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Data for the Assessment of the Shrimp (*Pandalus borealis*) Stock in Denmark Strait/off East Greenland, 2001

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 to 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.

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 10 000 tons during the following 10-year period. Since then catches have fluctuated between 7 500-11 500 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. 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 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

Materials and Methods

Catch and effort (hours fished) from logbooks were available from Greenland, Norway, Iceland, Faroe Islands and EU-Denmark since 1980 and from EU-France for the years 1980 to 1991. 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. Logbook data from the Danish, Faeroese and Greenlandic fleets were used to show the spatial distribution of the fishery in the Greenlandic zone.

Three standardised CPUE indices were constructed: one for each of the areas north and south of 65°N and a combined 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:

$$\ln\left(CPUE_{ijkl}\right) = \ln\left(u\right) + \ln\left(A_i\right) + \ln\left(S_j\right) + \ln\left(V_k\right) + \ln\left(Y_l\right) + e_{ijkl},$$

where $CPUE_{ijkl}$ is the mean CPUE for vessel k, fishing in area i in month j during year l (k = 1,...,n; i = 1,…,a; j = 1,…,s; l = 1,…,y), ln(u) is overall mean ln($CPUE$), A_i is effect of the i^{th} area, S_j is the effect of the j^{th} month, V_k is the effect of the k^{th} vessel, Y_l is the effect of the l^{th} year, e_{ijkl} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ here n is the number of observations in the cell. The standardized CPUE indices are the antilog of the year coefficient.

Parameter estimates of the vessel, month and area variable from a first run of model 1 were compared. Levels within each variable were combined in subsequent analyses if the parameter estimates were within the distance of one mean standard error. 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 Faroese and 6 Danish vessels. Based on an exploratory run of the main effects model the vessel effect was collapsed into 8 groups consisting of 4-8 vessels with similar fishing power. The month effect was reduced to 3 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 19 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. No data were available for 2001.

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 total area

In the 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 the Greenlandic zone model and the year coefficients from the Icelandic zone model (Appendix 2). This was done using a maximum-likelihood method and a MCMC resampling procedure. Individual CPUE series for the i^{th} fleet in year j, m_{ij}, was assumed to reflect an overall biomass series, Y_j, and a constant fleet coefficient, v_i, so that $m_{ij} = v_i Y_j + e_{ij}$. The error, e_{ij}, were considered to be normally distributed with mean zero and variance t_i^2. For the purpose of fitting we assumed that e_{ij}, had variances inversely proportional to the area of fishing ground, a_i, covered by fleet i. Hence, the combined index could be constructed by fitting v_i and Y_j to maximise the likelihood:

$$L = \sum_{ij} \frac{a_i}{\sqrt{2p}\, s^2 v_{ij}} \exp(0.5(m_{ij} - v_i Y_j)^2 (\frac{a_i}{s^2 v_{ij}})^2)$$

The area weighting factor, a_i, for the Greenlandic and Icelandic zone was estimated to 0.875 and 0.125, respectively.

The combined index of the area north of 65°N

The biomass index for the areas north of 65°N was derived by combining the year coefficients of the Icelandic zone model and the year effects for the northern areas in the Greenlandic zone model (i.e. the 'year-area north' cross effect). This was also done by the maximum likelihood method described above using an area-weighting factor of 0.75 for the Greenlandic zone data and thus 0.25 for the Icelandic zone data.

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

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 (Fig. 1A). In 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell (Fig. 1B). The fishery of Greenlandic, Faroese and Danish trawlers was generally distributed in accordance with this “new” fishing pattern in 2000 and 2001 (Fig. 1C). Most effort was spent in the southern areas (Fig. 2B).

Catch

As the fishery developed, catches increased rapidly to more than 12 000 tons in 1987-88, but declined thereafter to about 7 500 tons in 1992-93. Following the area expansion of the fishery to south of 65°N, catches increased again reaching 11 500 tons in 1997 (Fig. 2A, Tables 1and 2). In recent years annual catches have been around 9 500 tons and is for 2001 projected to be at around 10 000 tons (projected from November) of which 33% will be 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 12 000 to about 3 000 tons (Fig. 2A). According to Greenlandic skippers this 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 2001 are projected to be around 3 300 tons - close to the 2000-level.

Catches in the southern area increased from 1 500 tons in 1993 - the first year of fishery in this area - to about 7 500 tons in 1997 (Fig. 2A). They then decreased somewhat to the recent level of about 5-6 000 tons. However, catches in the southern areas are expected to be around 6 700 tons in 2001.

Fishing effort

The high increase in catches during the first ten-year period was 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 100 000 hr's and then declined again to about 30 000 hr's in 2000. For 2001 fishing effort is expected to increase again to around 44 000 hr's (Fig. 2B, Table 2). Approximately 41% of these 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 the current year effort in the northern areas is expected to decrease slightly to around 18 000 hr's (Fig. 2B, Table 2).

In the southern area, effort increased from about 11 000 hours in 1993 to 26 300 hours in 1997. In 1998 the amount of effort spent was down again at 11 000 hr's where it remained for the following two years. For 2001 effort in the southern areas is projected to increase to around 26 000 hr's (Fig. 2B, Table 2).

CPUE

Catch rates in the northern area decreased from 1980 (243 kg/hr) to a level about 100 kg/hr from 1989 to 1993, but has shown an increasing trend since then reaching about 200 kg/hr in recent years (Fig. 2C, Table 2). In the southern areas CPUE increased from 135 kg/hr in 1993 to over 500 kg per hour in 1999 and 2000. However, the mean CPUE obtained in this area in 2001 is only about half this size (261 kg/hr). Overall catch rates follow the same trend: increasing from 100 kg per hour in 1993 to about 300 kg per hour in recent years and then follow the decline in the southern areas for the current year reaching 229 kg/hr.

Indices of biomass

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 82% and 72%, 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 combined index for the total area (Fig. 3C, Table 3) indicates that the stock declined by more than a factor 3 in the period 1987-1993 after which it has been rebuilding at a corresponding rate. This increase seems to level off in 1999-2000 and the estimated 2001 mean value is 12% lower than that of the year before.

The separate indices for the northern (Fig. 3A, Table 3) and southern areas (Fig. 3B, Table 3) both show more or less the same trend. The index for the northern area (Fig. 3A) has declined from 1987 to 1993 succeeded by an overall increase until 1998 after which a decreasing trend is indicated. The CPUE indices of the southern area (Fig. 4B), starting in 1993, have increased until 1999 and then decreased thereafter.

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 standardized 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 (Fig. 4C) shows 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 37% lower level during 1998-2000. The projected value of year 2001 indicates an increase of about 28% as compared to the three previous years. The separate indices for the northern and southern areas are shown in Fig. 4A+B. As mentioned in the previous section the development in the fishing mortality indices might be to optimistic. Furthermore, the index of 2001 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 Grenlandic 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 Flemmish Cap (Div. 3M). Shrimp caught north of 65°N are the largest (Table 4).

For 2001 no samples were available from the northern areas. However, reports from some Greenlandic skippers say that catches are considered "good quality". The same is said about catches from the southern areas. The samples also indicate an increase in the proportion of female shrimp and a resulting increase in average individual size (Table 4). The length frequency distribution (Fig. 5B) indicates a demographic healty composition with a wide distribution of the sizes normally present in this fishery.

More detailed interpretations of the samples with respect to age compisition etc. should be done with reservation, 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 south of 65°N. In particular poor catches have been recorded in the Icelandic zone during the last two years (Table 1).

Since the mid-1990s 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 (Fig. 1B,C).

Since 1993 overall catch rates have been continuously improving except for a 50% decline from 2000 to 2001. This 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 (Fig. 2C).

Skippers state that the lower catch rates of 2001 is compensated for by a better size distribution i.e. more large shrimp in the catch. This is supported by the biological samples taken in the southern areas, which indicate demographically healty size composition.

The CPUE based biomass index (Fig. 3C) indicates that a rebuilding phase taking place since the early-1990s has ended with full recovery to the stock size of the mid-1980s. However the estimated 2001 value suggests a 12% decline as compared to the year before.

During the recent three years indices of harvest rate have been at the lowest level of the time series (Fig. 4C). A slight increase is however indicated for 2001.

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

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[1,2]
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	93
Faroe Islands	-	-	4233	713	737	443	668	674	727	595	679	595	843	1007	1092	554	368	745	800	509	1002	689	759	90
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	647
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
Norway	-	800	2461	2016	1896	1727	2128	2051	2026	2041	2052	2098	2500	2504	2500	1473	1736	1923	1241	639	1286	1416	2190	1916
Total	363	1285	8405	4792	4902	4175	6731	8110	10964	12178	12556	10742	10275	8657	7514	6116	4873	5974	2917	4156	4536	3992	3536	2756
South of 65°N																								
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	488	585	938	1328	1027	870	1508	1388
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	225	776	236	323	526	109	360	270	840
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	918	2870	2135	4257	3767	3120	3945	4155	3059
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	341	805	576	1278	1812	529	300	125	420
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1532	4939	3532	6796	7433	4785	5475	6058	5707
Total area																								
Denmark	-	-	702	581	740	204	443	353	500	555	444	366	390	358	160	159	687	827	959	1396	1344	1500	1872	1481
Faroe Islands	-	-	4233	713	737	443	668	674	727	595	679	595	843	1007	1092	779	1144	981	1123	1035	1111	1049	1029	930
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	3706
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
Norway	-	800	2461	2016	1896	1727	2128	2051	2026	2041	2052	2098	2500	2504	2500	1814	2541	2499	2519	2451	1815	1716	2315	2337
Total	363	1285	8405	4792	4902	4175	6731	8110	10964	12178	12556	10742	10275	8657	7514	7648	9812	9506	9713	11589	9321	9467	9594	8464
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	8464
Advised TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	10000[3]	10000[3]	10000[3]	8000	5000	5000	5000	5000	5000	5000	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

[1]Provisional

[2]Catch in 2000 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 and total area.

	Area north			Area south			Total area		
Year	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
1980	8405	34590	243				8405	34590	243
1981	4792	19588	245				4792	19588	245
1982	4900	23072	212				4900	23072	212
1983	4175	23670	176				4175	23670	176
1984	6731	31974	211				6731	31974	211
1985	8110	51738	157				8110	51738	157
1986	10964	56808	193				10964	56808	193
1987	12178	73255	166				12178	73255	166
1988	12543	99559	126				12543	99559	126
1989	10747	107903	100				10747	107903	100
1990	10224	94165	109				10224	94165	109
1991	8539	95194	90				8539	95194	90
1992	7514	83666	90				7514	83666	90
1993	6115	64172	95	1532	11386	135	7646	75558	101
1994	4872	30547	159	4936	18048	273	9808	48595	202
1995	5972	45626	131	3531	13185	268	9504	58812	162
1996	2916	24412	119	6795	25010	272	9712	49423	196
1997	4156	23107	180	7432	26268	283	11588	49375	235
1998	4538	21887	207	4785	11102	431	9323	32989	283
1999	3992	20850	191	5475	9994	548	9467	30844	307
2000	3536	18872	187	6058	11644	520	9594	30517	314
2001*	3257	17896	182	6743	25835	261	10000	43731	229

*projected from Nov. to end of year.

Table 3. Mean 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.

	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	1.58	-	1.00	-					1.17	-	1.00	-
1988	1.32	0.19	1.24	0.18					0.94	0.14	1.28	0.19
1989	0.92	0.13	1.51	0.21					0.69	0.10	1.50	0.23
1990	0.87	0.12	1.53	0.22					0.66	0.10	1.50	0.23
1991	0.72	0.10	1.57	0.22					0.56	0.08	1.49	0.23
1992	0.59	0.08	1.64	0.23					0.46	0.07	1.56	0.24
1993	0.46	0.07	1.74	0.25	0.34	-	1.00	-	0.35	0.05	2.10	0.33
1994	1.13	0.17	0.56	0.08	0.84	0.08	1.32	0.12	0.81	0.13	1.17	0.19
1995	0.83	0.12	0.93	0.13	0.76	0.07	1.05	0.10	0.64	0.10	1.42	0.22
1996	0.77	0.12	0.49	0.08	0.97	0.09	1.58	0.14	0.79	0.13	1.18	0.19
1997	1.26	0.20	0.43	0.07	0.93	0.09	1.80	0.17	0.86	0.14	1.30	0.21
1998	1.65	0.25	0.36	0.05	1.00	0.11	1.07	0.11	1.03	0.17	0.87	0.15
1999	1.29	0.20	0.40	0.06	1.54	0.18	0.80	0.09	1.15	0.19	0.80	0.13
2000	1.34	0.25	0.34	0.06	1.29	0.16	1.06	0.13	1.14	0.21	0.81	0.15
2001	1.00	0.41	0.42	0.17	1.00	0.17	1.52	0.25	1.00	0.25	0.96	0.24

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. Data for 2001 are preliminary.

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

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

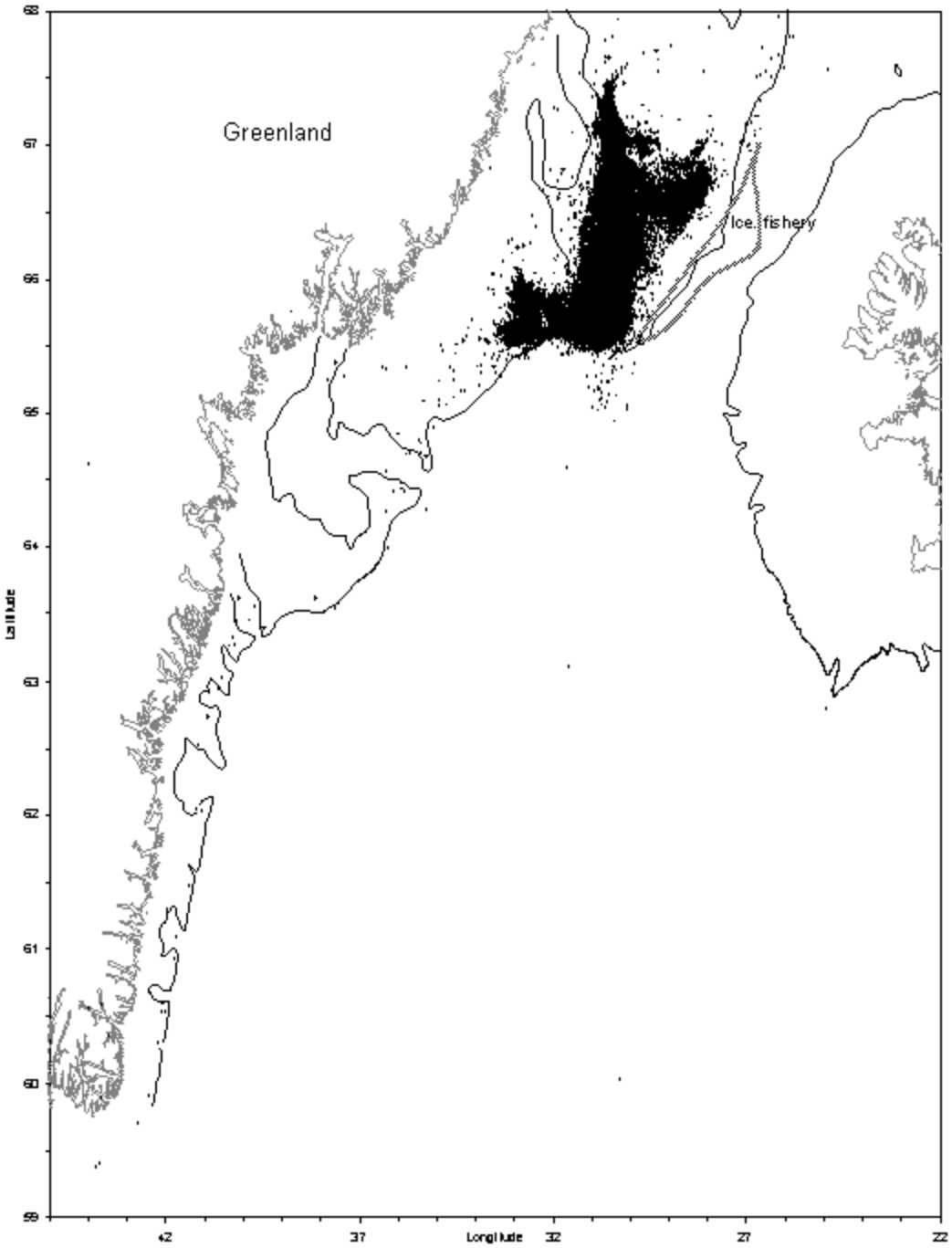
Table 5. Biological samples from catches taken in the greenlandic zone north and south of 65°N.

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



F ig. 1A. Distribution of hauls by Greenlandic, Faeroese and Danish trawlers in the shrimp fishery off East Greenland 1987-1992. Position of individual hauls are indicated by dots. An approximate area distribution of the Icelandic fishery is indicated (‘Ice. Fishery’) based on Skuladottir (1997). 400 meters depth curve are shown as a solid line.

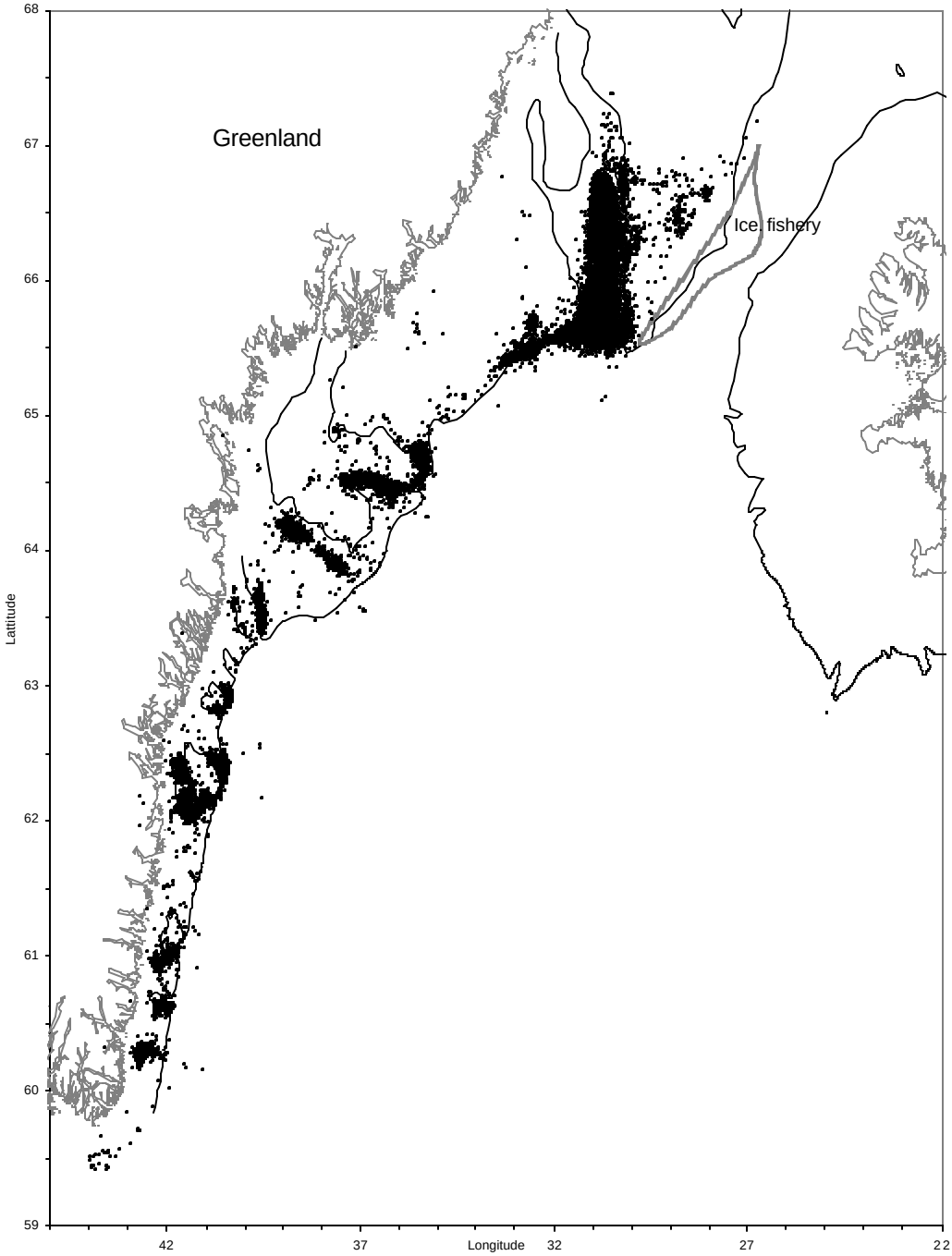


Fig. 1B. Distribution of hauls by Greenlandic, Faeroese and Danish trawlers in the shrimp fishery off East Greenland 1993-1999. Position of individual hauls are indicated by dots. An approximate area distribution of the Icelandic fishery is indicated ('Ice. Fishery') based on Skuladottir (1997). 400 meters depth curve are shown as a solid line.

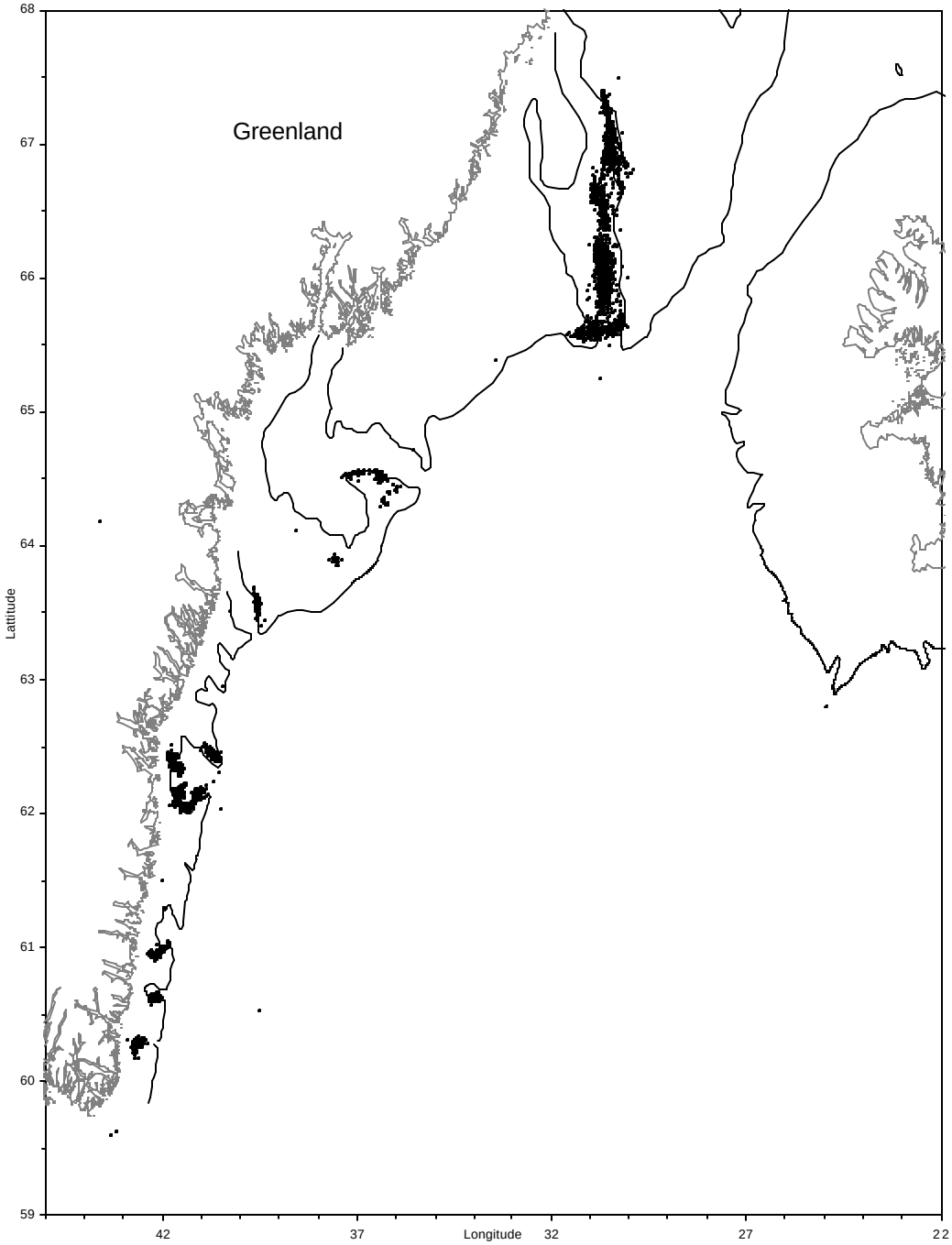


Fig. 1C. Distribution of hauls by Greenlandic, Faeroese and Danish trawlers in the shrimp fishery off East Greenland 2000-2001. Position of individual hauls are indicated by dots. 400 meters depth curve are shown as a solid line. No information on the Icelandic fishery.

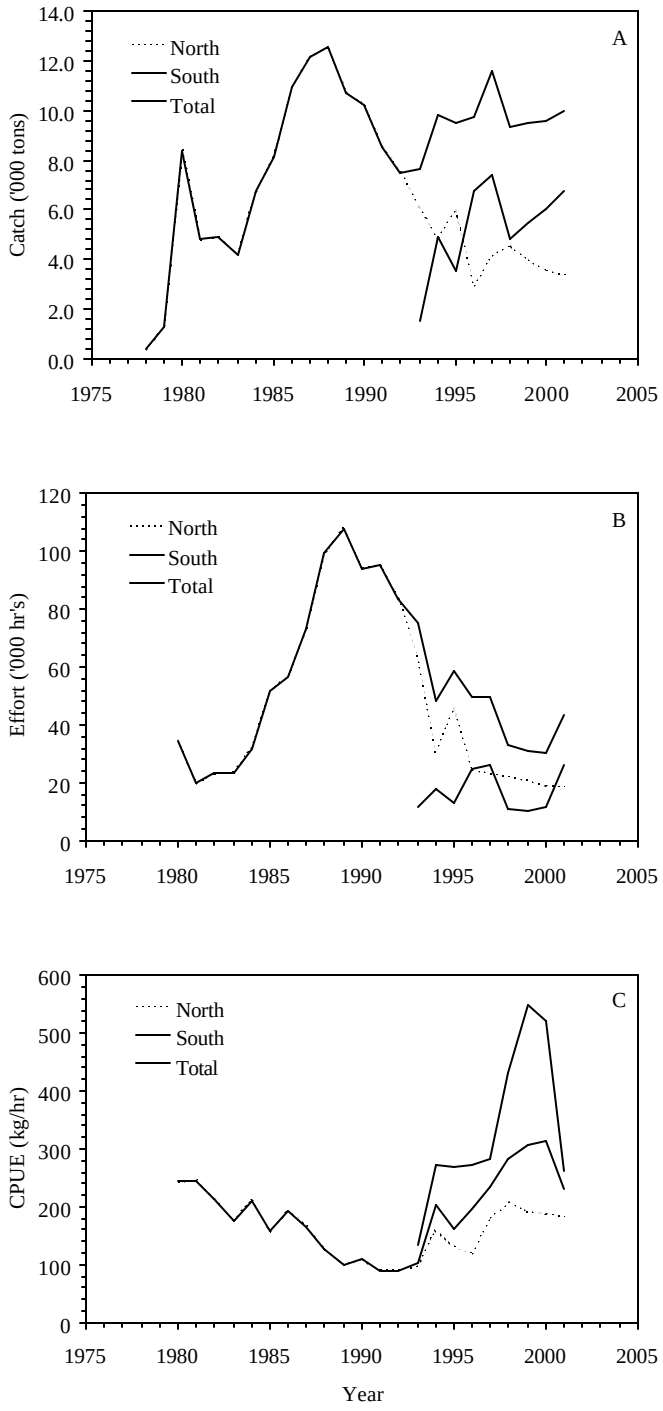


Fig. 2. Catch (A), Fishing effort (B) and Catch-per-unit-effort (C) by trawlers fishing in Denmark Strait/off East Greenland in areas north and south of 65°N and total area. Data for 2001 are projected from Nov. to the end of the year.

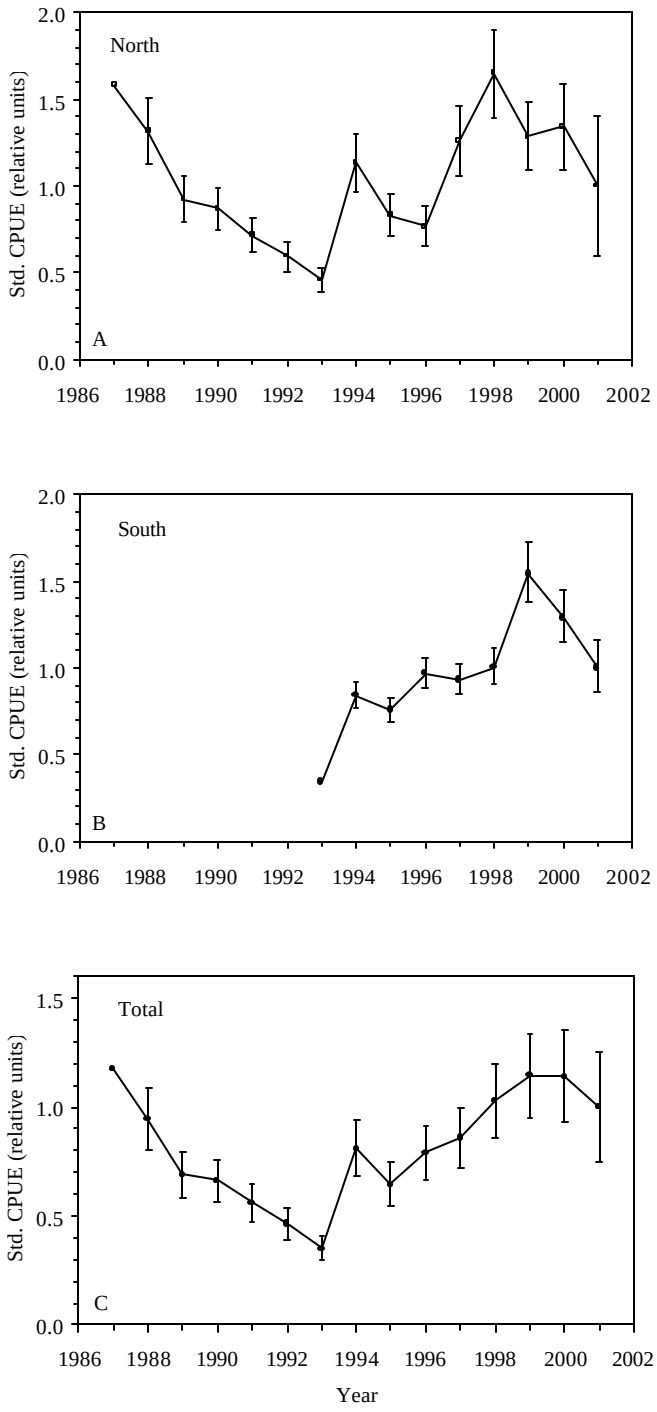


Fig. 3. Standardized Catch-Per-Unit-Effort indices for the shrimp fishing grounds in Denmark Strait and off East Greenland: A) north of 65°N, B) south of 65°N and C) total area. Estimates are based on data until July 2001.

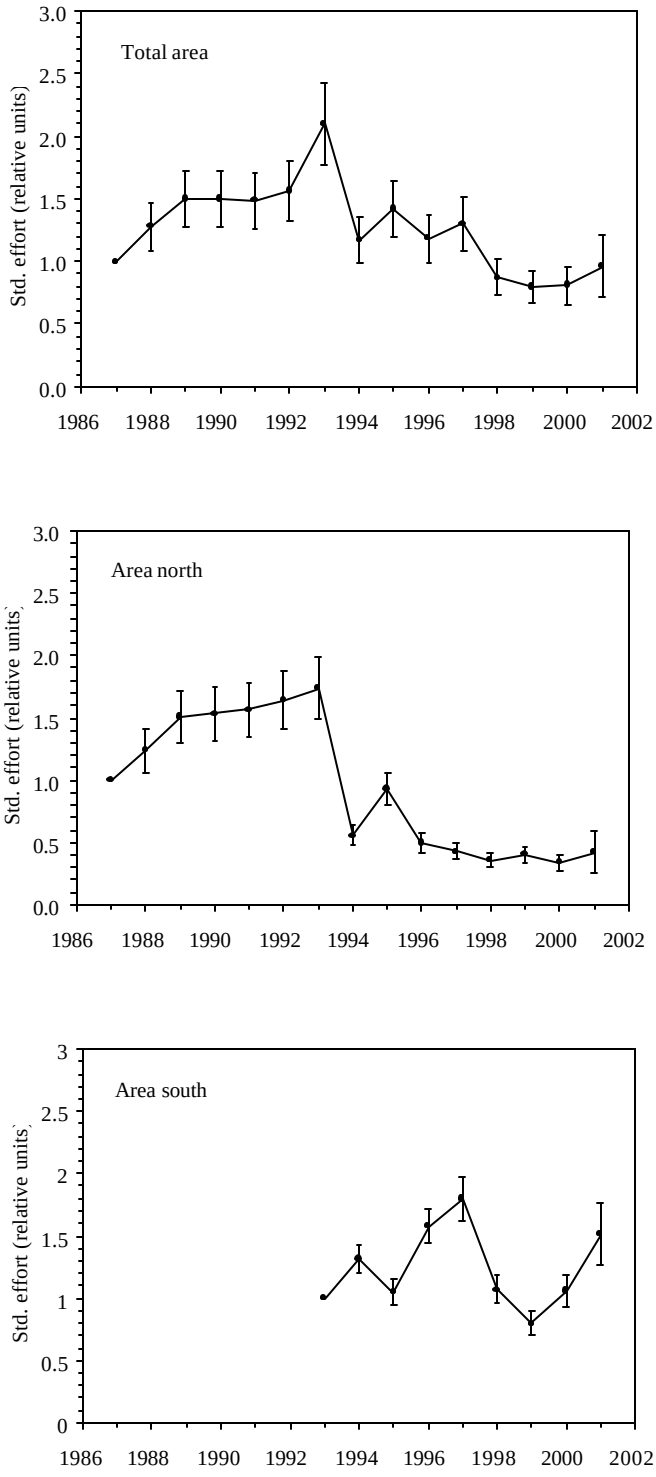


Fig. 4. Standardized effort indices of the shrimp fishery in Denmark Strait and off East Greenland: A) north of 65°N, B) south of 65°N and C) total area. Estimates are based on data until July 2001.

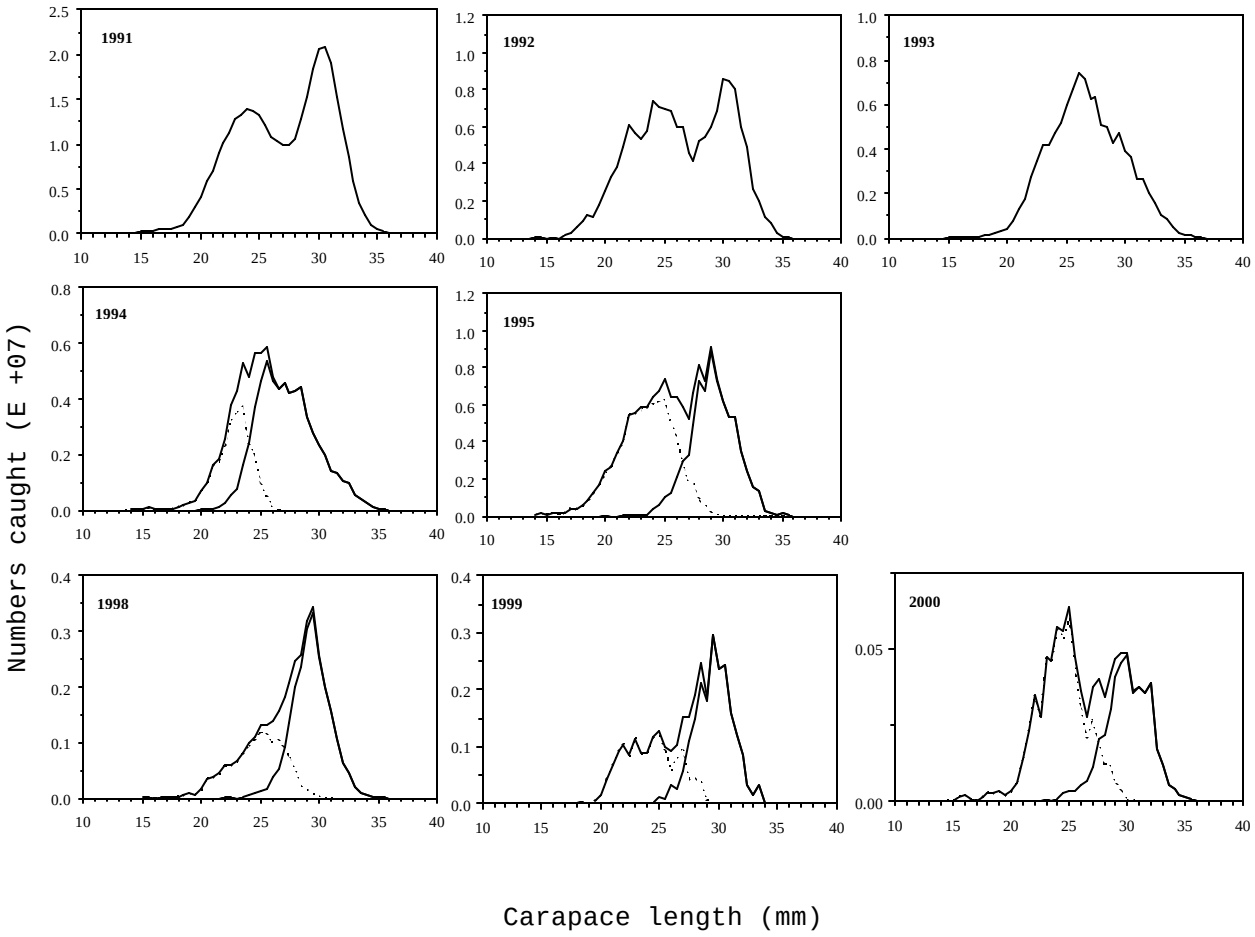


Fig. 5A. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland north of 65°N, 1991-2000 (no data available for 1996-1997). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line. Data for 2001 are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

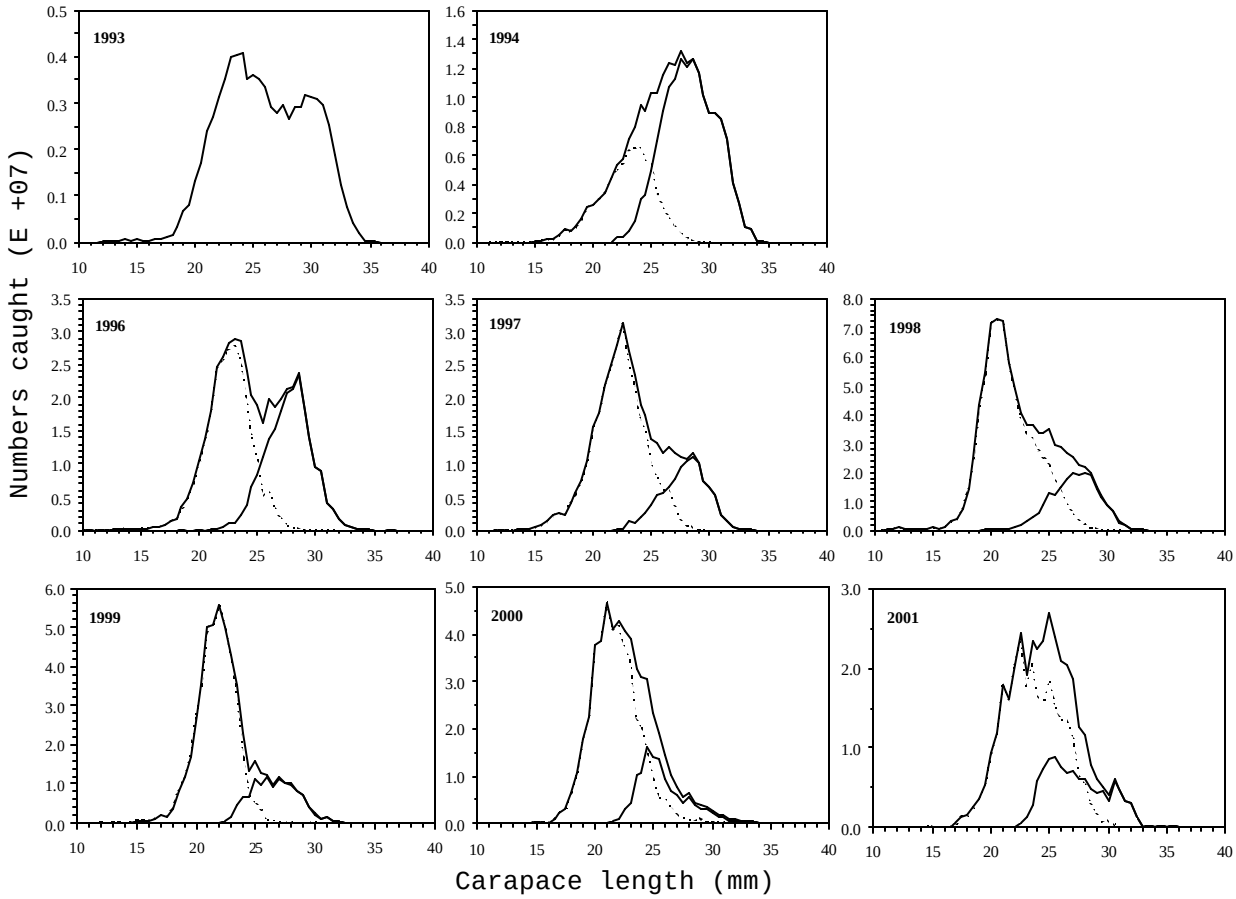


Fig. 5B. Length frequency distributions of Greenlandic commercial shrimp catches off East Greenland south of 65°N, 1993-2001 (no data available for 1995). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line. Data for 2001 are preliminary.

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           8    AAAA BBBB CCCC DDDD EEEE FFFF HHHH IIII
YEAR            15    87 88 89 90 91 92 94 95 96 97 98 99 100 101 111 (111=93)
MONTH            5    1 3 5 6 12
AREA             2    0 11 (0=north, 11=south)

                         Number of observations    2136

Dependent Variable: LNCPUE
Weight: HAULS
                                      Sum of
Source                        DF         Squares      Mean Square    F Value    Pr > F
Model                         38     51197.95358       1347.31457     140.76    <.0001
Error                       2097     20071.67051          9.57161
Corrected Total             2135     71269.62408

                  R-Square     Coeff Var      Root MSE    LNCPUE Mean
                  0.718370      336.3487      3.093802       0.919820

Source                        DF       Type I SS     Mean Square    F Value    Pr > F
VESSEL                         7     20429.39980      2918.48569     304.91    <.0001
AREA                           1     11796.18310     11796.18310    1232.41    <.0001
YEAR*AREA                     22     13077.28352       594.42198      62.10    <.0001
MONTH*AREA                     8      5895.08715       736.88589      76.99    <.0001

Source                        DF     Type III SS     Mean Square    F Value    Pr > F
VESSEL                         7      8769.16076      1252.73725     130.88    <.0001
AREA                           1      2369.80387      2369.80387     247.59    <.0001
YEAR*AREA                     22     13208.01983       600.36454      62.72    <.0001
MONTH*AREA                     8      5895.08715       736.88589      76.99    <.0001
                                                        Standard
    Parameter                    Estimate                 Error    t Value    Pr > |t|
    Intercept                0.566712725 B        0.09979628       5.68      <.0001
    VESSEL     AAAA          0.192587645 B        0.04651298       4.14      <.0001
    VESSEL     BBBB          0.508909368 B        0.05544389       9.18      <.0001
    VESSEL     CCCC          0.675609898 B        0.05043267      13.40      <.0001
    VESSEL     DDDD         -0.370188900 B        0.08865303      -4.18      <.0001
    VESSEL     EEEE         -0.082516713 B        0.04953403      -1.67      0.0959
    VESSEL     FFFF          0.349835612 B        0.04829164       7.24      <.0001
    VESSEL     HHHH          0.751019629 B        0.05073001      14.80      <.0001
    VESSEL     IIII          0.000000000 B         .               .         .
    AREA       0            -0.956315806 B        0.10224369      -9.35      <.0001
    AREA       11            0.000000000 B         .               .         .
    YEAR*AREA  87 0          1.251748074 B        0.05460184      22.93      <.0001
    YEAR*AREA  88 0          1.087719663 B        0.04805160      22.64      <.0001
    YEAR*AREA  89 0          0.719217370 B        0.04688190      15.34      <.0001
    YEAR*AREA  90 0          0.654710324 B        0.04631577      14.14      <.0001
    YEAR*AREA  91 0          0.457681401 B        0.04514078      10.14      <.0001
    YEAR*AREA  92 0          0.267115567 B        0.04899569       5.45      <.0001
    YEAR*AREA  94 0          0.925584838 B        0.07201668      12.85      <.0001
    YEAR*AREA  94 11         0.907153549 B        0.08161093      11.12      <.0001
    YEAR*AREA  95 0          0.607247125 B        0.05820827      10.43      <.0001
    YEAR*AREA  95 11         0.726708398 B        0.08820013       8.24      <.0001
    YEAR*AREA  96 0          0.523306292 B        0.08305259       6.30      <.0001
    YEAR*AREA  96 11         1.045560436 B        0.08157119      12.82      <.0001
    YEAR*AREA  97 0          1.059148934 B        0.09894213      10.70      <.0001
    YEAR*AREA  97 11         1.007339011 B        0.08548418      11.78      <.0001
    YEAR*AREA  98 0          1.338739758 B        0.08673614      15.43      <.0001
    YEAR*AREA  98 11         1.138790287 B        0.09229515      12.34      <.0001
    YEAR*AREA  99 0          1.068281369 B        0.08241962      12.96      <.0001
    YEAR*AREA  99 11         1.550684522 B        0.10357836      14.97      <.0001
    YEAR*AREA  100 0         1.110418196 B        0.15521018       7.15      <.0001
    YEAR*AREA  100 11        1.364872888 B        0.10563725      12.92      <.0001
    YEAR*AREA  101 0         0.655319060 B        0.66092880       0.99      0.3215
    YEAR*AREA  101 11        1.120313371 B        0.14309535       7.83      <.0001
    YEAR*AREA  93  0         0.000000000 B         .               .         .
    YEAR*AREA  93  11        0.000000000 B         .               .         .
    MONTH*AREA 1 0           0.350622809 B        0.03248579      10.79      <.0001
    MONTH*AREA 1 11         -0.320146352 B        0.06909634      -4.63      <.0001
    MONTH*AREA 3 0           0.169232053 B        0.03559885       4.75      <.0001
    MONTH*AREA 3 11         -0.326743287 B        0.07440306      -4.39      <.0001
    MONTH*AREA 5 0           0.116568764 B        0.05735384       2.03      0.0422
    MONTH*AREA 5 11         -0.243439454 B        0.10275481      -2.37      0.0179
    MONTH*AREA 6 0          -0.414093935 B        0.03867328     -10.71      <.0001
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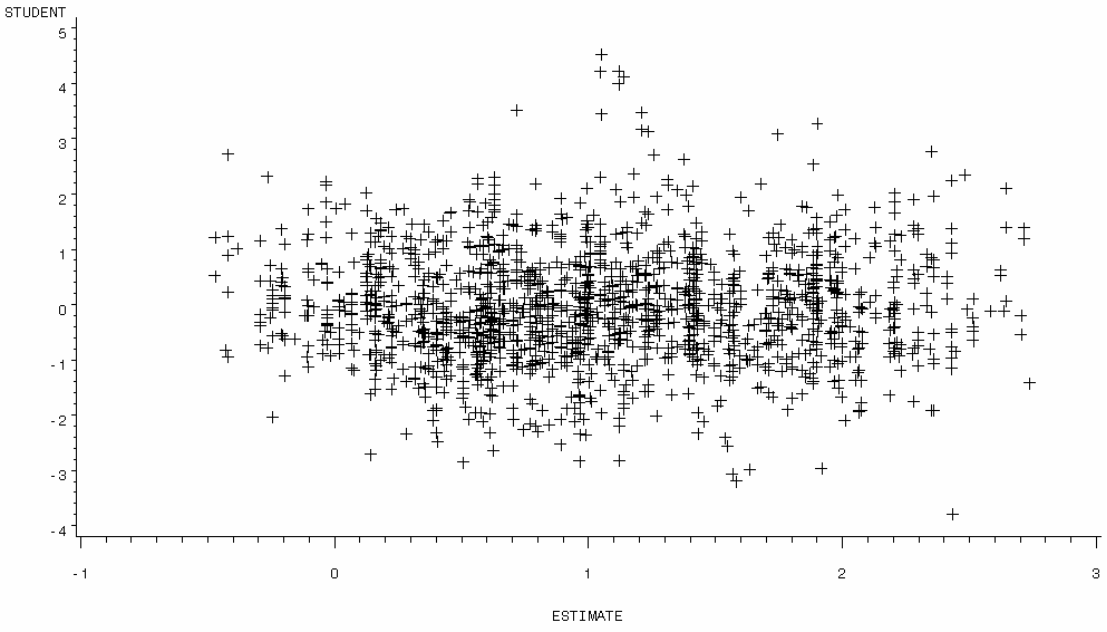
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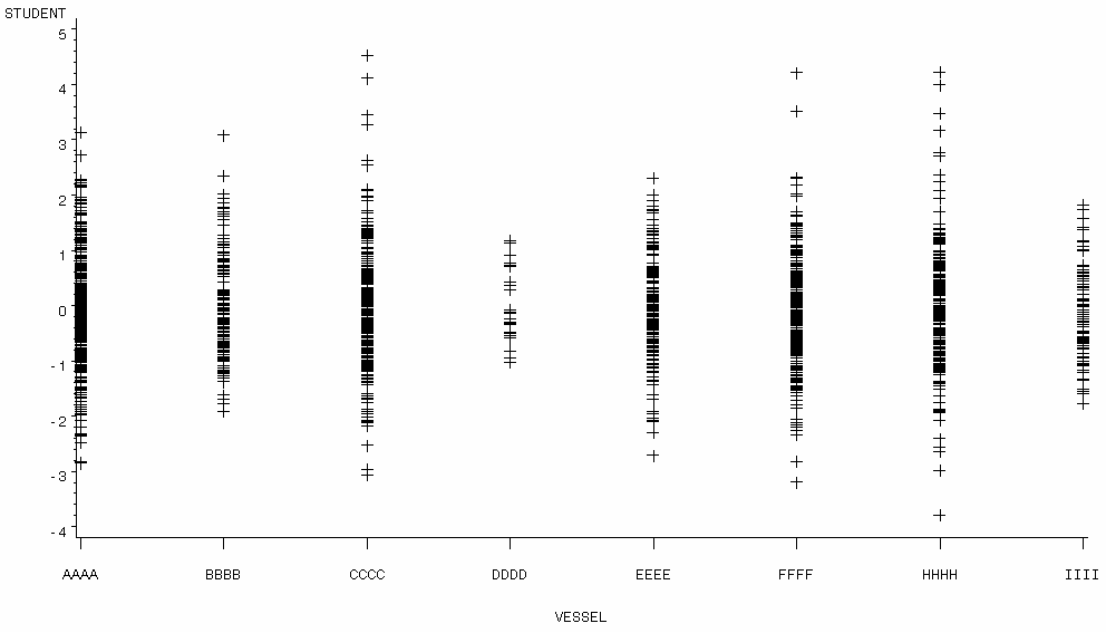
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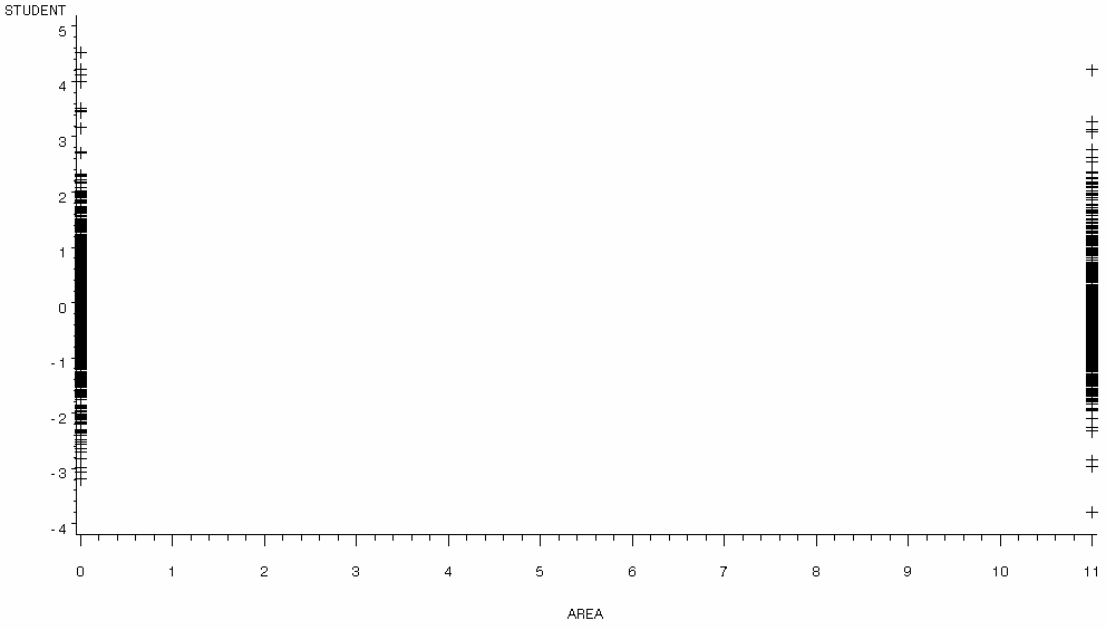
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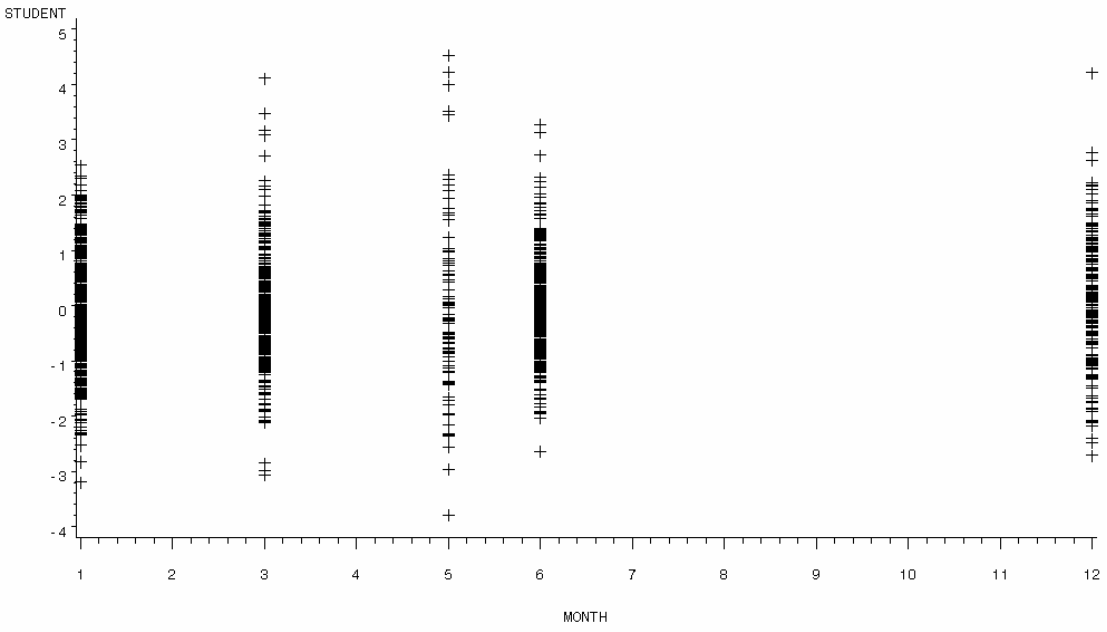
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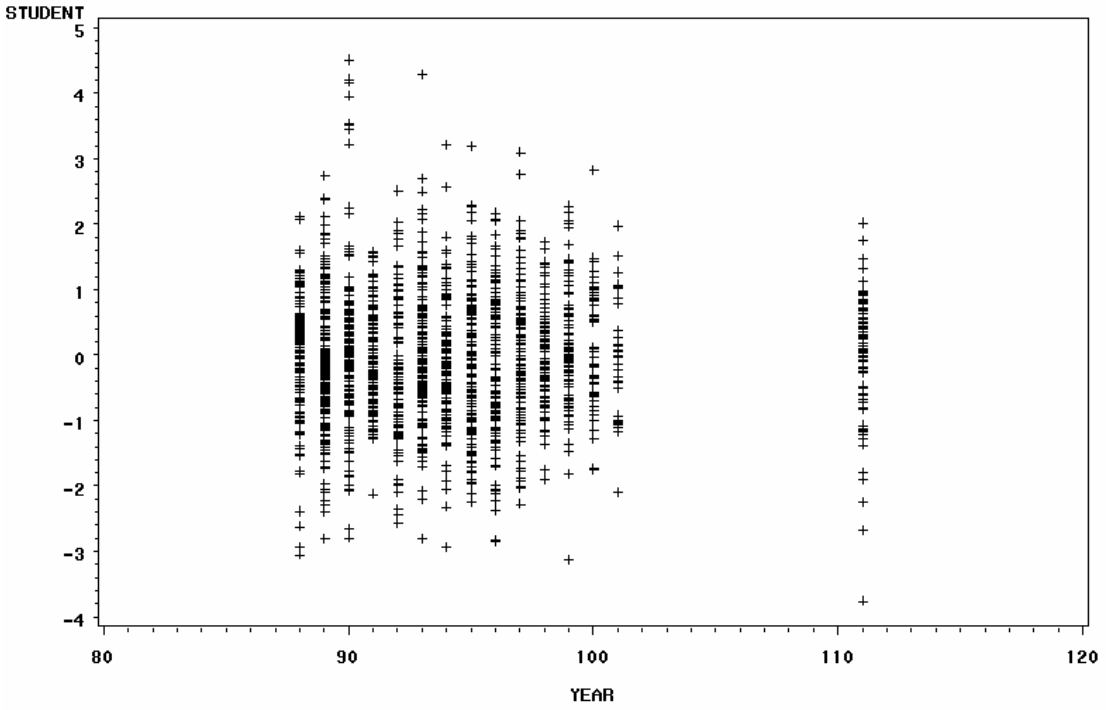
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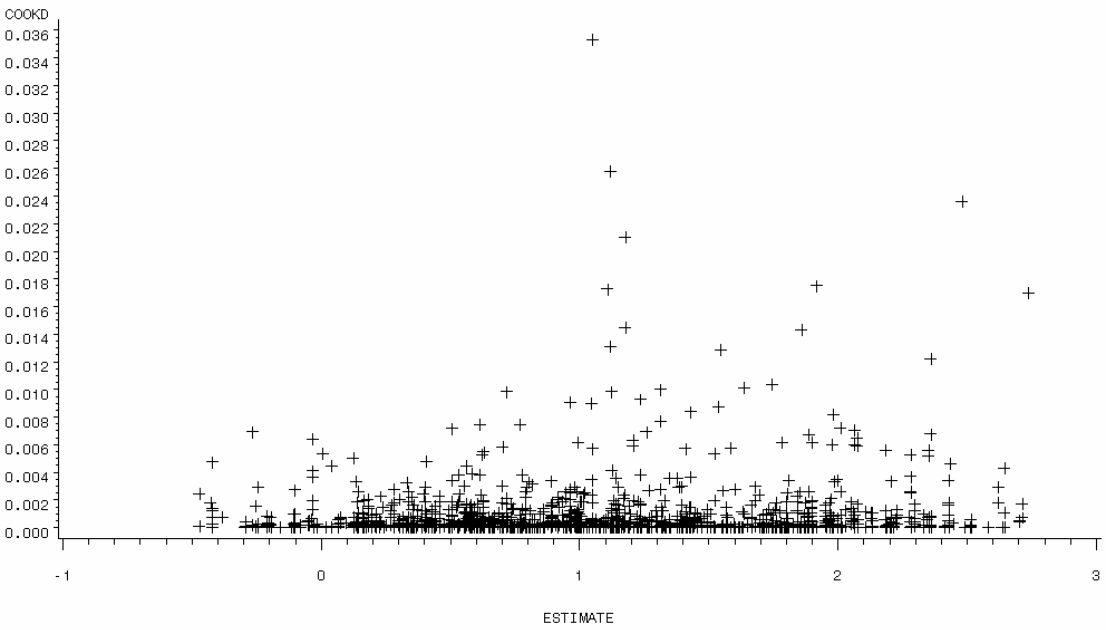
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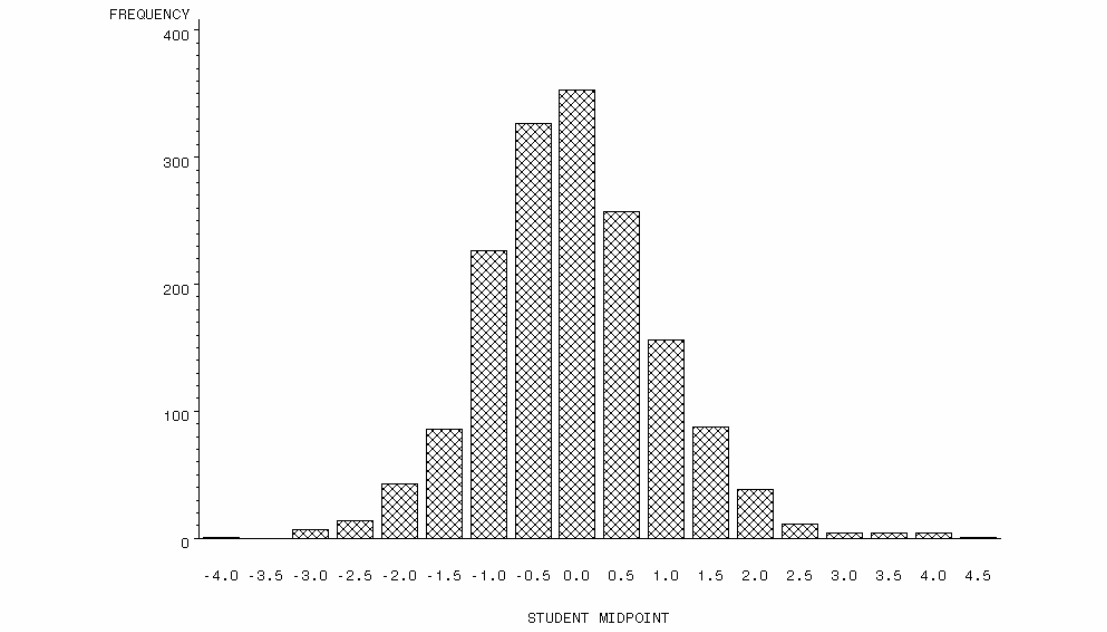
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STUDENT MIDPOINT

Appendix 2. Diagnostical outputs from GLM run of model for standardising CPUE in Icelandic zone. Data from Icelandic vessels only.

```
                    Class Level Information
Class       Levels  Values
YEAR            15  1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
                    1998 1999 2000 2001
MONTH            9  1 2 3 4 5 6 9 10 11
SHIP            19  253 1046 1586 1753 2061 2155 2204 3100 3200 3300 3400
                    3500 3600 3700 3800 3900 4000 4100 4200
TRAWL            2  1 2
                       Number of observations    871

Dependent Variable: LNCPUE
Weight: EFFORT   EFFORT
                                    Sum of
 Source                     DF       Squares   Mean Square  F Value  Pr > F
 Model                      41   2653207.133     64712.369    93.33  <.0001
 Error                     829    574793.819       693.358
 Corrected Total           870   3228000.952

            R-Square     Coeff Var      Root MSE    LNCPUE Mean
            0.821935      4159.394      26.33169       0.633066

 Source                     DF     Type I SS   Mean Square  F Value  Pr > F
 MONTH                       8   2205602.170    275700.271   397.63  <.0001
 SHIP                       18    237351.354     13186.186    19.02  <.0001
 YEAR                       14    204682.480     14620.177    21.09  <.0001
 TRAWL                       1      5571.128      5571.128     8.03  0.0047

 Source                     DF   Type III SS   Mean Square  F Value  Pr > F
 MONTH                       8   391413.3310    48926.6664    70.56  <.0001
 SHIP                       18   241365.0261    13409.1681    19.34  <.0001
 YEAR                       14   206469.0994    14747.7928    21.27  <.0001
 TRAWL                       1     5571.1275     5571.1275     8.03  0.0047

                                          Standard
 Parameter              Estimate             Error    t Value    Pr > |t|
 Intercept          0.638900586 B      0.10771186       5.93      <.0001
 MONTH     1        0.950135647 B      0.13924649       6.82      <.0001
 MONTH     2        1.726489994 B      0.12283859      14.05      <.0001
 MONTH     3        1.695329735 B      0.10969709      15.45      <.0001
 MONTH     4        1.771162842 B      0.10373679      17.07      <.0001
 MONTH     5        1.373724237 B      0.09919283      13.85      <.0001
 MONTH     6        0.837602350 B      0.09455510       8.86      <.0001
 MONTH     9        0.345314951 B      0.08334375       4.14      <.0001
 MONTH     10       0.177774087 B      0.08782763       2.02      0.0433
 MONTH     11       0.000000000 B       .                .         .
 SHIP      253     -0.891326908 B      0.15579583      -5.72      <.0001
 SHIP      1046     0.185053825 B      0.58087444       0.32      0.7501
 SHIP      1586    -0.390533580 B      0.07583167      -5.15      <.0001
 SHIP      1753     0.275813352 B      0.29518006       0.93      0.3504
 SHIP      2061     0.108573003 B      0.08881545       1.22      0.2219
 SHIP      2155    -0.895201620 B      0.12438079      -7.20      <.0001
 SHIP      2204    -1.227932450 B      0.24685394      -4.97      <.0001
 SHIP      3100    -0.676569496 B      0.06339026     -10.67      <.0001
 SHIP      3200    -0.575290347 B      0.06174211      -9.32      <.0001
 SHIP      3300    -0.527518714 B      0.05006996     -10.54      <.0001
 SHIP      3400    -0.487543378 B      0.05398573      -9.03      <.0001
 SHIP      3500    -0.399974699 B      0.06077717      -6.58      <.0001
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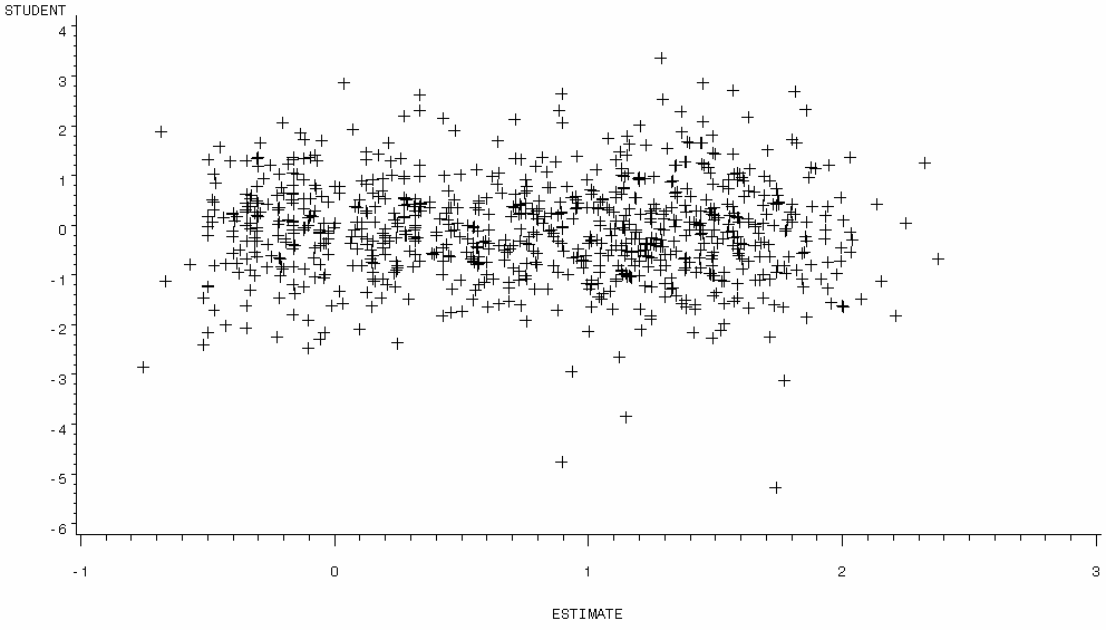
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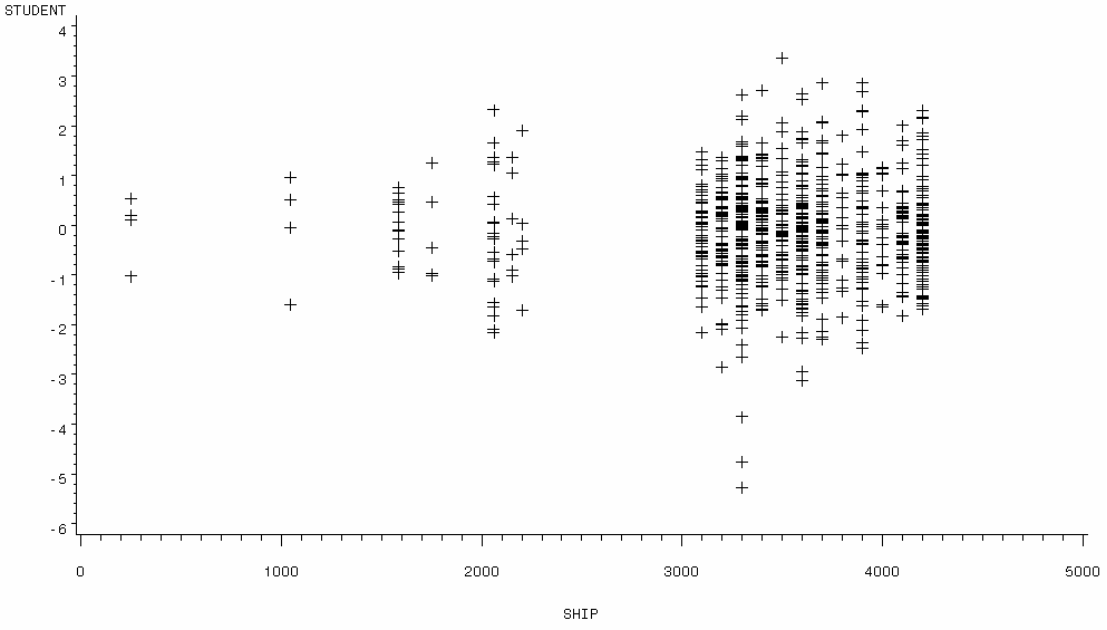
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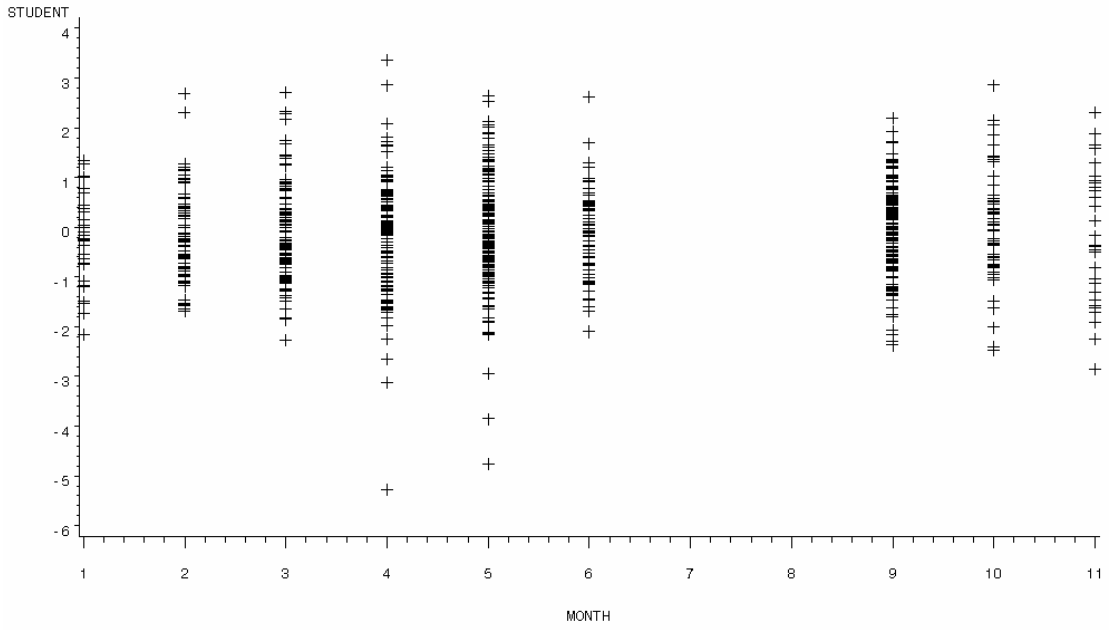
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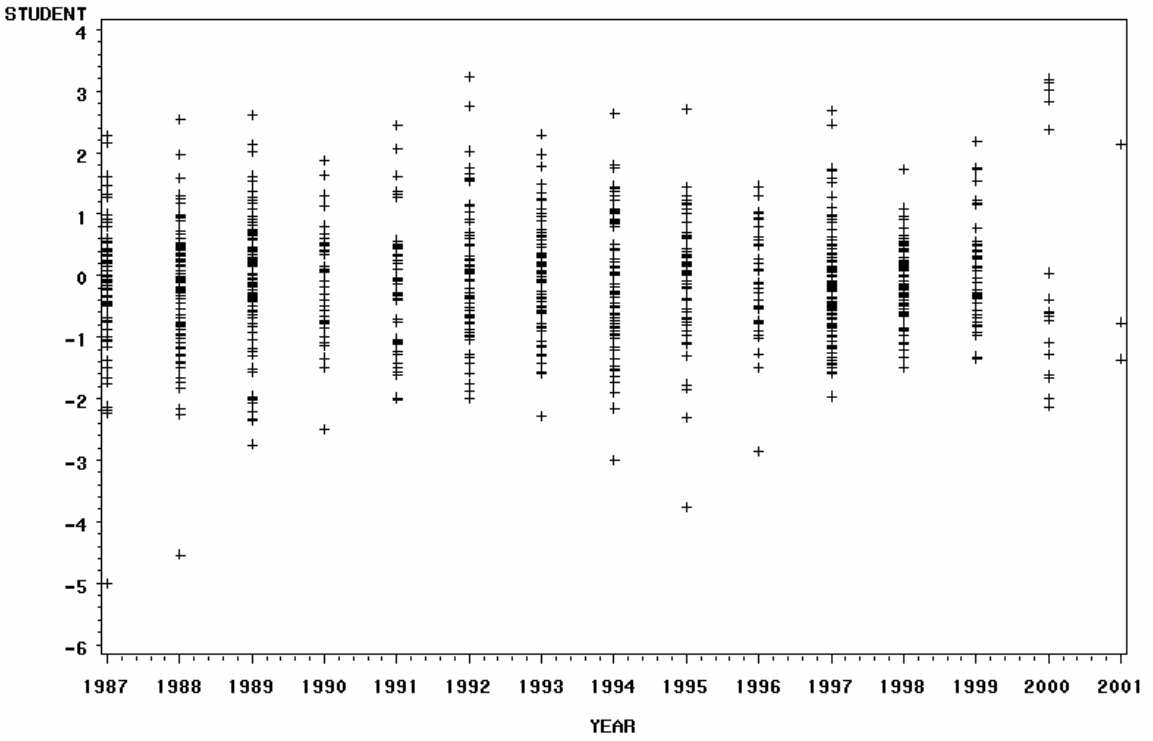
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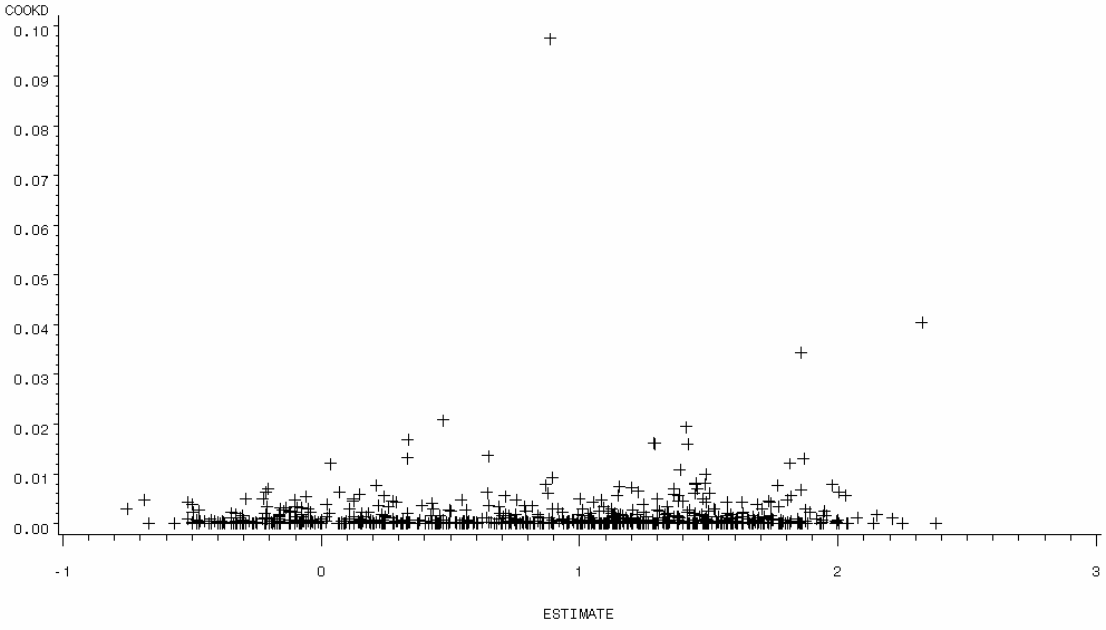
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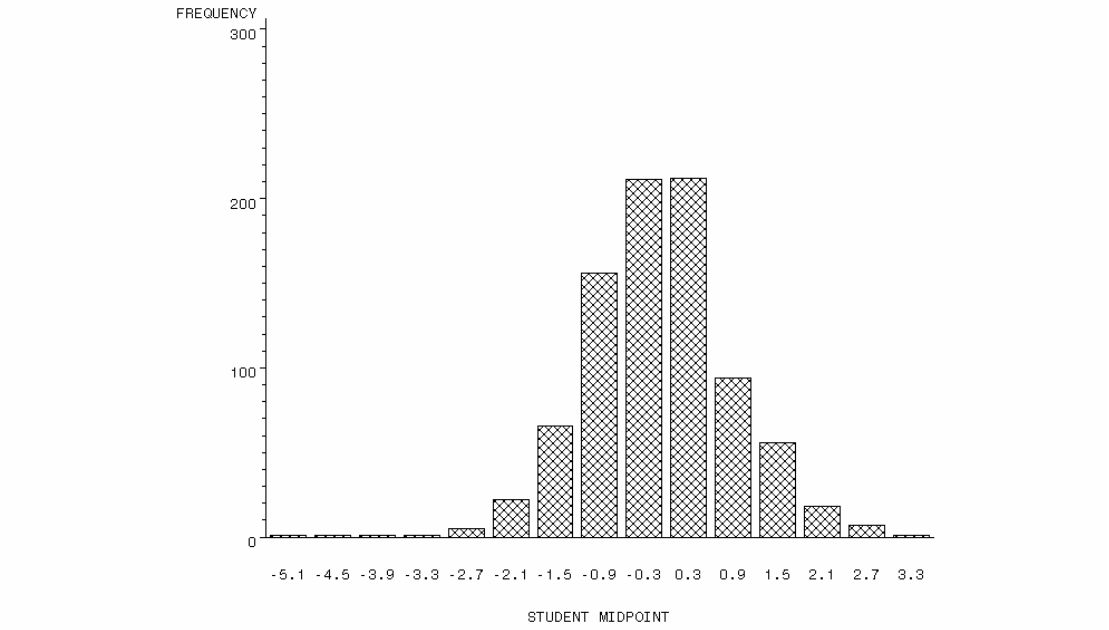
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STUDENT MIDPOINT