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Data for the assessment of the shrimp (*Pandalus borealis*) stock in Denmark Strait/off East Greenland, 2002

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 800m. 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 10 000 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 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 (Figure 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 1970's initiated by Icelandic trawlers. It soon became a multinational fishery with annual catches increasing rapidly to more than 10000 tons during the following 10-year period. Since then catches have fluctuated between 7500-11500 tons (Figure 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. However, in 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell (Figure 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 in both EEZ's are large factory trawlers in the range of 1000-3000 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

Rawdata

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. 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 positions of individual the 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 multiplicative model was represented in logarithmic form:

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

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.1.3, (www.mrc-bsu.cam.ac.uk/bugs; Gilks *et al*. 1994; Spiegelhalter *et al*. 2000). The individual CPUE series for the p^{th} fleet, m_{pi}, was assumed to reflect an overall biomass series, Y_i, and a constant fleet coefficient, v_p, so that:

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

The error, e_{pi}, were considered to be distributed with mean zero and variance s_{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, s_{pi}^2 was calculated by:

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

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
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.

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 (Figure 1A). In 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell (Figure 1B). The fishery of Greenlandic, Faroese and Danish trawlers was generally distributed in accordance with this "new" fishing pattern in 2001 and 2002 (Figure 1C).

Catch

As the fishery developed, catches increased rapidly to more than 12000 tons in 1987-88, but declined thereafter to about 7500 tons in 1992-93. Following the area expansion of the fishery south of 65°N catches increased again reaching 11500 tons in 1997 (Figure 2A, Table 1and 2). In recent years annual catches have been between 9-11000 tons and is for the current year projected to be close to 11 000 tons (projected from November) 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 12000 to about 2000 tons in 2001 (Figure 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 2002 are projected to be around 3400 tons.

Catches in the southern area increased from 1500 tons in 1993 - the first year of fishery in this area - to about 7500 tons in 1997 (Figure 2A). They then decreased somewhat to about 5-6000 tons in 1998-2000. In 2001 catches reached 9300 tons and are expected to be around 7500 tons in 2002.

Fishing effort

The high increase in catches during the first ten-year period was driven by increased fishing effort (Figure 2B, Table 2). Between 1981 and 1989, total effort increased from about 20 000 hr's to a peak of more than 100000 hr's and then declined again to about 23500 hr's in 2000. For 2001 fishing effort increased again to 35000 hr's but will most likely decrease again slightly in 2002 (Figure 2B). Approximately 42% of the effort in 2002 will be spent in the northern areas.

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. This level of 10000 hr's is expected to be maintained for 2002 (Figure 2B).

In the southern area, effort increased from about 10000 hours in 1993 to 21000 hours in 1997. In 1999 the amount of effort spent reached a low of 7500 hr's from where it increased again to 27000 hr's. For 2002 effort in the southern areas is projected to decrease to around 10000 hr's (Figure 2B, Table 2).

Catch rate

Catch rates (total area) decreased from 243 kg/hr to 100 kg/hr in the period 1980-1989, but has shown an increasing trend since then reaching about 400 kg/hr in 2000 (Figure 2C, Table 2). In 2001 catch rates were down at 316 kg/hr but the preliminary data for 2002 indicate that CPUE's for the current year are back up again at 400 kg/hr.

In the southern areas CPUE increased from 164 kg/hr in 1993 to over 700 kg per hour in 1999. During the following two years the mean CPUE obtained in this area was halved reaching 340 kg/hr in 2001. An improvement is however indicated for 2002 as CPUE are estimated to 484 kg/hr.

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 170-210 kg/hr except for an extreme of 123 kg/hr in 1996. An increase is registered for 2002 giving 323 kg/hr.

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 70% and 83%, respectively. The model-diagnostical outputs (residual plots, Cook's D influence statistics, test of normality etc., 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 (Figure 3A) declined from 1987 to 1993, increased again from 1993-1994 and then remained relatively stable until the late 1990's after which a slightly increasing trend might be inferred.

The CPUE index series of the southern area (Figure 3B), starting in 1993, have increased until 1999 and decreased thereafter.

The combined index for the total area (Figure 3C) indicates 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 1990's. Since then stock biomass is indicated to have been maintained around this level.

The addition of new data for 2001 and 2002, and a re-evaluation and correction of the existing logbook data have caused minor changes in the CPUE index series as compared to the corresponding series resulting from last years analyses (Hvingel, 2001). The means of the annual values resulting from the GLM-runs did not change much, but for the Greenlandic EEZ they were estimated with larger variance. This meant that the relative weighting of the series from the Greenlandic and Icelandic EEZ's was changed in favour of the series from the Icelandic EEZ when executing the process for constructing the combined indices "north" and "overall".

The change to be noted for the overall index is slightly more positive estimates of the 1999 to 2001 values as compared to the previous years. For the northern series the peak of 1998 has disappeared. The changes to the index series for the southern area were marginal. In spite of these changes the general perception of stock development as inferred form the catch rate index series has not changed.

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 index of harvest rate for the total area (Figure 4C) showed a decreasing trend since 1993. However, the development since the introduction of the southern areas in the fishery may be interpreted as showing two levels of fishing mortality – one covering the years 1994 to 97 and a second approximately 35% lower level during 1998-2001. The projected value of year 2002 indicates a further decrease of about 27% as compared to the four previous years and is the lowest of the time series. The separate indices for the northern and southern areas are shown in Figure 4A+B. As mentioned in the previous section the development in the fishing mortality indices might be to optimistic. Furthermore, the index of 2002 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). 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).

For 2002 no samples were available from neither the northern nor the southern areas. However, reports from some Greenlandic skippers say that catches are considered "good quality". The available length frequency distributions (Figure 5B) indicate a demographic healthy stock composition with a wide distribution of the sizes normally present in this fishery.

More detailed interpretations of the samples with respect to age composition etc. should be done with caution, as bias is likely due to incomplete coverage over time and areas.

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 1990's 50-70 % 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 (Figure 1B,C). Year 2001, however, was a special year with exceptionally low effort spent in the northern areas in favour of the southern areas.

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 CPUE's obtained in the southern areas whereas the CPUE in the northern areas showed much less variation during in the same period (Figure 2C).

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

The CPUE based biomass index (Figure 3C) indicates that a rebuilding phase taking place since the early 1990's has ended with full recovery to the stock size of the mid 1980's. Stock biomass seems to have been stable during the recent four years.

Indices of harvest rate have shown a decreasing trend since 1993 reaching the lowest level of the time series in 2002 (Figure 4C).

References

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Table 1. Nominal catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland 1978 to November 2002.

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[1,2]
North of 65°N																									
Denmark	-	-	702	581	740	204	443	353	500	555	444	366	390	358	160	111	199	242	21	68	317	630	364	57	259
Faroe Islands	-	-	4233	713	737	443	668	674	727	595	679	595	843	1007	1092	554	368	745	800	509	1002	689	759	170	327
France	-	-	50	353	414	291	500	642	780	1030	494	381	51	118	-	-	-	-	-	-	-	-	-	-	-
Greenland	-	-	200	1004	1115	1467	2250	2596	5781	6627	7456	5976	6210	4205	2012	1425	1056	1913	289	84	510	488	91	516	155
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	1141
Norway	-	800	2461	2016	1896	1727	2128	2051	2026	2041	2052	2098	2500	2504	2500	1473	1736	1923	1241	639	1286	1416	2190	1026	266
Total	363	1285	8405	4792	4902	4175	6731	8110	10964	12178	12556	10742	10275	8657	7514	6116	4873	5974	2917	4156	4536	3992	3536	1779	2149
South of 65°N																									
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	488	585	938	1328	1027	870	1508	1965	1264
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	225	776	236	323	526	109	360	270	1908	558
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	918	2870	2135	4257	3767	3120	3945	4155	3927	2062
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	341	805	576	1278	1812	529	300	125	1474	944
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1532	4939	3532	6796	7433	4785	5475	6058	9274	4827
Total area																									
Denmark	-	-	702	581	740	204	443	353	500	555	444	366	390	358	160	159	687	827	959	1396	1344	1500	1872	2022	1523
Faroe Islands	-	-	4233	713	737	443	668	674	727	595	679	595	843	1007	1092	779	1144	981	1123	1035	1111	1049	1029	2078	885
France	-	-	50	353	414	291	500	642	780	1030	494	381	51	118	-	-	-	-	-	-	-	-	-	-	-
Greenland	-	-	200	1004	1115	1467	2250	2596	5781	6627	7456	5976	6210	4205	2012	2343	3926	4048	4546	3851	3630	4433	4246	4443	2217
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	1141
Norway	-	800	2461	2016	1896	1727	2128	2051	2026	2041	2052	2098	2500	2504	2500	1814	2541	2499	2519	2451	1815	1716	2315	2500	1210
Total	363	1285	8405	4792	4902	4175	6731	8110	10964	12178	12556	10742	10275	8657	7514	7648	9812	9506	9713	11589	9321	9467	9594	11053	6976
Total all area	363	1285	8405	4792	4902	4175	6731	8110	10964	12178	12556	10742	10275	8657	7514	7648	9812	9506	9713	11589	9321	9467	9594	11053	6976
Advised TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	10000[3]	10000[3]	10000[3]	8000	5000	5000	5000	5000	5000	5000	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

[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	8405	34591	243				8405	34591	243
1981	4792	19588	245				4792	19588	245
1982	4902	23081	212				4902	23081	212
1983	4175	23668	176				4175	23668	176
1984	6731	31975	211				6731	31975	211
1985	8110	51738	157				8110	51738	157
1986	10964	56808	193				10964	56808	193
1987	12178	73255	166				12178	73255	166
1988	12556	99662	126				12556	99662	126
1989	10742	107852	100				10742	107852	100
1990	10275	72770	141				10275	72770	141
1991	8657	78349	110				8657	78349	110
1992	7514	67086	112				7514	67086	112
1993	6116	51092	120	1532	9335	164	7648	60020	127
1994	4873	24948	195	4939	16361	302	9812	39708	247
1995	5974	33743	177	3532	11328	312	9506	43541	218
1996	2917	23669	123	6796	21097	322	9713	40757	238
1997	4156	19966	208	7433	18994	391	11589	38876	298
1998	4536	21872	207	4785	10560	453	9321	30673	304
1999	3992	22653	176	5475	7679	713	9467	27212	348
2000	3536	19588	181	6058	10758	563	9594	23530	408
2001	1779	10349	172	9274	27043	343	11053	35029	316
2002*	2149	6645	323	4827	9975	484	6976	17403	401

*until Nov.

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 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	0.90	0.11	1.14	0.14					0.98	0.16	1.05	0.17
1989	0.62	0.07	1.41	0.17					0.68	0.11	1.30	0.21
1990	0.62	0.08	1.35	0.16					0.68	0.11	1.24	0.21
1991	0.55	0.07	1.29	0.15					0.61	0.10	1.16	0.19
1992	0.44	0.05	1.41	0.17					0.49	0.08	1.26	0.20
1993	0.37	0.05	1.34	0.16	1.00	-	1.00	-	0.39	0.06	1.60	0.26
1994	0.83	0.11	0.48	0.06	2.55	0.24	1.27	0.12	0.83	0.14	0.97	0.16
1995	0.68	0.09	0.72	0.09	2.50	0.26	0.92	0.09	0.74	0.12	1.05	0.18
1996	0.60	0.09	0.40	0.06	3.15	0.31	1.41	0.13	0.82	0.14	0.97	0.16
1997	0.76	0.12	0.45	0.07	3.11	0.31	1.56	0.15	0.86	0.14	1.11	0.18
1998	0.85	0.12	0.44	0.06	3.55	0.40	0.88	0.09	0.94	0.15	0.82	0.13
1999	0.67	0.11	0.49	0.08	5.93	0.79	0.60	0.08	1.14	0.20	0.68	0.12
2000	0.94	0.18	0.31	0.06	4.97	0.59	0.80	0.09	1.29	0.23	0.61	0.11
2001	0.82	0.29	0.18	0.06	3.85	0.44	1.57	0.17	1.10	0.20	0.83	0.15
2002	1.17	0.23	0.15	0.03	3.45	0.51	0.91	0.13	1.08	0.18	0.53	0.09

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

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

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

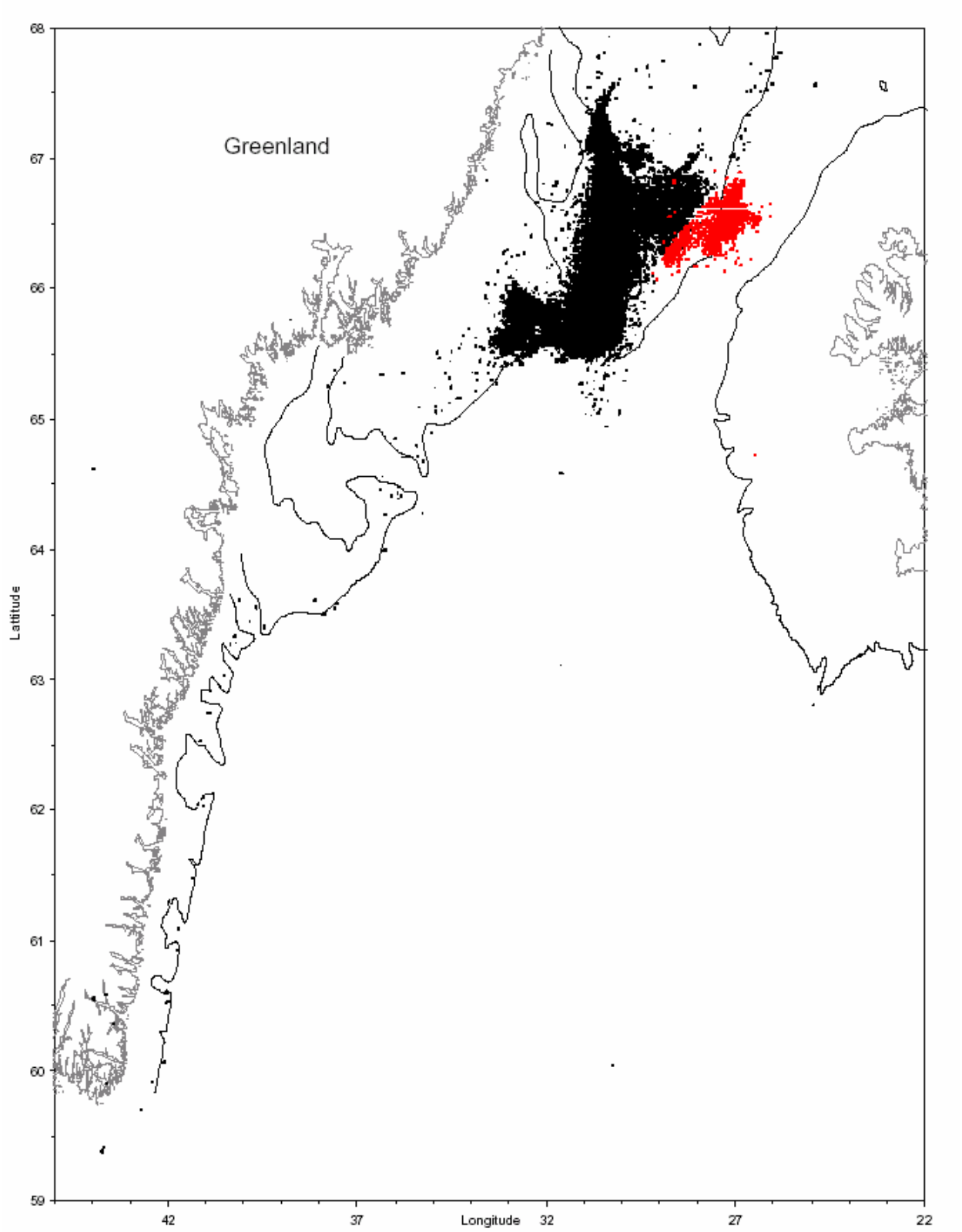


Figure 1A. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 1987-1992 (black dots) and Icelandic trawlers 1990-1992 (red dots). 400 meters depth curve are shown as a solid line.

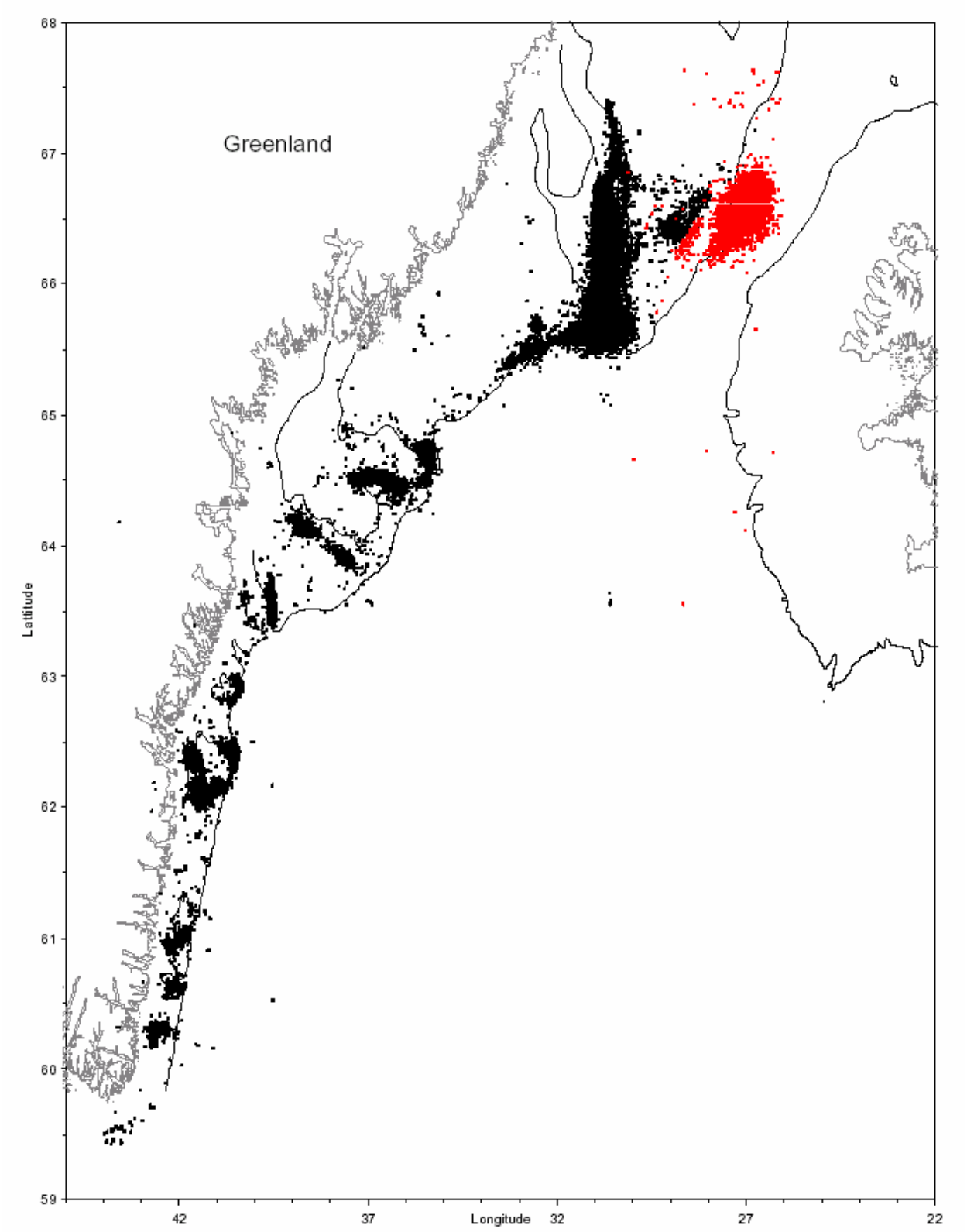


Figure 1B. Distribution of hauls in the shrimp fis hery in Denmark Strait/off East Greenland 1993-2000 by Greenlandic, Faeroese and Danish trawlers (black dots) and Icelandic trawlers (red dots). 400 meters depth curve are shown as a solid line.

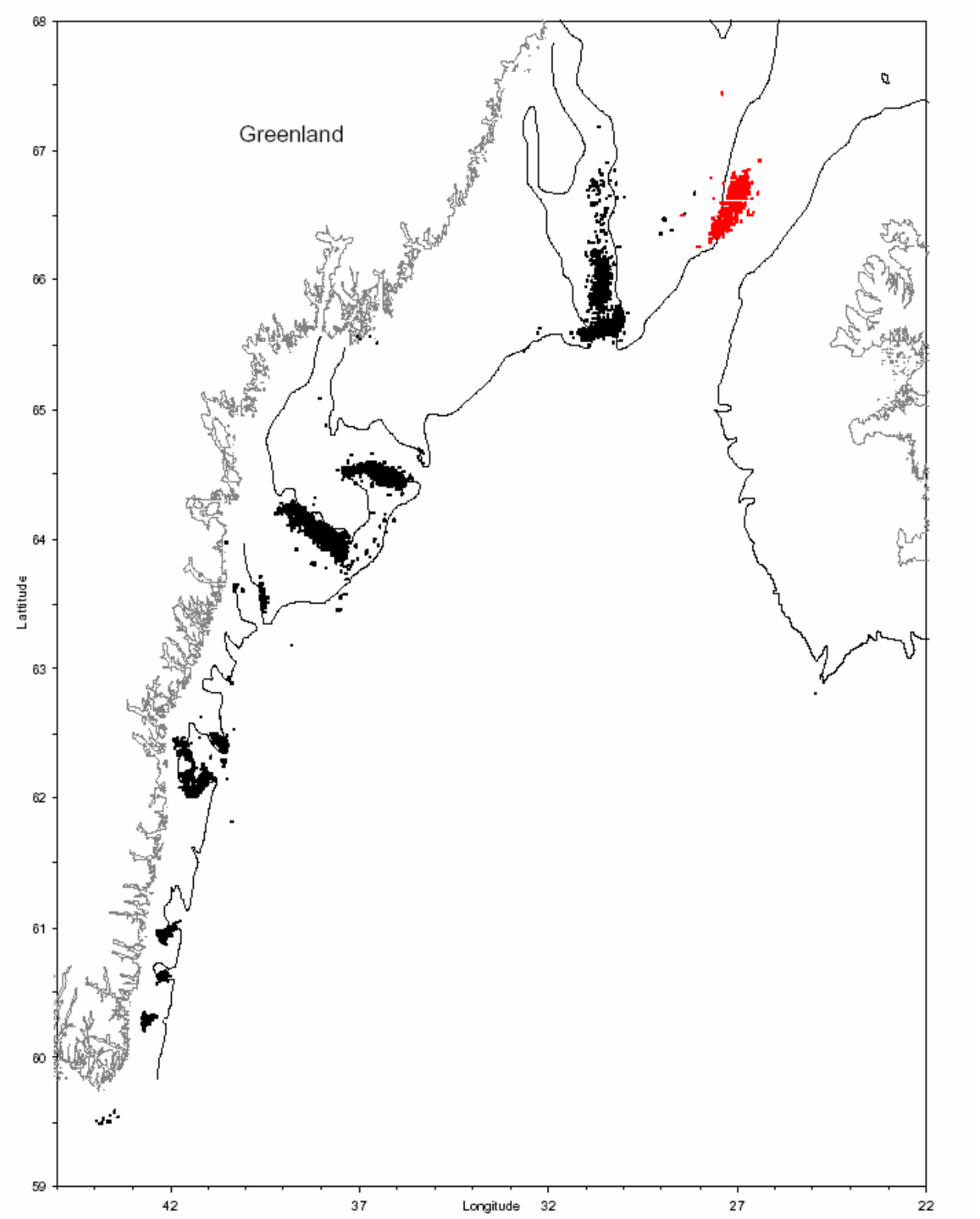


Figure 1C. Distribution of hauls in the shrimp fishery in Denmark Strait/off East Greenland 2001-September 2002 by Greenlandic, Faeroese and Danish trawlers (black dots) and Icelandic trawlers (red dots). 400 meters depth curve are shown as a solid line.

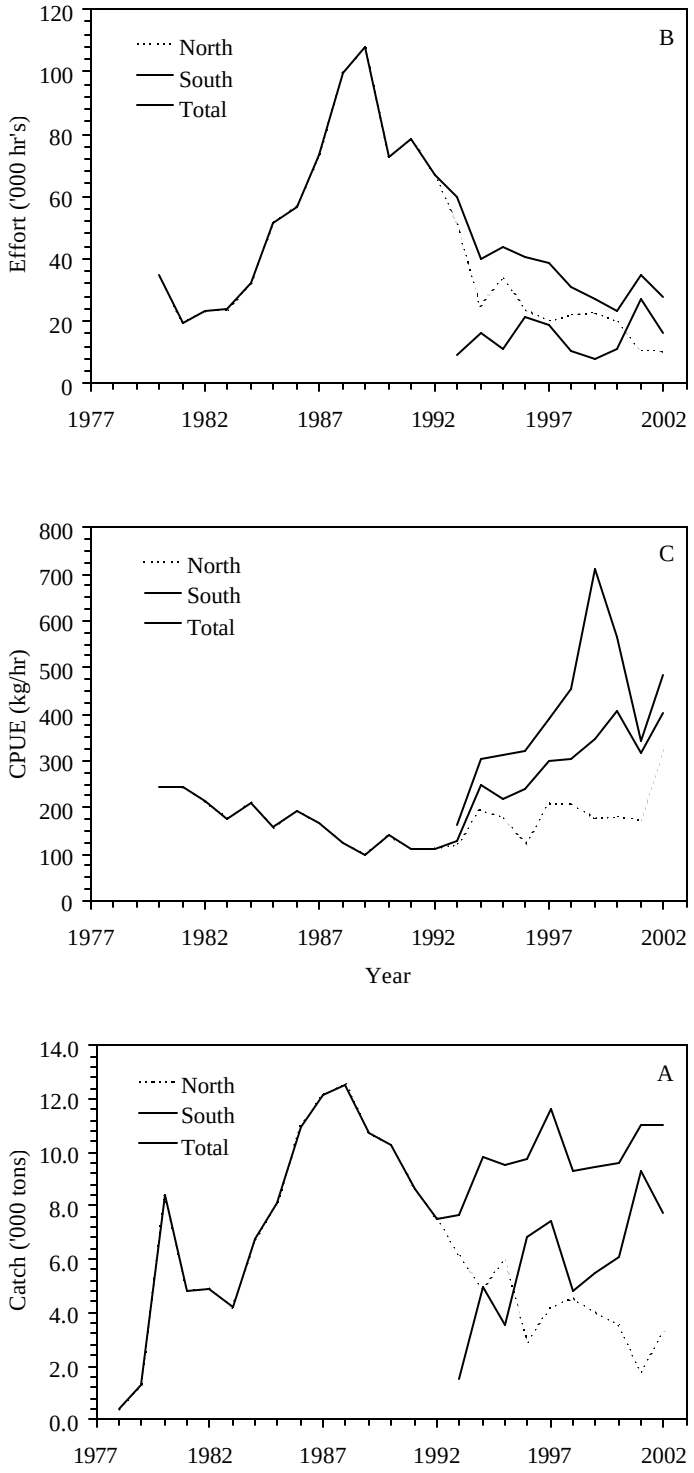


Figure 2. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall. Data for 2002 are projected from September to the end of the year.

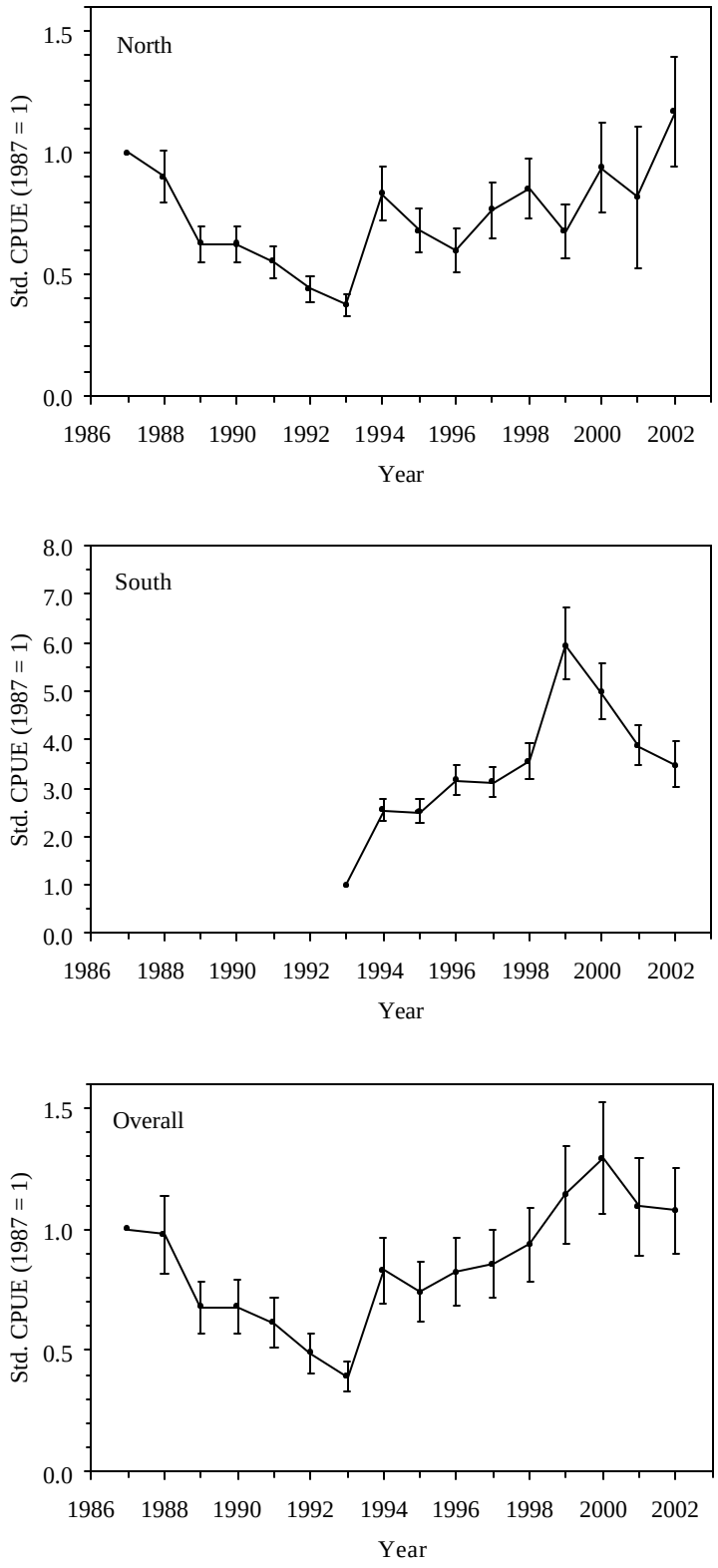


Figure 3. Standardised Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until September 2002.

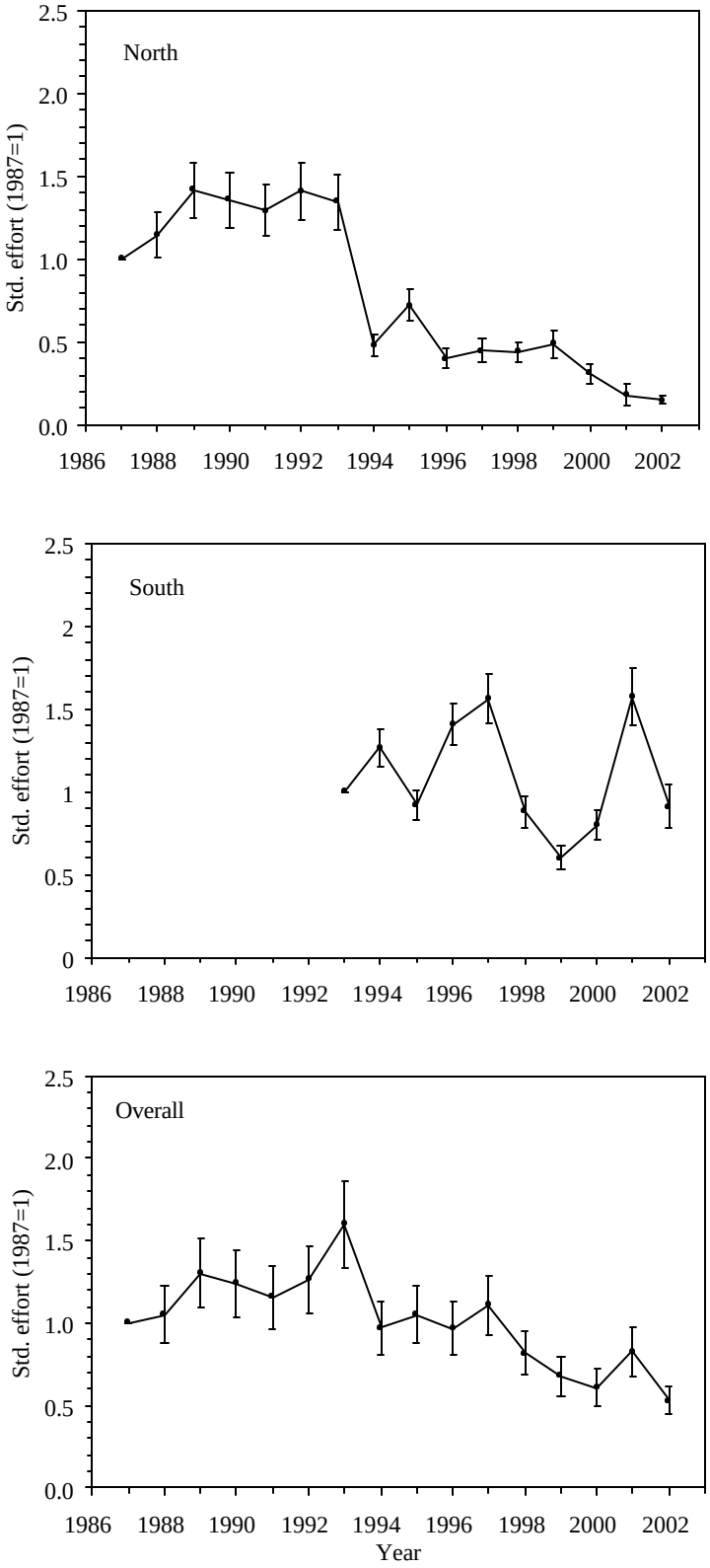


Figure 4. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until September 2002.

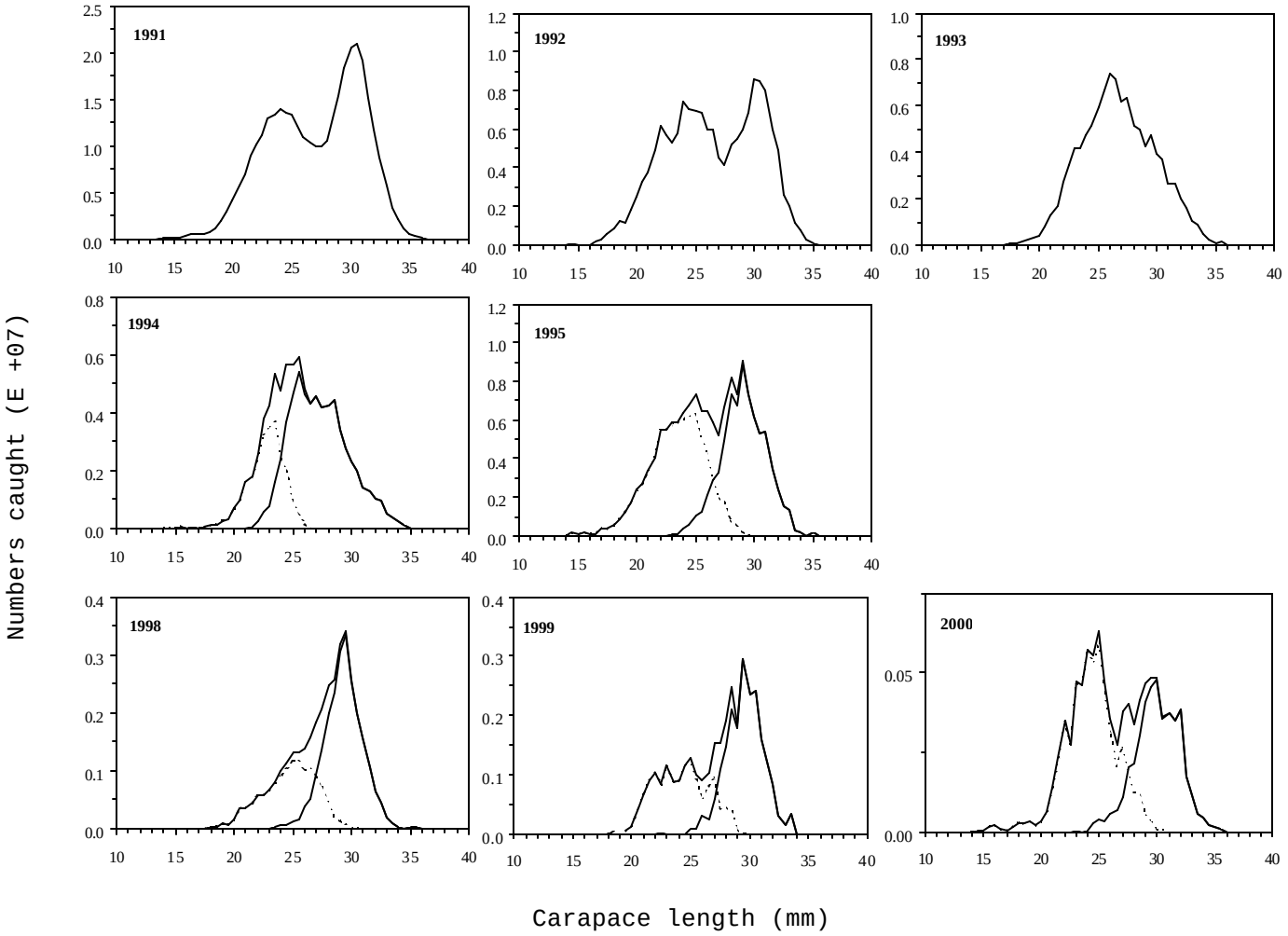


Figure 5A. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland north of 65°N, 1991 - 2000 (no data available for 1996-1997 and 2001-2001). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.

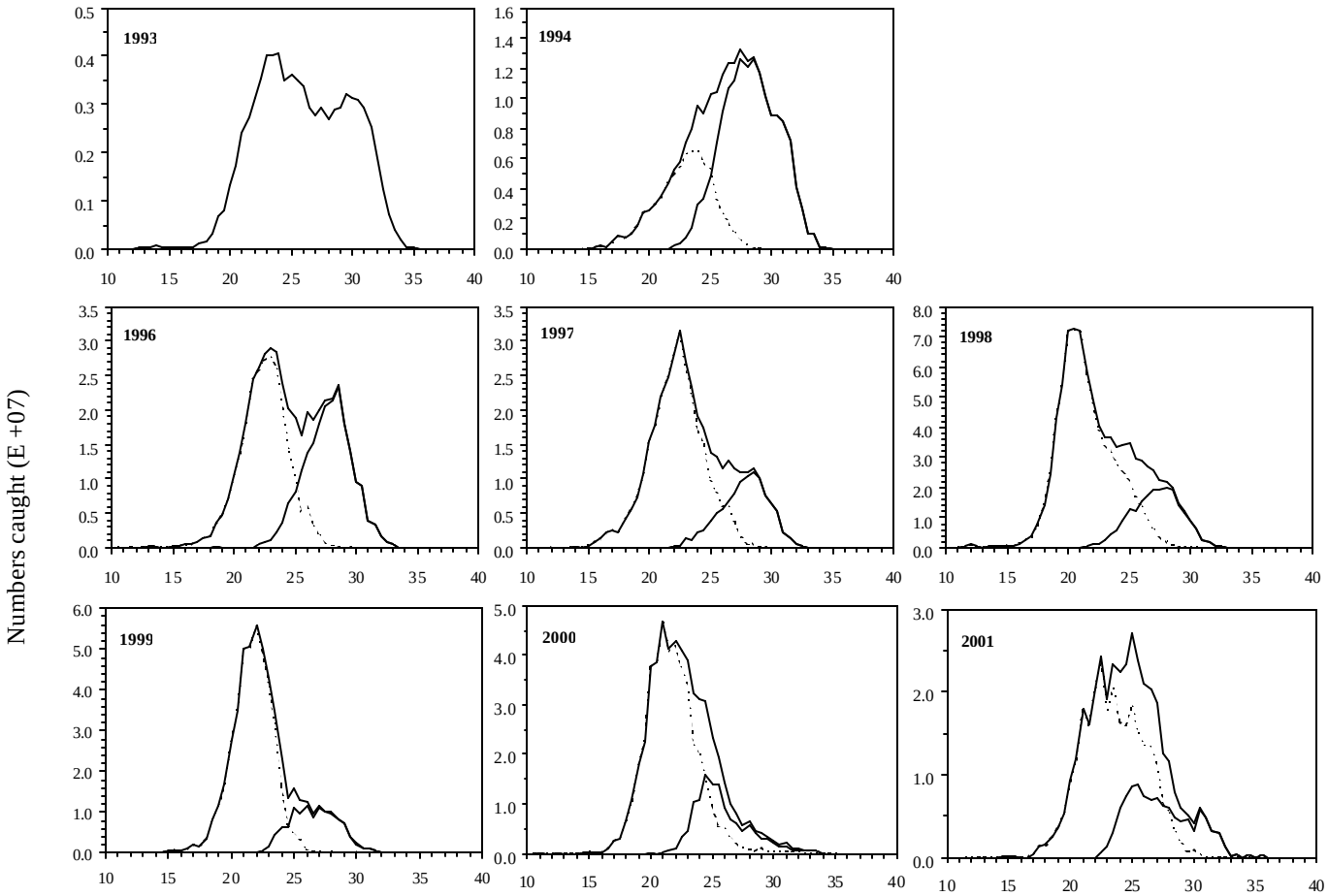


Figure 5B. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland south of 65°N, 1993-2001 (no data available for 1995 and 2002). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.

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

Class	Levels	Values
VESSEL	16	AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH IIII JJJJ KKKK LLLL MMMM OWWP OZHJ OZMA
YEAR	16	87 88 89 90 91 92 94 95 96 97 98 99 100 101 102 111 (111=93)
MONTH	5	1 3 5 6 12
AREA	2	21 22 (21=North, 22=South)

Number of observations 1749

Dependent Variable: LNCPUE
Weight: HAULS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	41558.43587	944.50991	89.92	<.0001
Error	1704	17898.63282	10.50389		
Corrected Total	1748	59457.06869			

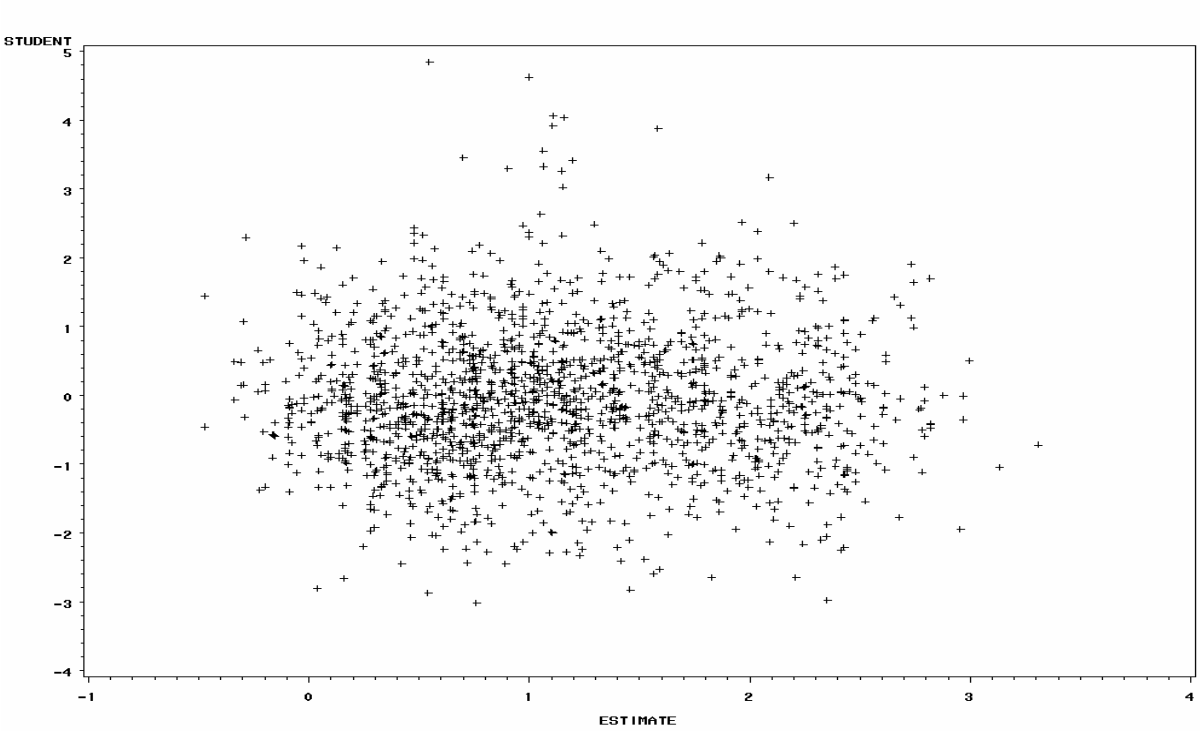
R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.698965	323.4589	3.240971	1.001973

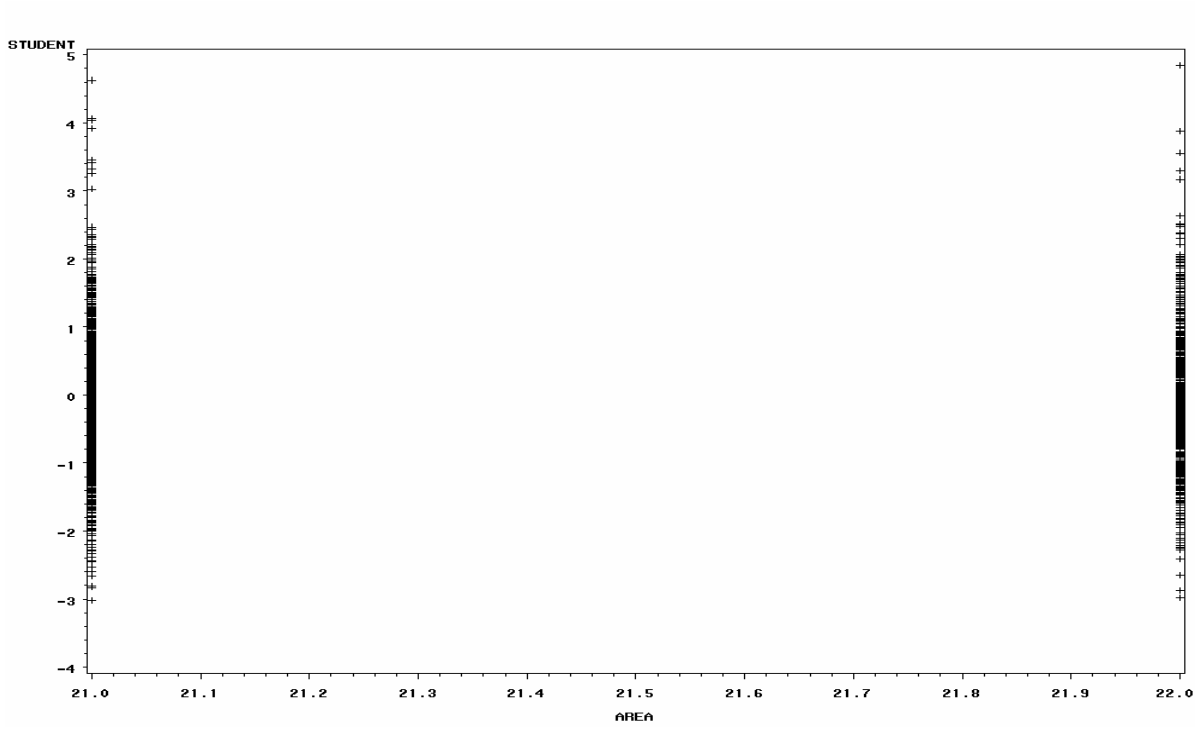
Source	DF	Type I SS	Mean Square	F Value	Pr > F
VESSEL	15	19162.64754	1277.50984	121.62	<.0001
YEAR*AREA	25	18858.87825	754.35513	71.82	<.0001
MONTH	4	3536.91008	884.22752	84.18	<.0001
AREA	0	0.00000	.	.	.

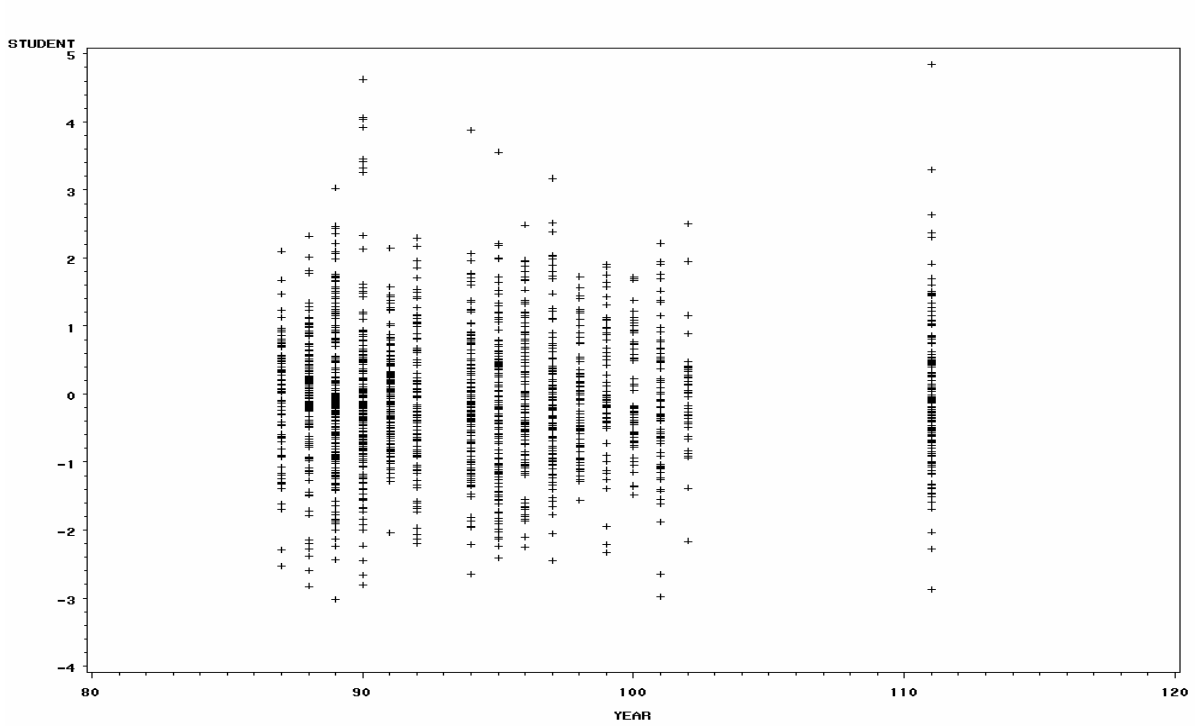
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VESSEL	15	7359.75235	490.65016	46.71	<.0001
YEAR*AREA	24	10810.12350	450.42181	42.88	<.0001
MONTH	4	3536.91008	884.22752	84.18	<.0001
AREA	1	4637.03602	4637.03602	441.46	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		0.874496805	B	0.16799388	5.21	<.0001
VESSEL	AAAA	-0.955857173	B	0.15965725	-5.99	<.0001
VESSEL	BBBB	-0.821754009	B	0.15332246	-5.36	<.0001
VESSEL	CCCC	-0.689544956	B	0.15118221	-4.56	<.0001
VESSEL	DDDD	-0.507841484	B	0.16397590	-3.10	0.0020
VESSEL	EEEE	-0.561184819	B	0.15103785	-3.72	0.0002
VESSEL	FFFF	-0.474534598	B	0.14959274	-3.17	0.0015
VESSEL	GGGG	-0.379425635	B	0.14916089	-2.54	0.0111
VESSEL	HHHH	-0.329529160	B	0.14974829	-2.20	0.0279
VESSEL	IIII	-0.186491504	B	0.15024117	-1.24	0.2147
VESSEL	JJJJ	-0.148480652	B	0.15351148	-0.97	0.3336
VESSEL	KKKK	-0.013537874	B	0.15043956	-0.09	0.9283
VESSEL	LLLL	0.026325169	B	0.14788118	0.18	0.8587
VESSEL	MMMM	0.076893668	B	0.15077038	0.51	0.6101
VESSEL	OWWP	-0.079948445	B	0.15650004	-0.51	0.6095
VESSEL	OZHJ	0.340787939	B	0.17214904	1.98	0.0479
VESSEL	OZMA	0.000000000	B	.	.	.
YEAR*AREA	87 21	0.690388876	B	0.08646701	7.98	<.0001
YEAR*AREA	88 21	0.522074773	B	0.08137755	6.42	<.0001
YEAR*AREA	89 21	0.112143471	B	0.07994345	1.40	0.1609
YEAR*AREA	90 21	0.105475744	B	0.07999057	1.32	0.1875
YEAR*AREA	91 21	-0.106154079	B	0.07885092	-1.35	0.1784
YEAR*AREA	92 21	-0.345910768	B	0.08239471	-4.20	<.0001
YEAR*AREA	94 21	0.328414462	B	0.10353680	3.17	0.0015
YEAR*AREA	94 22	0.935035699	B	0.09116986	10.26	<.0001
YEAR*AREA	95 21	0.146877238	B	0.09419645	1.56	0.1191
YEAR*AREA	95 22	0.915417464	B	0.09829842	9.31	<.0001
YEAR*AREA	96 21	0.017584254	B	0.12952960	0.14	0.8920
YEAR*AREA	96 22	1.148682591	B	0.09235770	12.44	<.0001
YEAR*AREA	97 21	0.391989382	B	0.14414578	2.72	0.0066
YEAR*AREA	97 22	1.135273648	B	0.09430643	12.04	<.0001
YEAR*AREA	98 21	0.698731888	B	0.12994300	5.38	<.0001
YEAR*AREA	98 22	1.266761191	B	0.10583504	11.97	<.0001
YEAR*AREA	99 21	0.369890693	B	0.16321282	2.27	0.0236
YEAR*AREA	99 22	1.780214740	B	0.12476447	14.27	<.0001
YEAR*AREA	100 21	0.583747541	B	0.17445962	3.35	0.0008
YEAR*AREA	100 22	1.603182286	B	0.11285899	14.21	<.0001
YEAR*AREA	101 21	0.341284869	B	0.32267920	1.06	0.2904
YEAR*AREA	101 22	1.348812342	B	0.10787762	12.50	<.0001
YEAR*AREA	102 21	0.460265283	B	0.27429149	1.68	0.0935
YEAR*AREA	102 22	1.239539657	B	0.13851526	8.95	<.0001
YEAR*AREA	111 21	-0.530984449	B	0.08677793	-6.12	<.0001
YEAR*AREA	111 22	0.000000000	B	.	.	.
MONTH	1	0.313016514	B	0.03478930	9.00	<.0001
MONTH	3	0.138979689	B	0.03781070	3.68	0.0002
MONTH	5	0.098126277	B	0.05762663	1.70	0.0888
MONTH	6	-0.254377042	B	0.03821386	-6.66	<.0001

MONTH	12	0.000000000	B	.	.
AREA	21	0.000000000	B	.	.
AREA	22	0.000000000	B	.	.



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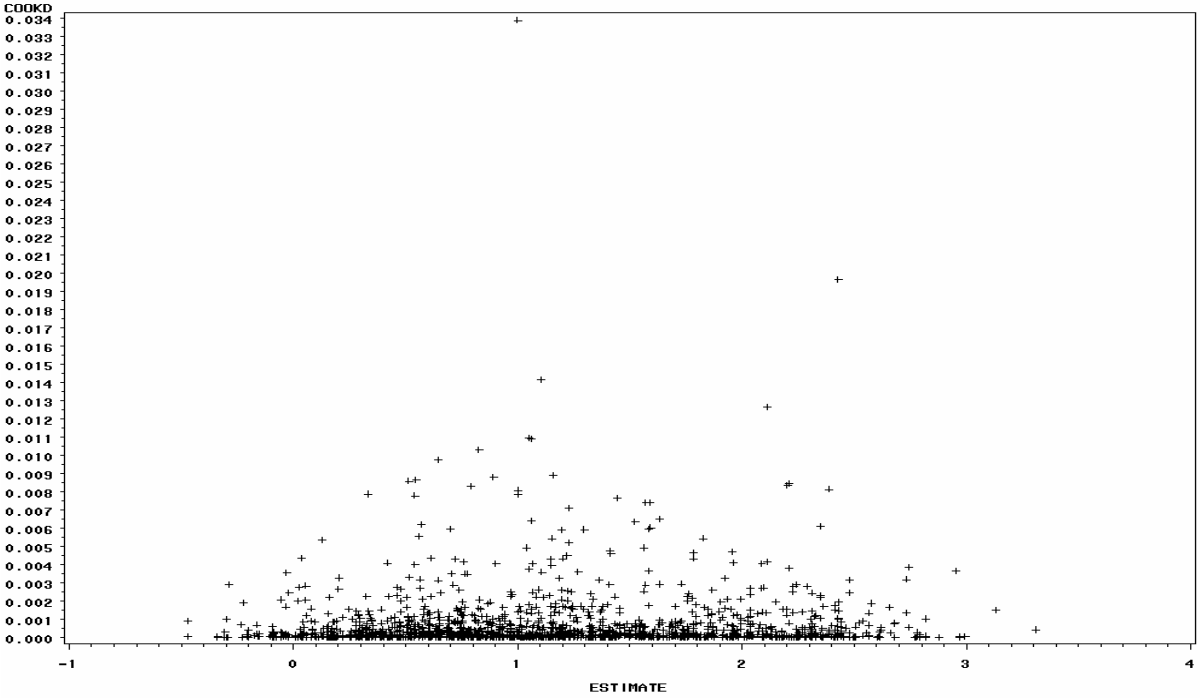
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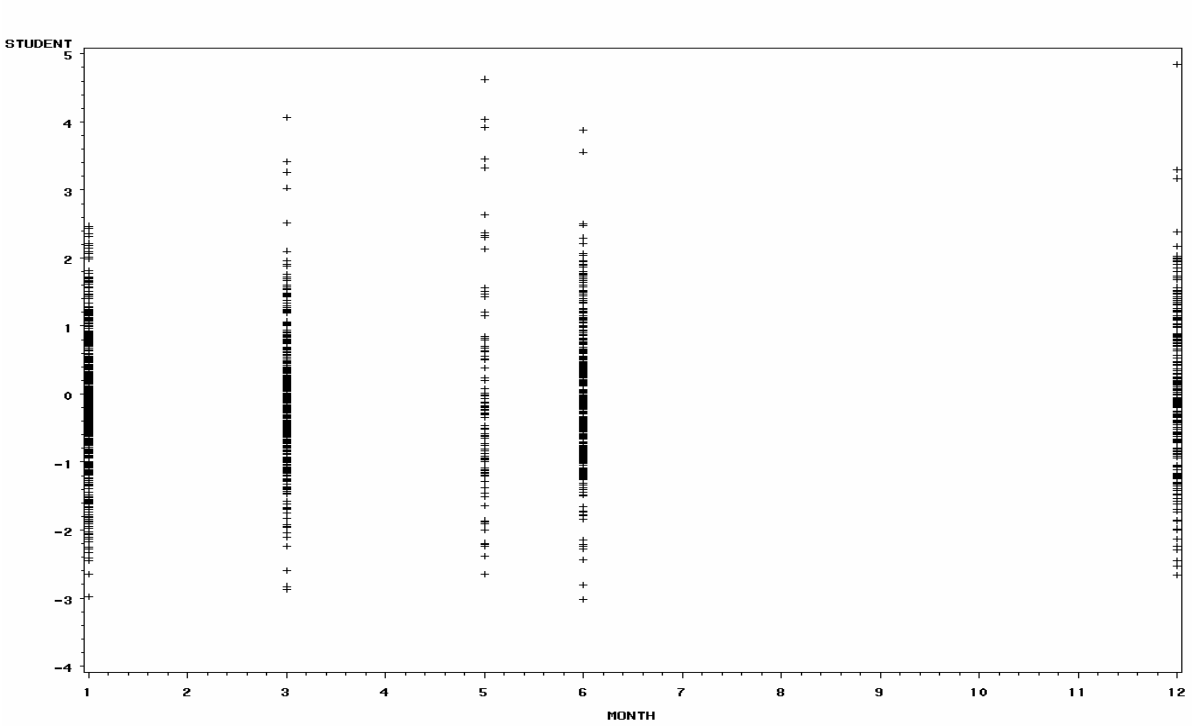
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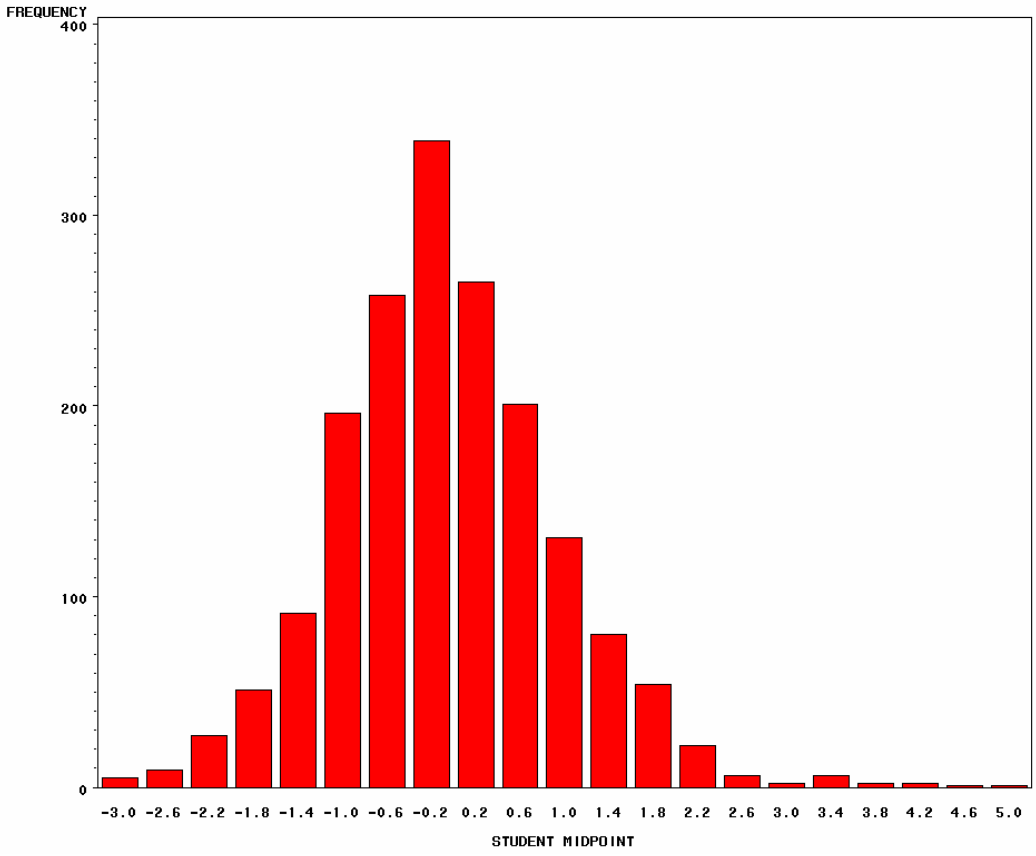
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STUDENT MIDPOINT

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	16	1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2010 (2010=1987)
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 885

Dependent Variable: LNCPUE
Weight: EFFORT EFFORT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	35	2873182.706	82090.934	121.06	<.0001
Error	849	575684.513	678.074		
Corrected Total	884	3448867.218			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.833080	3921.463	26.03985	0.664034

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MONTH	8	2329131.440	291141.430	429.37	<.0001
SHIP	11	265702.200	24154.745	35.62	<.0001
YEAR	15	273343.449	18222.897	26.87	<.0001
T	1	5005.618	5005.618	7.38	0.0067

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	8	424224.2381	53028.0298	78.20	<.0001
SHIP	11	239478.2000	21770.7455	32.11	<.0001
YEAR	15	276925.5040	18461.7003	27.23	<.0001
T	1	5005.6176	5005.6176	7.38	0.0067

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		1.632649939	B	0.14938791	10.93	<.0001
MONTH	1	-0.450951491	B	0.30310145	-1.49	0.1372
MONTH	3	0.780215873	B	0.12098402	6.45	<.0001
MONTH	4	0.854295124	B	0.12188266	7.01	<.0001
MONTH	5	0.430858081	B	0.12152969	3.55	0.0004
MONTH	6	-0.104291026	B	0.12836556	-0.81	0.4168
MONTH	9	-0.595694623	B	0.12465804	-4.78	<.0001
MONTH	10	-0.757976075	B	0.12789621	-5.93	<.0001
MONTH	11	-0.929888806	B	0.14450040	-6.44	<.0001
MONTH	12	0.000000000	B	.	.	.
SHIP	1046	0.122193343	B	0.57728504	0.21	0.8324
SHIP	1753	0.211089662	B	0.27240938	0.77	0.4386
SHIP	2061	0.065029163	B	0.09972456	0.65	0.5145
SHIP	2204	-1.280145938	B	0.25009840	-5.12	<.0001
SHIP	3100	-0.952201308	B	0.11576994	-8.22	<.0001
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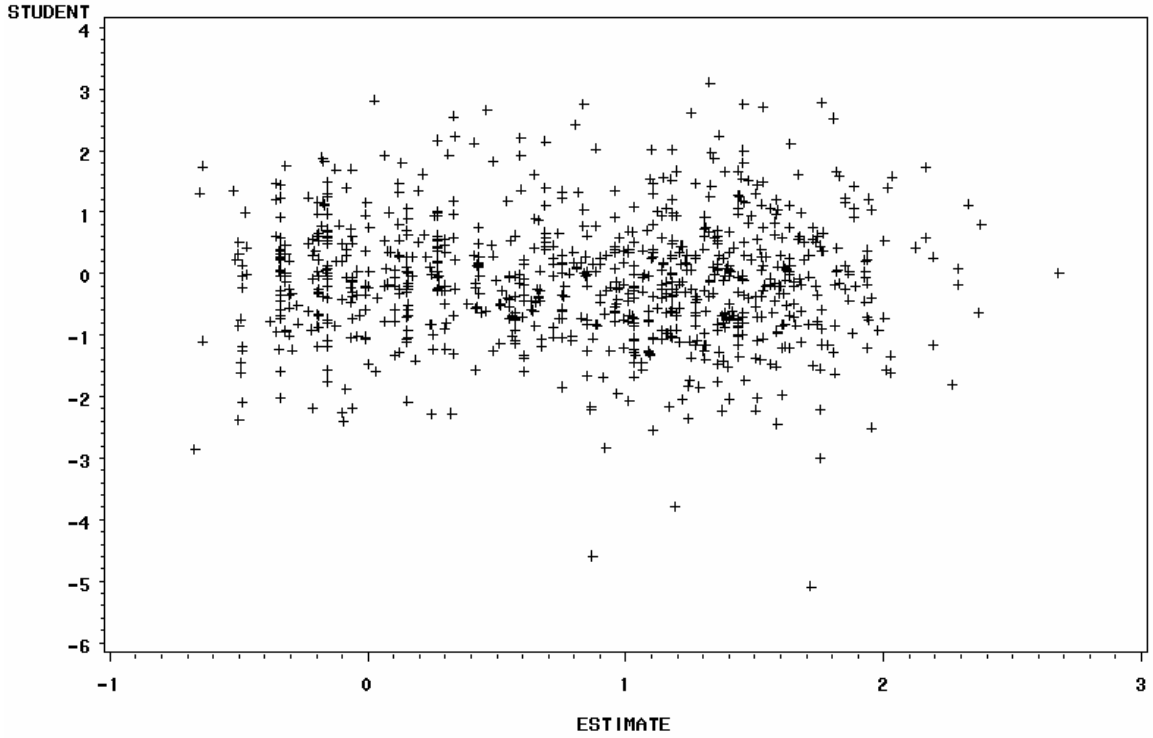
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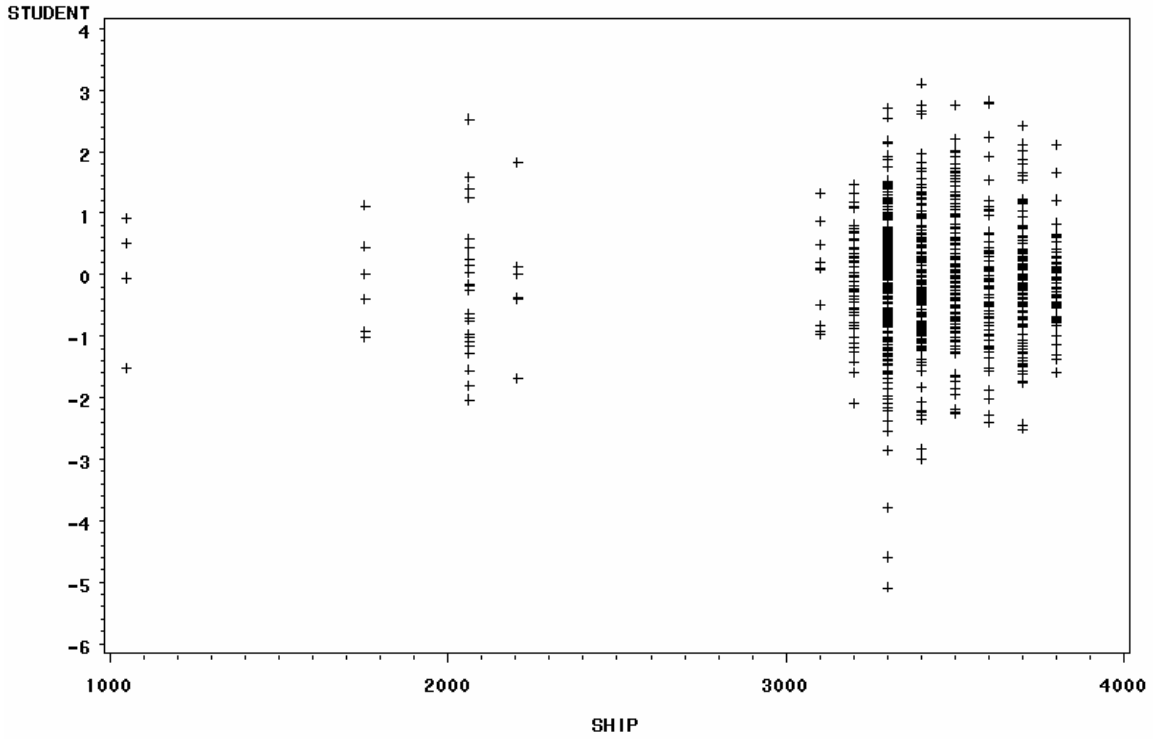
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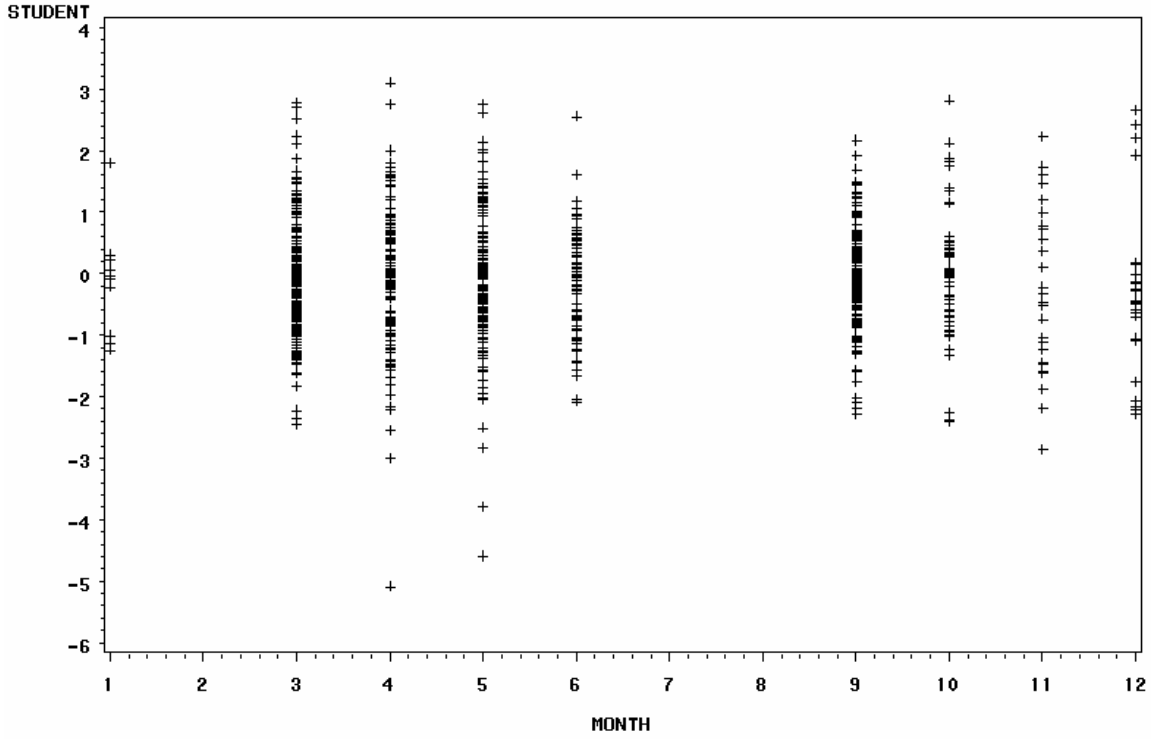
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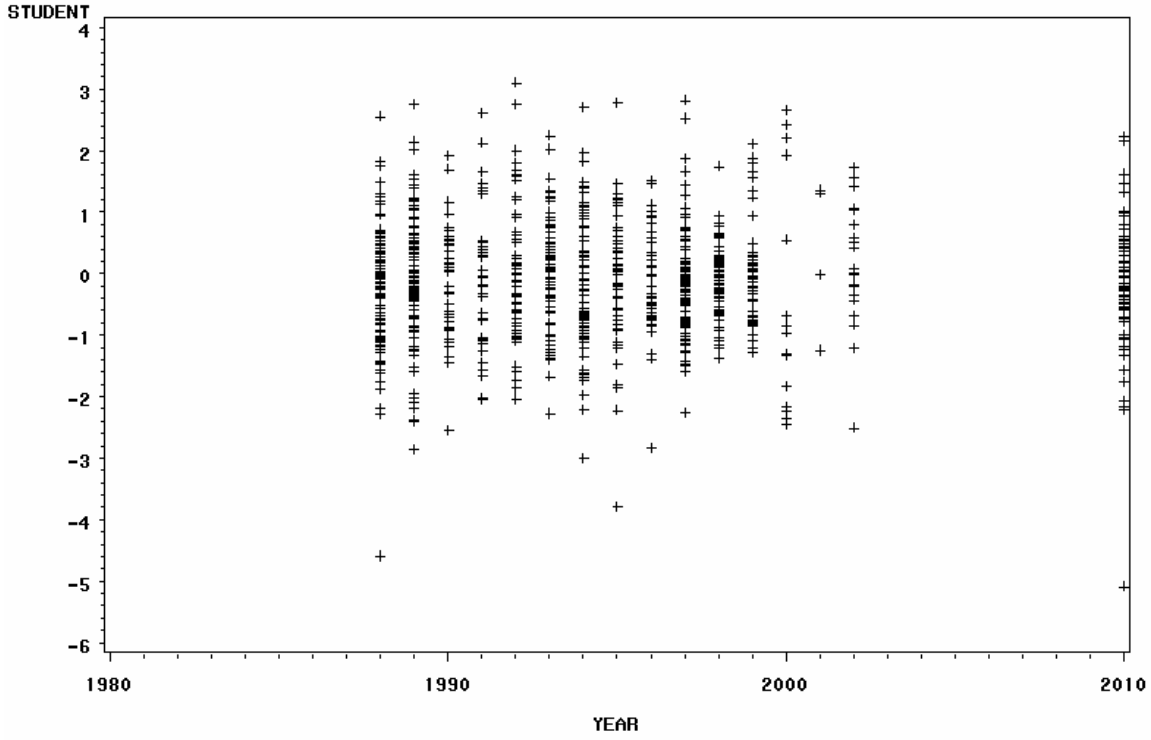
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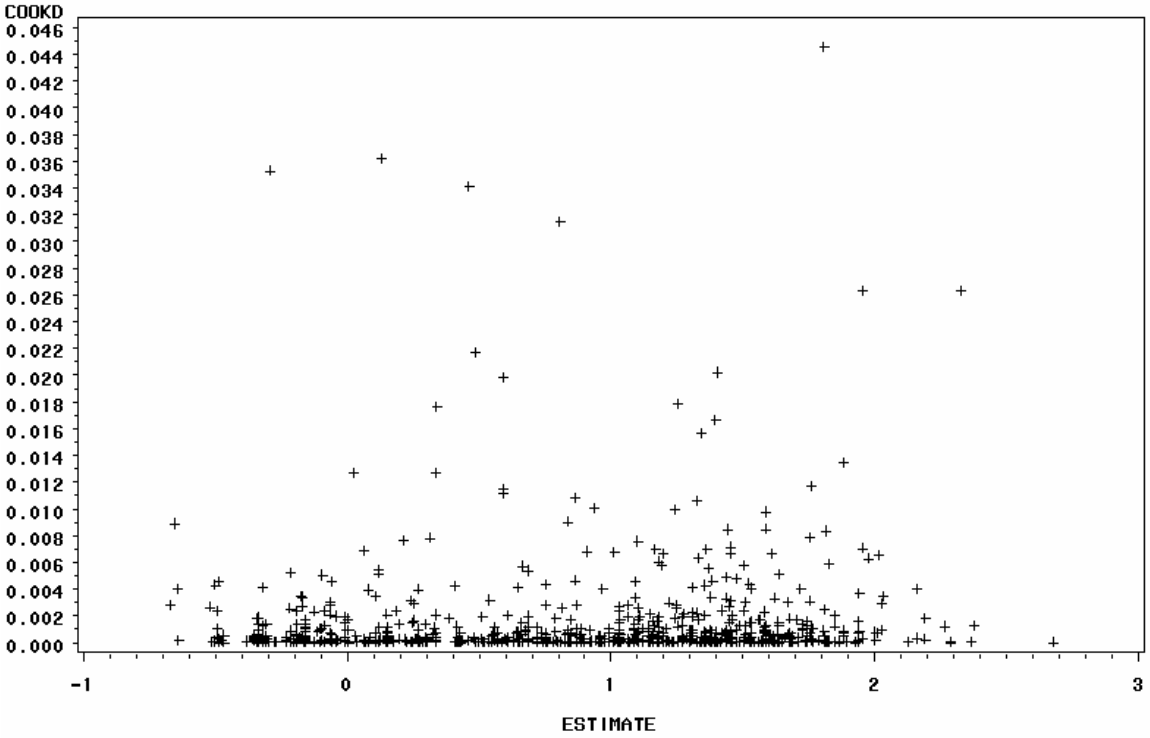
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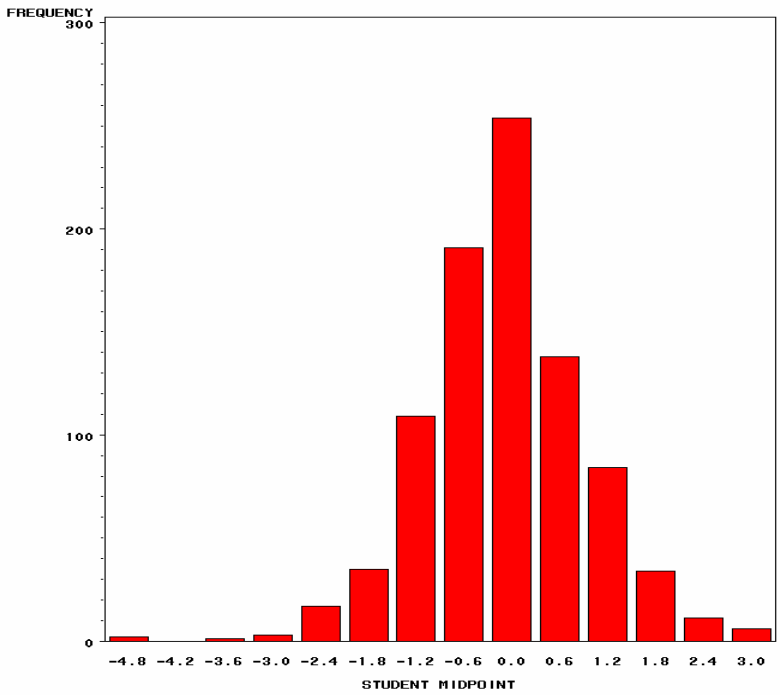
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STUDENT MIDPOINT