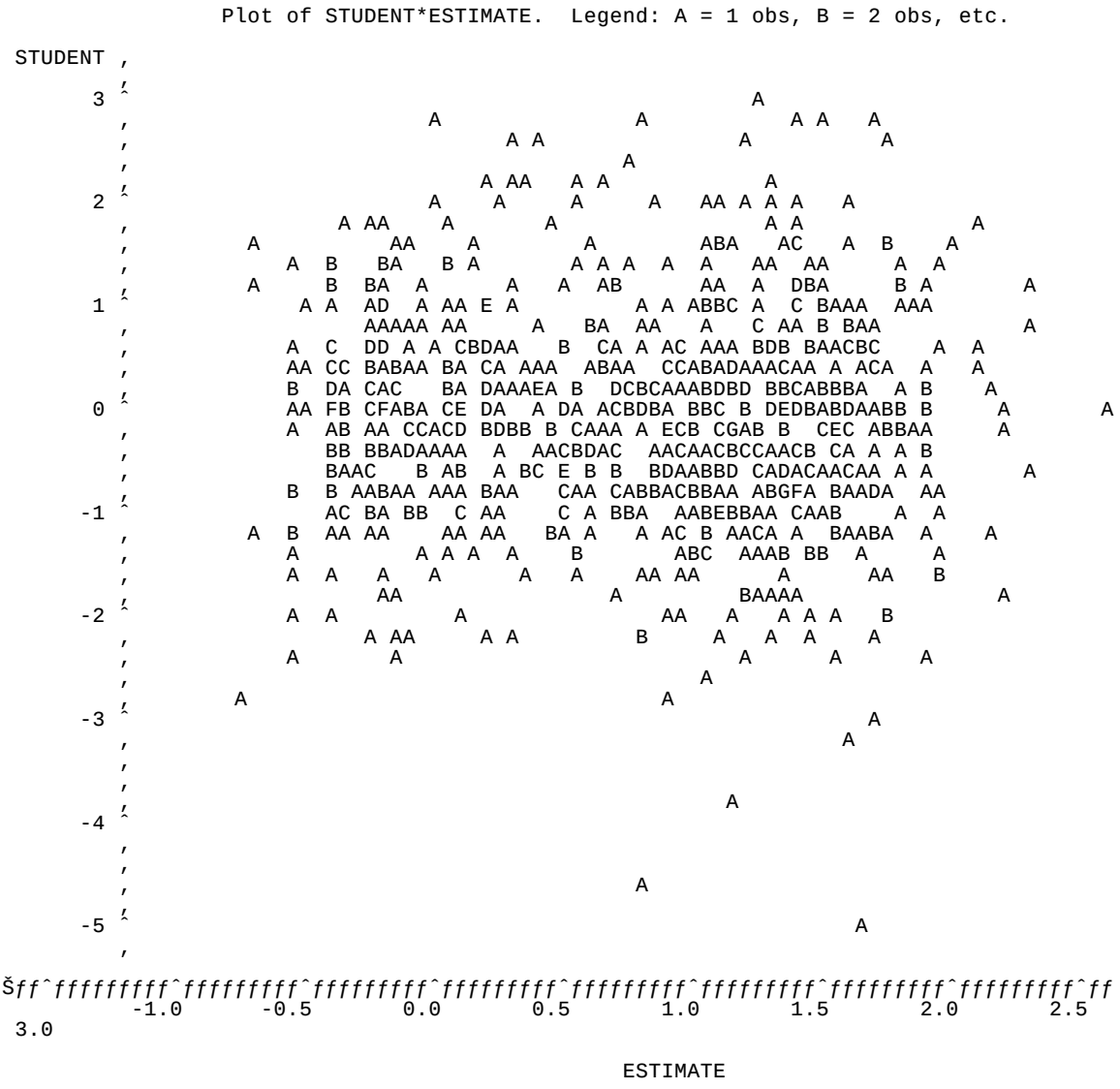
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	2995554.360	80960.929	118.17	<.0001
Error	872	597445.440	685.144		
Corrected Total	909	3592999.799			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.833720	3787.569	26.17525	0.691083

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MONTH	8	2433383.219	304172.902	443.95	<.0001
SHIP	11	272951.077	24813.734	36.22	<.0001
YEAR	17	284245.123	16720.301	24.40	<.0001
T	1	4974.942	4974.942	7.26	0.0072

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	8	428834.3972	53604.2997	78.24	<.0001
SHIP	11	241964.7471	21996.7952	32.11	<.0001
YEAR	17	288060.1909	16944.7171	24.73	<.0001
T	1	4974.9417	4974.9417	7.26	0.0072

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		1.628009360	B	0.15000685	10.85	<.0001
MONTH	1	-0.452730479	B	0.30464802	-1.49	0.1376
MONTH	3	0.776919663	B	0.12157283	6.39	<.0001
MONTH	4	0.844404804	B	0.12230425	6.90	<.0001
MONTH	5	0.433683833	B	0.12200589	3.55	0.0004
MONTH	6	-0.094159670	B	0.12844372	-0.73	0.4637
MONTH	9	-0.589615339	B	0.12507973	-4.71	<.0001
MONTH	10	-0.752121039	B	0.12837413	-5.86	<.0001
MONTH	11	-0.924529437	B	0.14511704	-6.37	<.0001
MONTH	12	0.000000000	B	.	.	.
SHIP	1046	0.123061875	B	0.58028164	0.21	0.8321
SHIP	1753	0.212280402	B	0.27381977	0.78	0.4384
SHIP	2061	0.062829850	B	0.10023020	0.63	0.5309
SHIP	2204	-1.280507340	B	0.25139498	-5.09	<.0001
SHIP	3100	-0.954875009	B	0.11634801	-8.21	<.0001
SHIP	3200	-0.734959535	B	0.08486361	-8.66	<.0001
SHIP	3300	-0.587541212	B	0.07389082	-7.95	<.0001
SHIP	3400	-0.432857375	B	0.07355338	-5.88	<.0001
SHIP	3500	-0.305978320	B	0.07482829	-4.09	<.0001
SHIP	3600	-0.184154866	B	0.08098417	-2.27	0.0232
SHIP	3700	-0.098452820	B	0.07557636	-1.30	0.1930
SHIP	3800	0.000000000	B	.	.	.
YEAR	1988	-0.425987366	B	0.04328770	-9.84	<.0001
YEAR	1989	-0.607766057	B	0.04927438	-12.33	<.0001
YEAR	1990	-0.614893423	B	0.08087310	-7.60	<.0001
YEAR	1991	-0.188591681	B	0.08814046	-2.14	0.0327
YEAR	1992	-0.533031942	B	0.07834486	-6.80	<.0001
YEAR	1993	-0.676810106	B	0.07470726	-9.06	<.0001
YEAR	1994	-0.107357275	B	0.08146169	-1.32	0.1879
YEAR	1995	-0.278818509	B	0.10157257	-2.75	0.0062
YEAR	1996	-0.511508273	B	0.10931772	-4.68	<.0001
YEAR	1997	-0.477126143	B	0.08119766	-5.88	<.0001
YEAR	1998	-0.715642410	B	0.08104026	-8.83	<.0001
YEAR	1999	-0.768840636	B	0.09661222	-7.96	<.0001
YEAR	2000	-0.542339949	B	0.15797200	-3.43	0.0006
YEAR	2001	-1.191000547	B	0.38768071	-3.07	0.0022
YEAR	2002	0.170424761	B	0.09061432	1.88	0.0603
YEAR	2003	-0.354812390	B	0.09930596	-3.57	0.0004
YEAR	2004	-0.191948315	B	0.11602400	-1.65	0.0984
YEAR	19870	0.000000000	B	.	.	.
T	1	-0.184542709	B	0.06848473	-2.69	0.0072
T	2	0.000000000	B	.	.	.


Plot of STUDENT*ESTIMATE. Legend: A = 1 obs, B = 2 obs, etc.
STUDENT
3
2
1
0
-1
-2
-3
-4
-5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
ESTIMATE