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An assessment of the shrimp stock in Denmark Strait / off East Greenland – 2009.

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 exploited the stock taking annual catches between 11.500 tons and 14.000 tons from 1994 to 2003. Catches decreased to 3118 tons in 2008, the lowest since 1980. 2009 catches, up to October, were close to 5000 tons. A biomass index decreased steadily from 1987 to 1993, but then showed an increasing trend until the beginning of the 2000s. It fluctuated without trend until 2008, and then nearly doubled in 2009. However, part of the fishing fleet has decreased their effort in recent years, which gives some uncertainty on whether recent values are a true reflection of the stock biomass. The index of harvest rates have declined since 1993 and recent levels are the lowest of the time series.

Sampling of the commercial fishery is nonexistent and consequently insufficient to obtain annual estimates of catch 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 (Fig.1) in depths down to around 800 meters. 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.

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 15000 tons during the following 10-year period. Total catches fluctuated around 12000 tons from 1994 to 2003 (Table 1, Fig. 2A). Catches decreased to 3118 tons in 2008. The catch in 2009 (until October) is nearly 5000 tons. 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.1). However, in 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell. At any time access to fishing grounds depends on ice conditions.

During the recent ten years fleets from Greenland, EU-Denmark, the Faroe Islands and Norway have participated in the fishery in the Greenlandic zone. The fishery is managed by a Total Allowable Catch (TAC) in the Greenlandic EEZ.

Icelandic vessels operate exclusively in the Icelandic EEZ and the fishery is unrestricted by management initiatives. Annual catches in the Greenlandic zone from 1999 to 2005 accounted for 70-99 % of the total catches. Since 2006 there has been no fishery in the Icelandic zone. Vessels taking part in the fishery on both sides of the national midline are large factory trawlers in the range of 1000-4000 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 and catch-per-unit-effort based biomass indices and indices of harvest rate.

Materials and methods

Raw data

Logbooks from Greenland, Iceland, Faroe Islands and EU-Denmark since 1980, from Norway since 2000 and from EU-France for the years 1980 to 1991 supplied data on catch and effort (hours fished) on a by haul basis. Since 1998 approximately 40% of all hauls were performed with double trawl and the 2009 assessment included both single and double trawl in the standardized catch rates calculations. The catches in the Greenland EEZ were corrected "overpack" according to Hvingel 2003.

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 geographical distribution of the fishery is shown by plotting the unstandardized CPUE by statistical units of 7.5' latitude and 15' longitude.

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, EU and Norwegian vessels, operating exclusively in the Greenlandic zone and from the Icelandic fleet fishing exclusively in the Icelandic zone (north of 65°N). Until 2005 Norwegian fishery data was considered to have too sparse information on the different areas fished and data was therefore not included in the standardized catch rates calculations. In 2006 Norwegian fishery data was included in the catch rates calculations after a positive evaluation of new logbook data from Greenland License Office, where Norwegian fishery data has been recorded in standard format since 2000.

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, (4) annual mean CPUE and (5) single and double trawl. 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. To reduce the number of empty cells in the models, classes of effect variables were combined, if a pairwise contrast analyses had an F statistic less than one. However, posterior grouping on the basis of similar effects causes uncertainty to be underestimated.

For the model pertaining to the Greenlandic zone 75 of 112 vessels met the criteria for inclusion in the analysis (at least three years of fishing in the area). Based on an exploratory run of the main effects model the vessel effect was collapsed into 15 groups consisting of 2-10 vessels with similar fishing power. The month effect was reduced to 9 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 from 1987 to 2005. Almost no fishery has been conducted in 2005 (21 tons) and there has been no fishery since 2006. The 61 vessels qualifying for the index were collapsed into 18 groups consisting of 1-8 vessels of equal fishing power. The month effect was reduced to 6 levels. No area effect was included. A two level trawl effect was introduced to account for the effect of twin trawling.

Results and diagnostically output from the GLM run show that data from the Icelandic zone in 2005 (catches was very small in 2005) was unsuitable to further analyses and therefore not included. This analysis has not been repeated since 2006.

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 be 0.9 and 0.1 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.

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. 1). In 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell. From 1996 to 2005 catches in the area south of 65°N accounted for around 50% of the total catch (Fig 2A, 2B). Since 2004 catches and effort in the area south of 65°N appears to be decreasing (Fig. 5a, b, c, d, e). In 2009 the catches and effort in the area south of 65°N has increased.

Catch

As the fishery developed, catches increased rapidly to more than 15000 tons in 1987-88, but declined thereafter to about 9000 tons in 1992-93(Fig. 2A, Table 1 and 2). Following the area expansion of the fishery south of 65°N in 1993 catches increased again reaching 11900 tons in 1994. From 1994 to 2003 catches fluctuated between 11500 and 14000 tons (Fig. 2A). In 2004 the catches started dropping, from 10000 tons in 2004 to a low of 3100 tons in 2008. 5000 tons has already been caught during the first 9 months of 2009.

In the northern area the amount caught has declined by about 85%, i.e. from 15000 tons in 1988 to 2200 tons in 2001 (Fig. 2A, Table 2). Catch and effort more than doubled in 2002 to 5350 tons and 20000 hours, but decreased again thereafter to around 2850 tons and 6200 hours in 2008 (Table 2, Fig. 2A and 2B). 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.

Catches in the southern area increased from 1900 tons in 1993 - the first year of fishery in this area - to about 11.700 tons in 2001 (Fig. 2A). Since 2001 catches in the southern area has declined reaching a low of 265 tons in 2008. In 2009 the catch taken during the first 9 months of the year in the southern area has gone up amounting to 1300 tons.

Fishing effort

The high increase in catches during the first ten-year period was mainly driven by increased fishing effort (Fig. 2B, Table 2). Between 1981 and 1989, total effort increased from about 20000 hr's to a peak of nearly 120000 hours and has declined since then to a low of 6824 hours in 2008 (Table 2, Fig. 2B). In 2009 (until October) total effort is 6825.

The historic development of fishing effort spent in the northern area follows the one described for the total area closely – except for 2001, when a lot of effort shifted to the south. In the southern areas, effort increased from about 10000 hours in 1993 to 25000 hours in 1997. In 1999 it reached a low of 7500 hr's but increased again to 20000 hr's in 2001. Since then effort in the southern area has been declining to less than 600 hours in 2008. The preliminary value for 2009 is more than 1000 hours (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 502 kg/hr in 2003 (Fig. 2C, Table 2). The catch rate in 2004 was 365 kg/hr rising slowly to 457 kg/hr in 2008. Provisional data from 2009 indicates an increase to 717 kg/hr, the highest catch rate ever obtained.

In the southern areas CPUE increased from 204 kg/hr in 1993 to 925 kg/hour in 1999. During the following years the mean CPUE in this area fluctuated between 450 and 700 kg/hr. Provisional data from 2009 indicates a CPUE at nearly 1300 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 1994-2002 CPUE's have fluctuated around 225 kg/hr except for an extreme low of 129 kg/hr in 1996. From 2003 to 2007 annual mean CPUE fluctuated around 350 kg/hr rising to 457 kg/hr in 2008. Provisional data for 2009 indicates catch rates around 660 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 for Greenland and Iceland were 68% and 78%, respectively. The model-diagnostical outputs (see appendix) indicate that the model and error structures were correct. All first-order interactions between the effects of YEAR, MONTH and VESSEL were also highly significant, suggesting that the effect of YEAR on CPUE differ from month to month and from vessel to vessel. The contributions of these interactions to the variability within the data set however were small compared to that of the main effects. Thus, the basic model without interactions was considered a good description of the data.

The combined CPUE index for the total area (Fig. 3, Table 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 1990's. The mean index values increased thereafter and stabilized at a level one third above that of 1987 until 2008. Preliminary data for 2009 indicates that the index has more than doubled compared to 1987.

The CPUE index series of the northern areas (Fig. 3, Table 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. From 2004 to 2007 the mean index values have stabilized at a level one third above that of 1987. In 2008 the index increased 1½ times compared to 1987 and in 2009 the index increased 2½ times compared to 1987 (Provisional data for 2009). The CPUE index series of the southern area (Fig. 3, Table 3) increased until 1999, with stability until 2008. In 2009 the index rose with one third compared to the period from 2000 to 2008 (Provisional data).

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, have shown a decreasing trend since the mid 1990s for the total area (Table 3, Fig. 4) reaching its lowest levels in 2008 and 2009. The separate indices for the northern and southern areas are also shown in Fig. 4 and follows the trend seen for the total area. As mentioned in the previous section the development in the harvest rate indices might be to optimistic.

Conclusions

Total catches fluctuated around 12000 tons from 1994 to 2003 (Table 1, Fig. 2A). Catches decreased thereafter to 3100 tons in 2008. Provisional data indicate that catches will double in 2009 compared to 2008.

There is no recent information on stock size composition.

A combined standardized catch-rate index for the total area decreased steadily from 1987 to 1993(Fig. 3C), showed an increasing trend until 2000, and fluctuated at this level thereafter, but has shown a steep increase in 2009 (Provisional data for 2009).

Since the mid 1990s exploitation rate index (standardized effort) has decreased to its lowest levels in the series.

State of the stock: Standardized CPUE data for all the areas combined indicates an increasing trend in the fishable biomass from 1993 to beginning of 2000s and has fluctuated at this level until 2009, where an increase is seen. However, part of the fishing fleet has decreased their effort in recent years, which gives some uncertainty on whether recent values are a true reflection of the stock biomass.

References

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Table 1. Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland 1981 to October 2009. Values for the fishery in the Greenland EEZ by EU-Denmark, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel 2003.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004[1,5]	2005[1]	2006[1]	2007[1]	2008[1]	2009[1,2]
North of 65°N																					
EU (DK,EST,LTU)	454	476	450	199	138	250	302	26	85	401	793	459	72	816	861	482	304	618	421	389	1002
Faroe Islands	738	1029	1265	1355	689	462	931	995	635	1268	867	956	214	1029	1062	894	615	342	319	614	1311
France	472	62	148	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-
Greenland	7408	7580	5283	2496	1771	1326	2390	359	105	646	614	115	650	638	695	578	454	223	802	225	723
Iceland	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1231	703	411	29	0	0	0	0
Norway	2601	3052	3146	3102	1831	2180	2402	1544	797	1628	1783	2759	1291	1630	2861	2700	2614	2704	1771	1625	528
Total	12999	12480	10757	8901	6982	5731	7176	3490	4478	5364	4827	4420	2237	5344	6183	5065	4016	3887	3314	2853	3563
South of 65°N																					
Denmark (EU)	-	-	-	-	60	613	731	1167	1657	1300	1095	1900	2473	2309	1827	1022	644	683	431	251	12
Faroe Island	-	-	-	-	280	974	295	402	656	138	453	340	2402	1013	303	255	176	227	169	14	43
Greenland	-	-	-	-	1141	3603	2667	5295	4701	3950	4966	5235	4943	4333	4194	3488	2737	316	639	0	809
Norway	-	-	-	-	424	1011	720	1590	2261	670	378	157	1855	1098	197	186	180	76	48	0	462
Total	-	-	-	-	1904	6201	4412	8453	9276	6057	6893	7632	11674	5985	6522	4951	3737	1302	1286	265	1327
Total area																					
EU (DK,EST,LTU)	454	476	450	199	198	863	1033	1193	1742	1701	1888	2358	2545	2548	2688	1504	948	1301	852	640	1014
Faroe Islands	738	1029	1265	1355	968	1436	1225	1397	1292	1406	1321	1296	2616	1322	1365	1149	791	569	488	628	1354
France	472	62	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	7408	7580	5283	2496	2912	4929	5057	5655	4806	4595	5581	5349	5593	4484	4890	4066	3191	539	1441	225	1532
Iceland	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1231	703	411	29	0	0	0	0
Norway	2601	3052	3146	3102	2255	3190	3122	3133	3059	2298	2160	2917	3147	1743	3059	2886	2794	2780	1819	1625	990
Total	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11329	12705	10016	7753	5189	4600	3118	4890
Total all areas	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12637	9985	7753	5189	4600	3118	4890
Advised TAC	100003	100003	100003	8000	5000	5000	5000	5000	5000	5000	9600	9600	9600	9600	9600	12400	12400	12400	12400	12400	12835
Effective TAC[3]	90255	14100	14500	13000	9563	9563	9563	9563	9563	9563	10600	12600	10600	10600	10600	15043	12400	12400	12400	12400	12835

[1] Provisional
[2] Catch in 2008 until October
[3] For Greenland zone only; no restrictions in Iceland zone
[4] Not including Greenland fishery north of 66°30'N

Table 2. Catch (tons), effort (hrs) 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	72736	172				12480	72736	172
1991	10757	78714	137				10757	78714	137
1992	8901	68349	130				8901	68349	130
1993	6982	52381	133	1904	9335	204	8886	61003	146
1994	5731	31417	182	6201	18371	338	11932	49428	241
1995	7176	33953	211	4412	13157	335	11588	46927	247
1996	3490	27029	129	8453	24589	344	11944	51049	234
1997	4478	22175	202	9276	25992	357	13754	47519	289
1998	5364	20881	257	6057	10498	577	11422	31205	366
1999	4827	19388	249	6893	7449	925	11719	25742	455
2000	4420	17474	253	7632	10705	713	12053	28096	429
2001	2237	9822	228	11674	20435	571	13911	29933	465
2002	5344	20052	267	5985	8546	700	11329	22843	496
2003	6183	18053	342	6522	9317	700	12705	25295	502
2004	5065	15848	320	4951	8972	552	10016	27450	365
2005	4016	11251	357	3737	8004	467	7753	19257	403
2006	3887	10413	373	1302	2436	534	5189	12851	404
2007	3314	8977	369	1286	1974	651	4600	10951	420
2008	2853	6238	457	265	585	454	3118	6824	457
2009*	3563	5410	659	1327	1023	1297	4890	6825	717

*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 2009.

	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	0.87	0.08	1.17	0.11					0.84	0.06	1.21	0.00
1989	0.61	0.06	1.42	0.13					0.57	0.04	1.50	0.11
1990	0.60	0.06	1.38	0.13					0.57	0.04	1.45	0.10
1991	0.51	0.05	1.40	0.13					0.48	0.03	1.49	0.11
1992	0.41	0.04	1.42	0.14					0.39	0.03	1.52	0.11
1993	0.34	0.03	1.37	0.14	1.00	-	1.00	-	0.37	0.03	1.61	0.12
1994	0.79	0.08	0.48	0.05	2.25	0.18	1.45	0.11	0.95	0.07	0.84	0.06
1995	0.65	0.07	0.73	0.08	1.90	0.19	1.22	0.11	0.71	0.06	1.08	0.08
1996	0.59	0.07	0.39	0.05	2.65	0.21	1.68	0.13	0.97	0.08	0.82	0.06
1997	0.79	0.10	0.38	0.05	2.52	0.21	1.94	0.16	1.06	0.09	0.86	0.07
1998	1.01	0.12	0.35	0.04	2.82	0.27	1.13	0.10	1.14	0.10	0.66	0.06
1999	0.87	0.11	0.37	0.05	3.66	0.44	0.99	0.11	1.15	0.11	0.68	0.07
2000	1.07	0.12	0.27	0.03	3.60	0.34	1.11	0.10	1.25	0.10	0.64	0.05
2001	0.94	0.13	0.16	0.02	2.75	0.22	2.23	0.17	1.27	0.10	0.73	0.06
2002	0.97	0.12	0.37	0.05	3.39	0.30	0.93	0.08	1.39	0.12	0.54	0.05
2003	0.94	0.10	0.44	0.05	2.83	0.26	1.21	0.11	1.08	0.09	0.78	0.06
2004	1.29	0.14	0.26	0.03	2.73	0.30	0.95	0.10	1.21	0.10	0.55	0.05
2005	1.30	0.15	0.20	0.02	3.45	0.39	0.57	0.06	1.40	0.13	0.37	0.03
2006	1.36	0.16	0.19	0.02	3.29	0.46	0.21	0.03	1.36	0.13	0.25	0.02
2007	1.20	0.14	0.18	0.02	3.63	0.56	0.19	0.03	1.24	0.12	0.25	0.02
2008	1.55	0.20	0.12	0.02	2.32	0.65	0.06	0.01	1.41	0.16	0.14	0.02
2009	2.45	0.37	0.10	0.01	4.87	1.77	0.14	0.04	2.32	0.32	0.14	0.02

Figure 1. Thematic mapping of different values of effort (in hours) in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2000-2005.

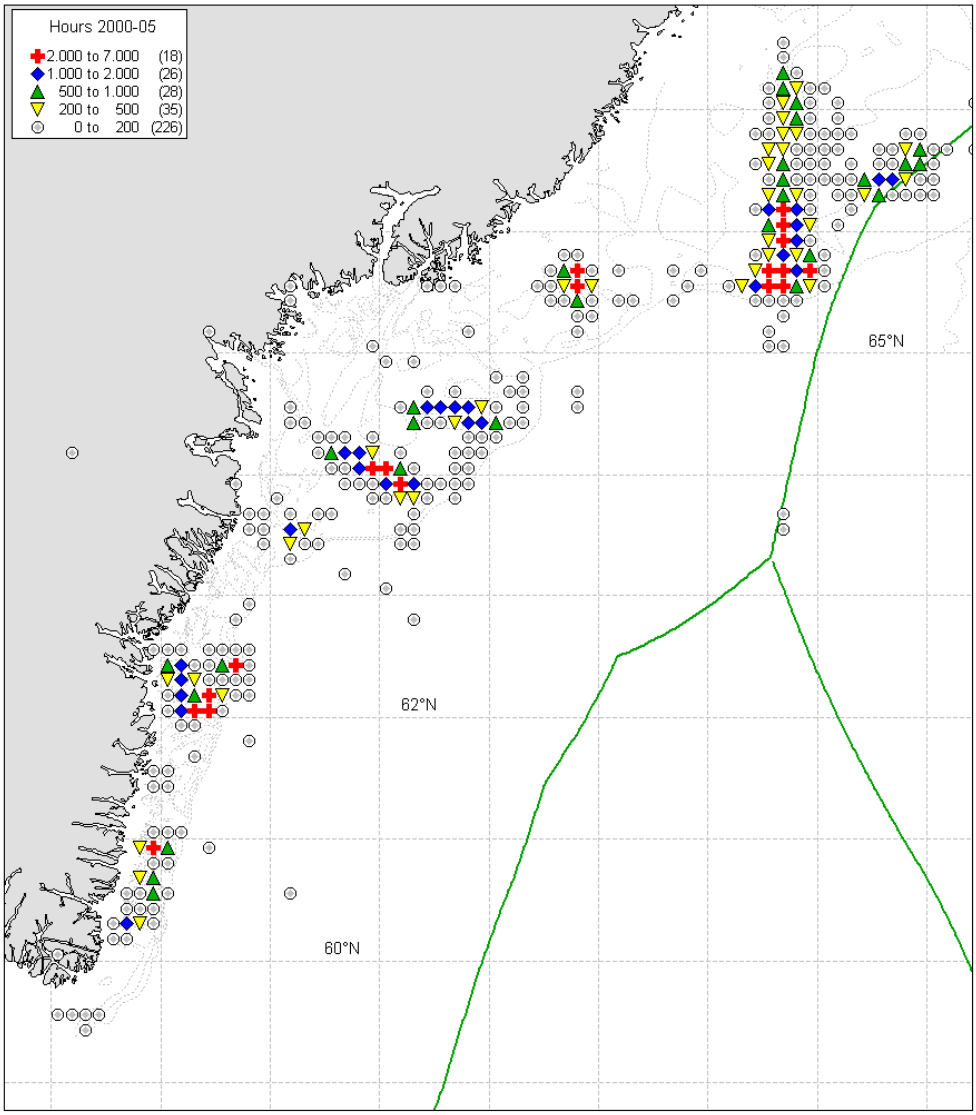


Figure 2. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall.

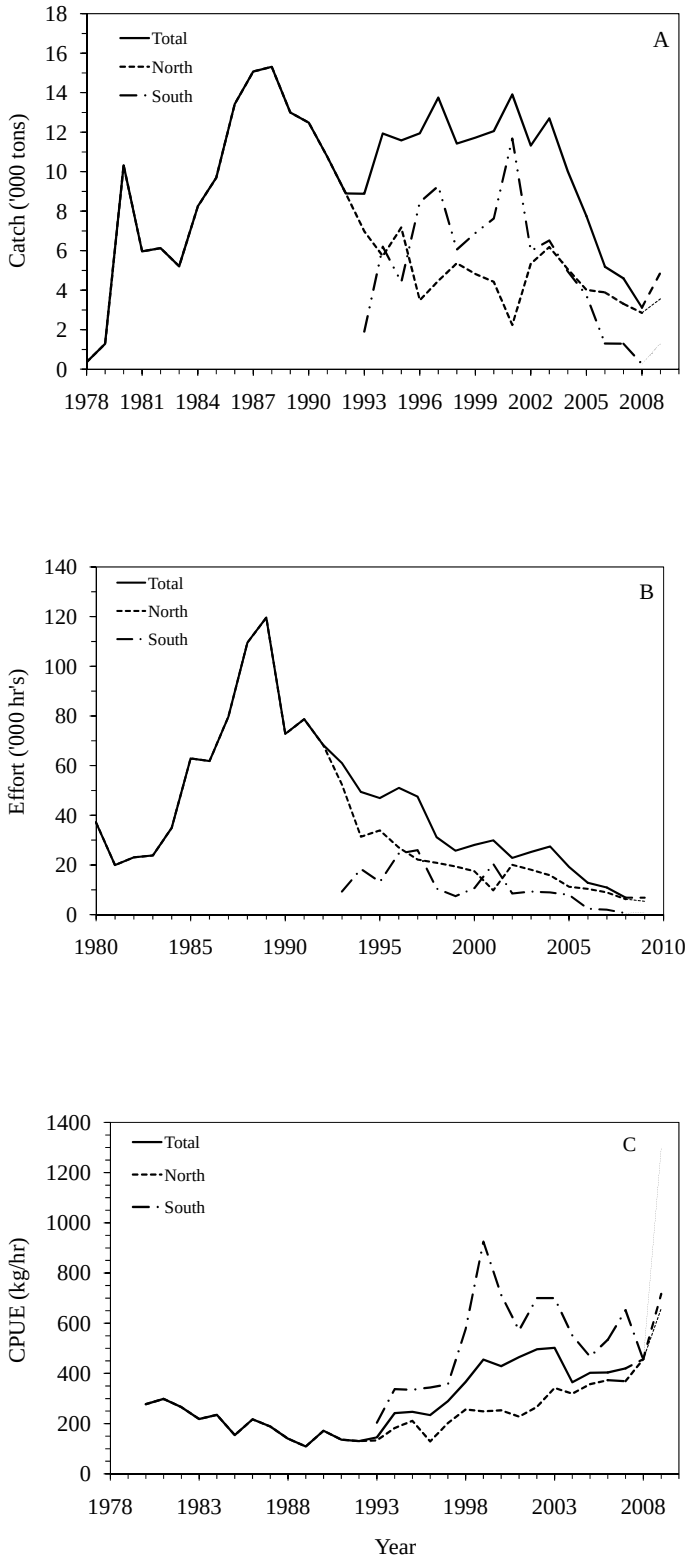
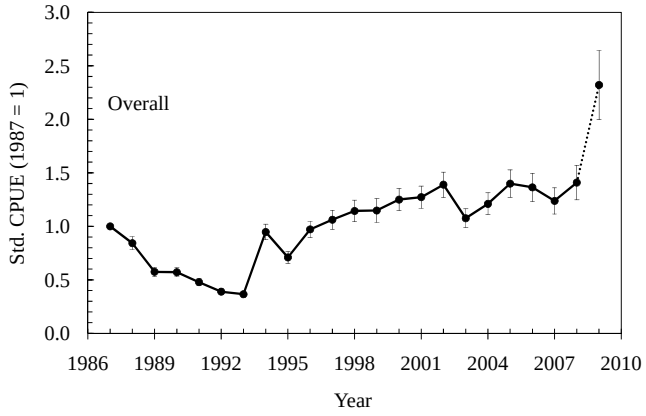
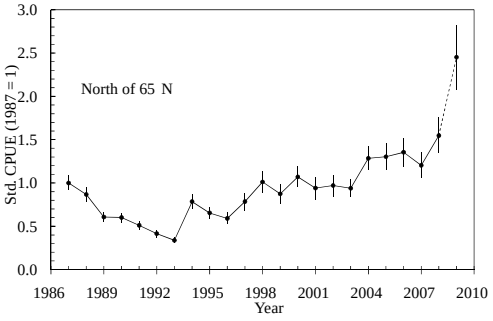


Figure 3. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas south of 65°N, in Iceland EZZ, overall fishery north of 65°N (both in Greenland and Iceland EEZ), and overall standardized CPUE for the stock. Estimates are based on data until October 2009.





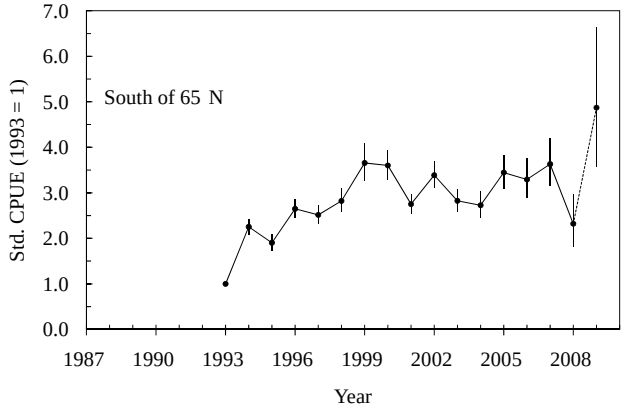
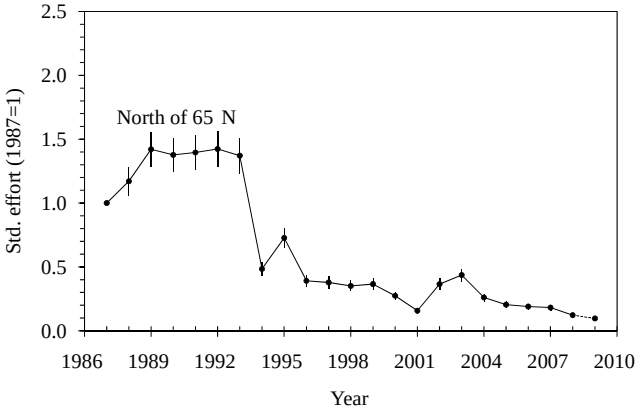
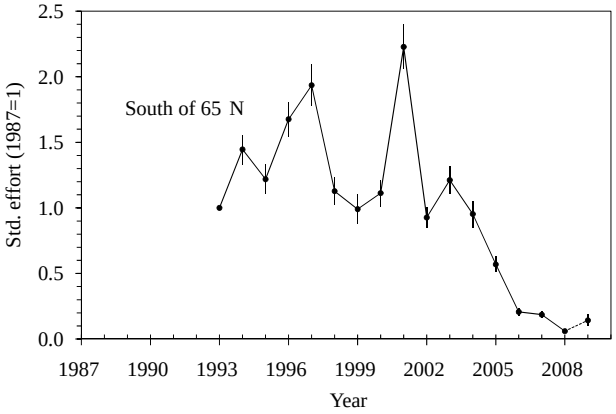


Figure 4. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until October 2008





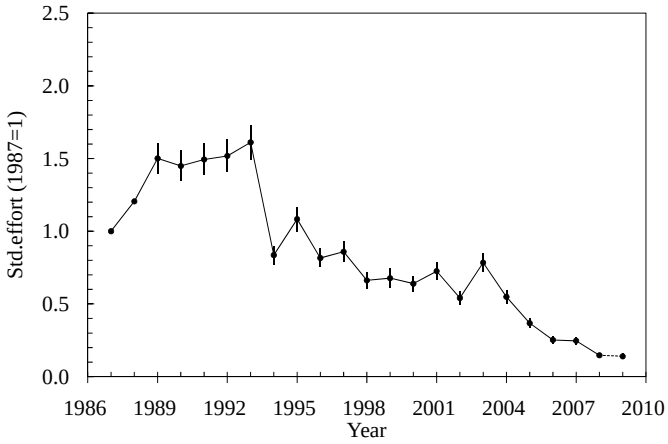


Figure 5a. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2005.

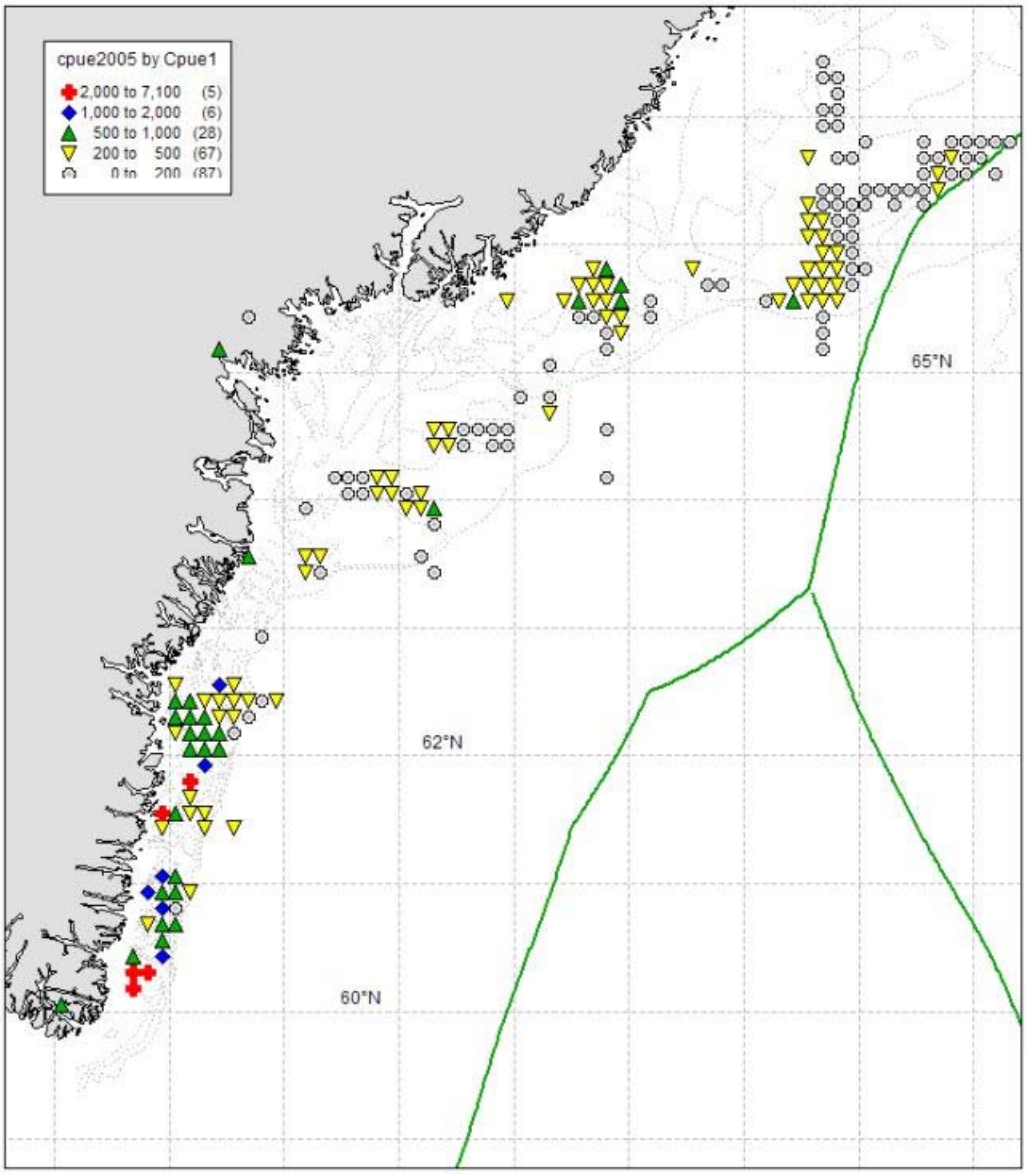


Figure 5b. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2006.

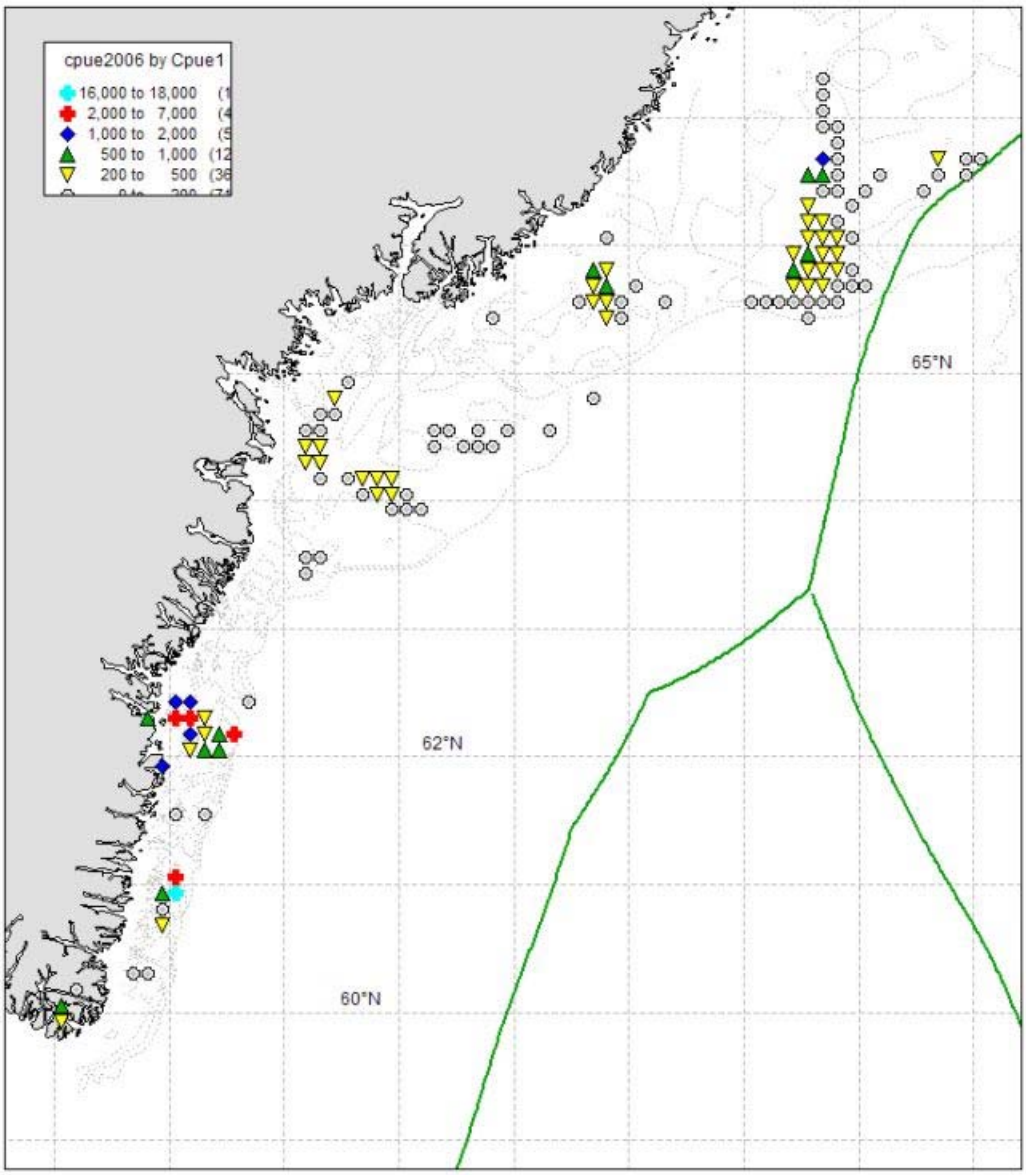


Figure 5c. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2007.

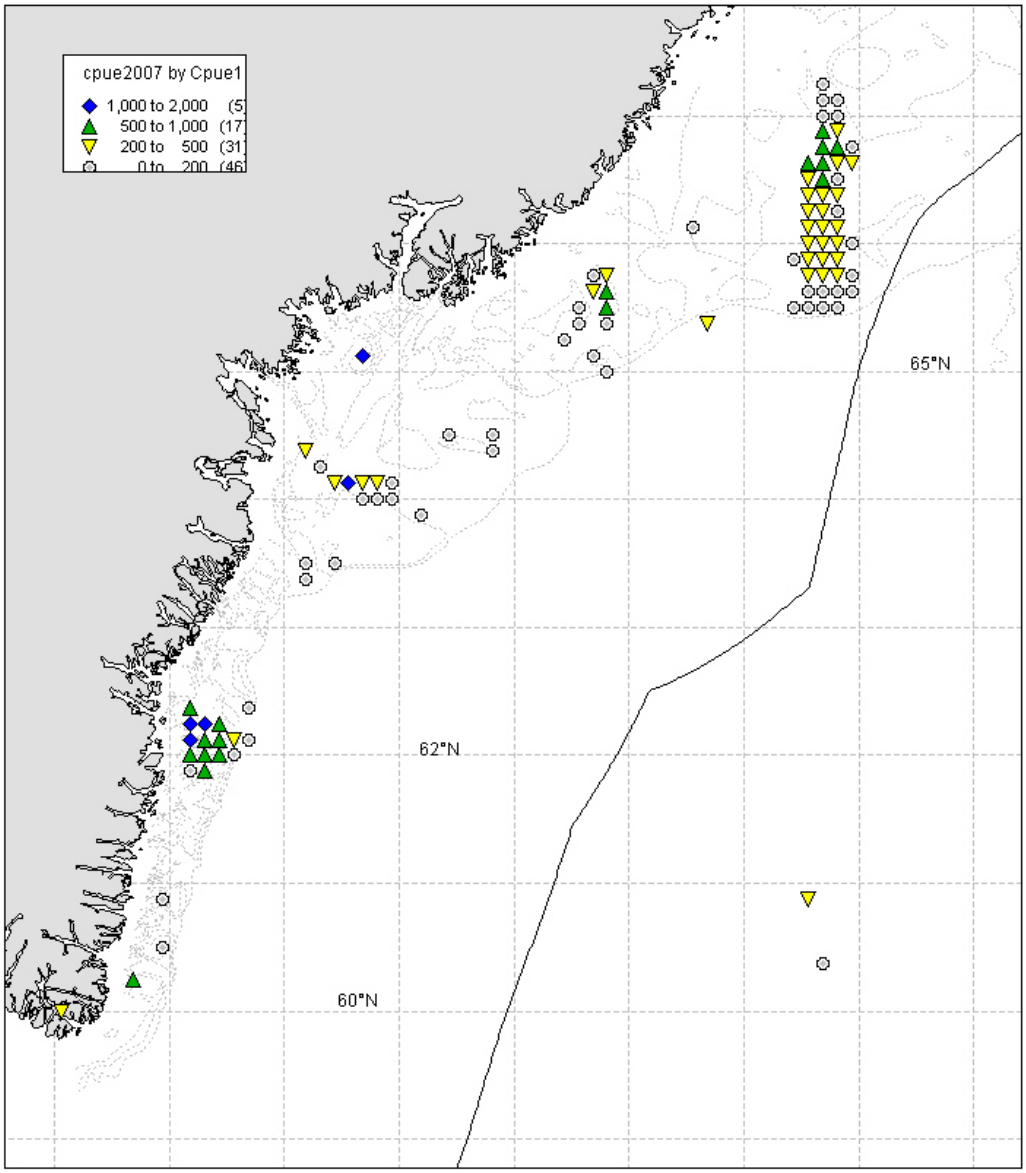


Figure 5d. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2008 (until October).

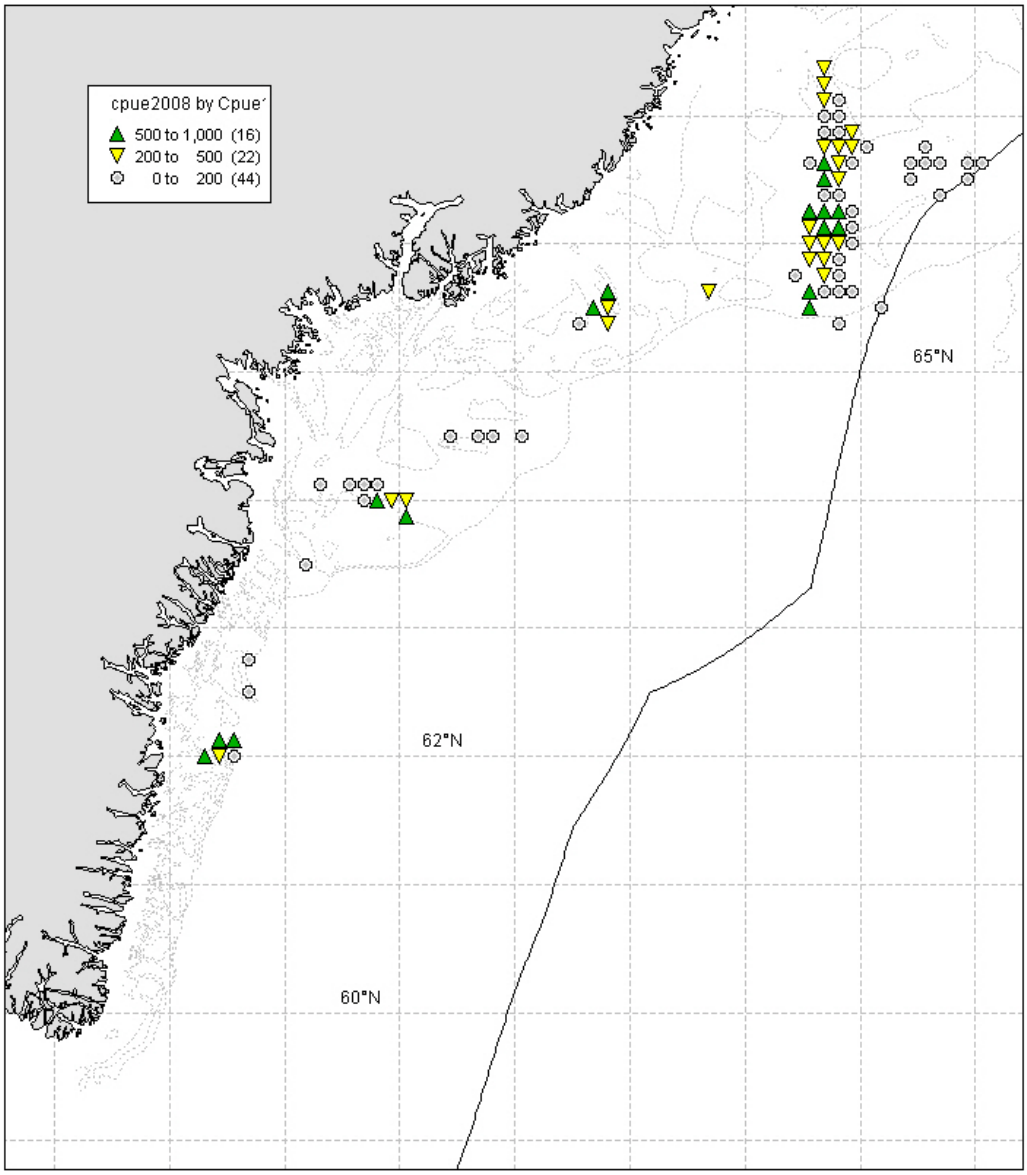
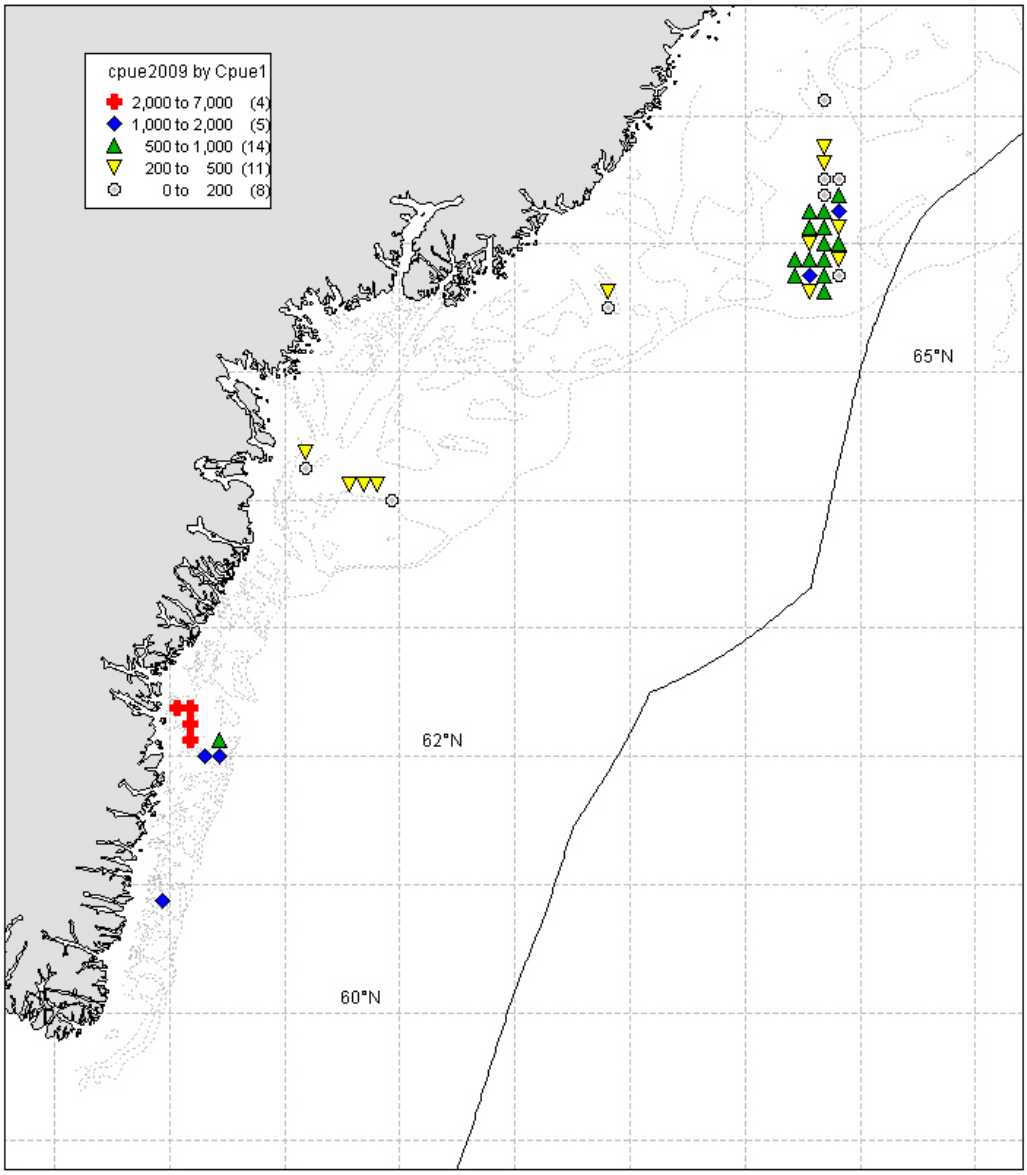


Figure 5e. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2009 (until October).



Appendix 1. Results and diagnostical outputs from GLM run of model for standardising CPUE in Greenlandic zone. Data from Greenlandic, Faeroese, Norway and EUvessels.

```
                          The SAS System                          1


                        The GLM Procedure

                    Class Level Information

Class       Levels  Values

BAAD            15  E005 E010 E013 E018 E024 E028 E030 E033 E043 E048
                    E057 E062 E067 E069 E075

YEAR            23  87 88 89 90 91 92 94 95 96 97 98 99 100 101 102
                    103 104 105 106 107 108 109 111

MONTH            9  1 2 4 5 6 7 8 11 12

AREA             2  21 22

HOLD             2  2 9


               Number of Observations Read        3093
               Number of Observations Used        3093
```

The GLM Procedure

Dependent Variable: LNCPUE

Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	62	49393.05028	796.66210	103.60	<.0001
Error	3030	23299.14397	7.68949		
Corrected Total	3092	72692.19425			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.679482	254.9518	2.772992	1.087653

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	14	22164.04594	1583.14614	205.88	<.0001
YEAR*AREA	39	22980.62393	589.24677	76.63	<.0001
MONTH	8	4230.70521	528.83815	68.77	<.0001
AREA	0	0.00000	.	.	
HOLD	1	17.67520	17.67520	2.30	0.1296

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	14	8832.83004	630.91643	82.05	<.0001
YEAR*AREA	38	14692.12234	386.63480	50.28	<.0001
MONTH	8	4200.26449	525.03306	68.28	<.0001
AREA	1	2045.05143	2045.05143	265.95	<.0001
HOLD	1	17.67520	17.67520	2.30	0.1296

The GLM Procedure

Dependent Variable: LNCPUE

Weight: Hauls

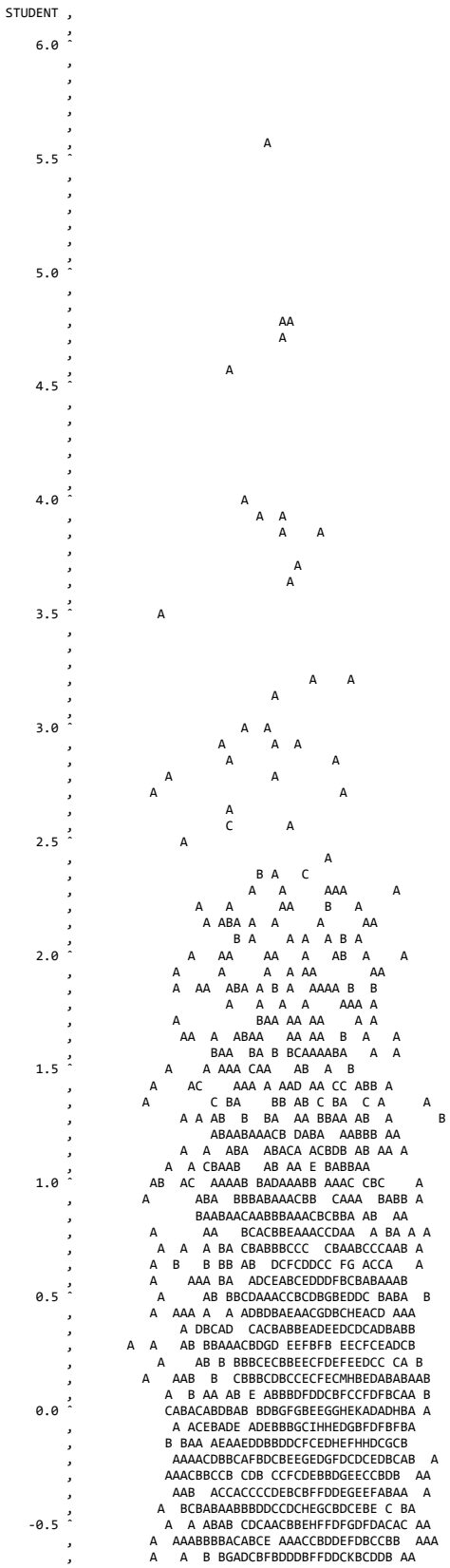
Contrast	DF	Contrast SS	Mean Square	F Value
m01 v m02	1	17.9986290	17.9986290	2.34
m02 v m04	1	198.1861193	198.1861193	25.77
m04 v m05	1	33.3405056	33.3405056	4.34
m05 v m06	1	13.9554616	13.9554616	1.81
m06 v m07	1	104.7589701	104.7589701	13.62
m07 v m08	1	90.5671298	90.5671298	11.78
m08 v m11	1	313.9343176	313.9343176	40.83
m11 v m12	1	544.7172318	544.7172318	70.84
E005 v E010	1	17.9133349	17.9133349	2.33
E010 v E013	1	24.3743409	24.3743409	3.17
E013 v E018	1	10.4619458	10.4619458	1.36
E018 v E024	1	27.4206646	27.4206646	3.57
E024 v E028	1	30.5984963	30.5984963	3.98
E028 v E030	1	15.1999735	15.1999735	1.98
E030 v E033	1	14.5707928	14.5707928	1.89
E033 v E043	1	10.3368634	10.3368634	1.34
E043 v E048	1	27.5839756	27.5839756	3.59
E048 v E057	1	16.9753823	16.9753823	2.21
E057 v E062	1	29.9433250	29.9433250	3.89
E062 v E067	1	64.0206101	64.0206101	8.33
E067 v E069	1	29.0679375	29.0679375	3.78
E069 v E075	1	14.2040537	14.2040537	1.85

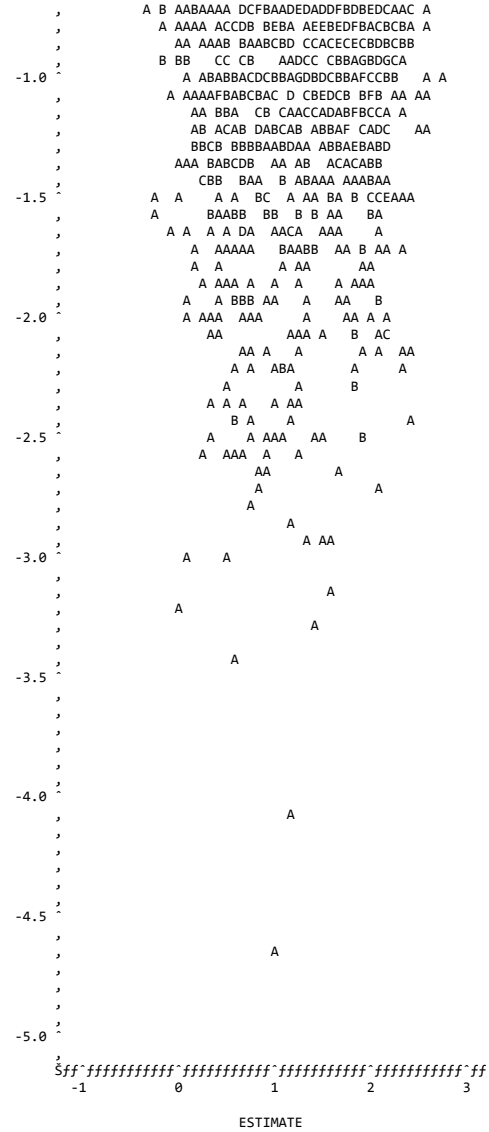
Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		1.045878747	B	0.08363970	12.50	<.0001
BAAD	E005	-1.140216048	B	0.07506901	-15.19	<.0001
BAAD	E010	-1.045206609	B	0.06810821	-15.35	<.0001
BAAD	E013	-0.942330739	B	0.07228221	-13.04	<.0001
BAAD	E018	-0.872112177	B	0.06983146	-12.49	<.0001
BAAD	E024	-0.776538550	B	0.06402868	-12.13	<.0001
BAAD	E028	-0.693126087	B	0.06366835	-10.89	<.0001
BAAD	E030	-0.632012771	B	0.06529665	-9.68	<.0001
BAAD	E033	-0.564845820	B	0.06724183	-8.40	<.0001
BAAD	E043	-0.516468412	B	0.06014143	-8.59	<.0001
BAAD	E048	-0.426325227	B	0.06951090	-6.13	<.0001
BAAD	E057	-0.353045714	B	0.06201090	-5.69	<.0001
BAAD	E062	-0.279144218	B	0.06012949	-4.64	<.0001
BAAD	E067	-0.180104943	B	0.05934502	-3.03	0.0024
BAAD	E069	-0.092293326	B	0.06790673	-1.36	0.1742
BAAD	E075	0.000000000	B	.	.	.
MONTH	1	0.312908709	B	0.03034223	10.31	<.0001
MONTH	2	0.273548031	B	0.03038823	9.00	<.0001
MONTH	4	0.149202649	B	0.02937254	5.08	<.0001
MONTH	5	0.069201210	B	0.04278804	1.62	0.1059
MONTH	6	-0.041754272	B	0.07930326	-0.53	0.5986
MONTH	7	0.324584378	B	0.07233820	4.49	<.0001
MONTH	8	0.051470808	B	0.05236916	0.98	0.3258
MONTH	11	-0.267101781	B	0.03173510	-8.42	<.0001
MONTH	12	0.000000000	B	.	.	.
AREA	21	0.000000000	B	.	.	.
AREA	22	0.000000000	B	.	.	.
HOLD	2	0.046183649	B	0.03046174	1.52	0.1296
HOLD	9	0.000000000	B	.	.	.

Parameter	Estimate	Standard Error	t Value	Pr > |t|
YEAR*AREA 87 21	0.724286443 B	0.07132356	10.15	<.0001
YEAR*AREA 88 21	0.518916780 B	0.06743630	7.69	<.0001
YEAR*AREA 89 21	0.116857963 B	0.06660051	1.75	0.0794
YEAR*AREA 90 21	0.106909668 B	0.06656712	1.61	0.1084
YEAR*AREA 91 21	-0.089522292 B	0.06570362	-1.36	0.1731
YEAR*AREA 92 21	-0.301046615 B	0.06875012	-4.38	<.0001
YEAR*AREA 94 21	0.347677550 B	0.08397128	4.14	<.0001
YEAR*AREA 94 22	0.811920788 B	0.07713321	10.53	<.0001
YEAR*AREA 95 21	0.177897447 B	0.07578566	2.35	0.0190
YEAR*AREA 95 22	0.642690729 B	0.09306893	6.91	<.0001
YEAR*AREA 96 21	0.077923769 B	0.09167063	0.85	0.3954
YEAR*AREA 96 22	0.974076190 B	0.07800799	12.49	<.0001
YEAR*AREA 97 21	0.397598912 B	0.11285398	3.52	0.0004
YEAR*AREA 97 22	0.922928902 B	0.08181758	11.28	<.0001
YEAR*AREA 98 21	0.740638941 B	0.10434466	7.10	<.0001
YEAR*AREA 98 22	1.037412350 B	0.09245922	11.22	<.0001
YEAR*AREA 99 21	0.542015922 B	0.10782771	5.03	<.0001
YEAR*AREA 99 22	1.296255513 B	0.11248532	11.52	<.0001
YEAR*AREA 100 21	0.696693068 B	0.08294621	8.40	<.0001
YEAR*AREA 100 22	1.281395019 B	0.09070416	14.13	<.0001
YEAR*AREA 101 21	0.553513781 B	0.11191698	4.95	<.0001
YEAR*AREA 101 22	1.012086011 B	0.07652022	13.23	<.0001
YEAR*AREA 102 21	0.526788140 B	0.10883716	4.84	<.0001
YEAR*AREA 102 22	1.220583331 B	0.08418028	14.50	<.0001
YEAR*AREA 103 21	0.566850842 B	0.08500259	6.67	<.0001
YEAR*AREA 103 22	1.038677392 B	0.08770003	11.84	<.0001
YEAR*AREA 104 21	0.887968082 B	0.08089357	10.98	<.0001
YEAR*AREA 104 22	1.003533219 B	0.10446158	9.61	<.0001
YEAR*AREA 105 21	0.875455287 B	0.08981930	9.75	<.0001
YEAR*AREA 105 22	1.237368738 B	0.10609860	11.66	<.0001
YEAR*AREA 106 21	0.913297763 B	0.09249284	9.87	<.0001
YEAR*AREA 106 22	1.191817507 B	0.13069746	9.12	<.0001
YEAR*AREA 107 21	0.794972875 B	0.09376936	8.48	<.0001
YEAR*AREA 107 22	1.289461831 B	0.14391013	8.96	<.0001
YEAR*AREA 108 21	1.041846760 B	0.10580469	9.85	<.0001
YEAR*AREA 108 22	0.842038878 B	0.24598117	3.42	0.0006
YEAR*AREA 109 21	1.494159544 B	0.12808808	11.67	<.0001
YEAR*AREA 109 22	1.583585255 B	0.30938450	5.12	<.0001
YEAR*AREA 111 21	-0.513157942 B	0.07186065	-7.14	<.0001
YEAR*AREA 111 22	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

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

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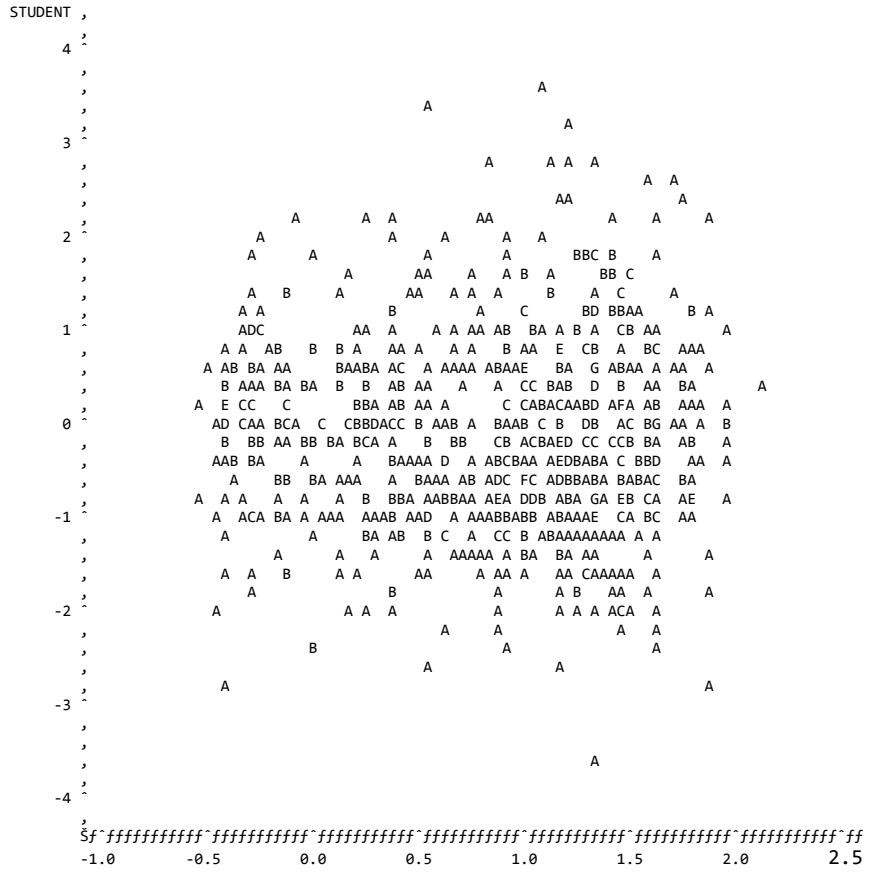
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-1
0
1
2
3
ESTIMATE

Appendix 2. Results and diagnostical outputs from GLM run of model for standardising CPUE in Islandic Zone zone. Data from Icelandic vessel only.

```
Class       Levels  Values
YEAR            18  1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002
                    2003 2004 2010
MONTH            6  1 3 5 8 10 12
SHIP             8  3100 3200 3300 3400 3500 3600 3700 3800
T                2  1 2
                              Number of Observations Read         839
                              Number of Observations Used         839
Dependent Variable: LNCPUE
Weight: EFFORT   EFFORT
                                        Sum of
       Source                     DF         Squares     Mean Square    F Value    Pr > F
       Model                      30     2464912.001       82163.733      96.60    <.0001
       Error                     808      687281.482         850.596
       Corrected Total           838     3152193.482

                     R-Square     Coeff Var      Root MSE    LNCPUE Mean
                     0.781967      4129.035      29.16498       0.706339

       Source                     DF       Type I SS     Mean Square    F Value    Pr > F
       MONTH                       5     1876847.067      375369.413     441.30    <.0001
       SHIP                        7      264825.858       37832.265      44.48    <.0001
       YEAR                       17      320504.417       18853.201      22.16    <.0001
       T                           1        2734.659        2734.659       3.21    0.0733

       Source                     DF     Type III SS     Mean Square    F Value    Pr > F
       MONTH                       5     213264.7800      42652.9560      50.14    <.0001
       SHIP                        7     206529.8841      29504.2692      34.69    <.0001
       YEAR                       17     321650.1454      18920.5968      22.24    <.0001
       T                           1       2734.6593       2734.6593       3.21    0.0733

                                                 Standard
           Parameter              Estimate             Error    t Value    Pr > |t|
           Intercept           1.321660414 B      0.17677189       7.48      <.0001
           MONTH     1        -0.637490260 B      0.34899235      -1.83      0.0681
           MONTH     3         0.520015729 B      0.14642095       3.55      0.0004
           MONTH     5         0.374949284 B      0.14508139       2.58      0.0099
           MONTH     8        -0.305620232 B      0.15027424      -2.03      0.0423
           MONTH     10       -0.398342709 B      0.14775544      -2.70      0.0072
           MONTH     12        0.000000000 B       .               .          .
           SHIP      3100     -1.005896125 B      0.13011552      -7.73      <.0001
           SHIP      3200     -0.754134016 B      0.09518021      -7.92      <.0001
           SHIP      3300     -0.629918759 B      0.08330996      -7.56      <.0001
           SHIP      3400     -0.466377476 B      0.08262698      -5.64      <.0001
           SHIP      3500     -0.346546409 B      0.08400094      -4.13      <.0001
           SHIP      3600     -0.195926626 B      0.09089502      -2.16      0.0314
           SHIP      3700     -0.160251597 B      0.08478247      -1.89      0.0591
           SHIP      3800      0.000000000 B       .               .          .
           YEAR      1988     -0.416075081 B      0.05186956      -8.02      <.0001
           YEAR      1989     -0.552896972 B      0.05802895      -9.53      <.0001
           YEAR      1990     -0.658864060 B      0.09128576      -7.22      <.0001
           YEAR      1991      0.068570010 B      0.10014730       0.68      0.4937
           YEAR      1992      0.023186723 B      0.08068950       0.29      0.7739
           YEAR      1993     -0.056355141 B      0.07407438      -0.76      0.4470
           YEAR      1994      0.259254899 B      0.08880591       2.92      0.0036
           YEAR      1995      0.270286784 B      0.11045958       2.45      0.0146
           YEAR      1996      0.100701767 B      0.11649502       0.86      0.3876
           YEAR      1997      0.103795279 B      0.08403396       1.24      0.2171
           YEAR      1998     -0.141329513 B      0.08330010      -1.70      0.0902
           YEAR      1999     -0.204163719 B      0.10246696      -1.99      0.0467
           YEAR      2000     -0.070998031 B      0.17514782      -0.41      0.6853
           YEAR      2001     -0.722745562 B      0.43162545      -1.67      0.0944
           YEAR      2002      0.500462085 B      0.09994008       5.01      <.0001
           YEAR      2003      0.252323432 B      0.10446284       2.42      0.0159
           YEAR      2004      0.108196462 B      0.12127255       0.89      0.3726
           YEAR      2010      0.000000000 B       .               .          .
           T         1        -0.154977333 B      0.08643273      -1.79      0.0733
                 T         2         0.000000000 B       .               .          .

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


STUDENT
4
3
2
1
0
-1
-2
-3
-4
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5