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An assessment of the shrimp stock
in Denmark Strait/off East Greenland – 2007.

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 12000 tons from 1994 to 2003. Catches decreased to 5107 tons in 2006 and preliminary data indicate that catches will stay at that level in 2007. A biomass index indicates that the stock decreased steadily from 1987 to 1993, but has show an increasing trend until beginning of the 2000s, and fluctuated at this level thereafter. Fishing mortality indices have decline since 1993 and recent levels are the lowest of the time series.

Sampling of the commercial fishery in recent years has been insufficient to obtain annual estimates of catch composition.

The status of the shrimp stock in Denmark Strait/off East Greenland indicates an increasing trend in the fishable biomass from 1993 to beginning of 2000s with stabilities thereafter. However, part of the fishing fleet has decreased their effort in recent years, which gives some uncertainty on whether recent values is a true reflection of the stock biomass.

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. The highest concentrations occur from 150-600 m (Fig. 1). 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 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 5100 in 2006 and preliminary data indicate that catches will stay at that level in 2007. The fishery was originally conducted north of 65°N in the Dohrnbank-Stredbank 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, Denmark, the Faroe Islands and Norway have participated in the fishery in the Greenlandic zone. Annual catches in this area accounts for around 70-98% of the total and the fishery is managed by a Total Allowable Catch (TAC). Icelandic vessels operate exclusively in the Icelandic EEZ and the fishery is unrestricted by management initiatives. Vessels taking part in the fishery on both sides of the national midline are large factory trawlers in the range of 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 2004 more than 60% of all hauls were performed with double trawl and the 2007 assessment both included 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 are shown by plotting the unstandardised 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 (Danish, Lithuania, Estonia), 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 different area fished and data was therefore not include in the standardized catch rates calculations. In 2006 Norwegian fishery data was included in the catch rates calculations after a positive evaluation of new logbooks 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:

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

Where $CPUE_{ijk}$ is the mean CPUE for vessel k , fishing in area m in month j during year i ($k = 1, \dots, n$; $m = 1, \dots, a$; $j = 1, \dots, s$; $i = 1, \dots, y$); $\ln(u)$ 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_{mjk} 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 53 of 72 vessels met the criteria for inclusion in the analysis (at least

three years of fishing in the area) i.e. 41 Greenlandic, 14 Faeroese, 5 Danish, 12 Norwegian vessels. Based on an exploratory run of the main effects model the vessel effect was collapsed into 14 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 from 1987 to 2005. Almost no fishery has been conducted in 2005 (21 tons) and there has been no fishery in 2006 and 2007. 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 2007 in the northern area (uncorrected data) and from the Icelandic zone (catches was very small in 2005) was unsuitable to further analyses and data from that area was therefore not included.

The index of the area south of 65°N

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

The combined index of the area north of 65°N

In the second calculation step the biomass index for the areas north of 65°N was derived by combining the year coefficients of the Icelandic zone model (appendix 2) and the year effects for the northern areas in the Greenlandic zone model (i.e. the 'year-area north' cross effect, see appendix 1). A Monte Carlo Markov Chain (MCMC) sampling process was used to construct distributions of likelihoods of possible values of the combined index. This was done within the programming framework WinBUGS v.1.4, (www.mrc-bsu.cam.ac.uk/bugs; Gilks *et al.* 1994; Spiegelhalter *et al.* 2000). The individual CPUE series for the p^{th} fleet, μ_{pi} , was assumed to reflect an overall biomass series, Y_i , and a constant fleet coefficient, v_p , so that:

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

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

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

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

The combined index of the total area

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

Harvest rate indices

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

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 2003 catches in the area south of 65°N accounted for more than 60% of the total catch. Since 2004 catches and effort in the area south of 65°N now appears to be decreasing (Fig. 5a,b,c).

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 catches increased again reaching 13700 tons in 1997. Catches from 1998 to 2004 have been between 10-14 000 tons (Fig. 2A). The 2006 catch decreased to 5.100 tons and preliminary data indicate that catches will stay at that level in 2007 (projected from October)

In the northern area the amount caught has declined by about 75%, i.e. from 15000 tons in 1988 to about 2000 tons in 2001 (Fig. 2A). Catch and effort more than double in 2002, but decreased again thereafter to around 4.000 tons and 10.000 hours. 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 11.000 tons in 2001 (Fig. 2A). Since 2001 catches in the southern area has declined to 1.200 tons in 2006. 2007 figures are expected to be at the 2006 level.

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 more than 119000 hr's and then declined again to a low of less than 20 000 hr's in 2002. Since then total effort had been declining to less than 13.000 hr's in 2006 - the 2007-value is expected to be at the 2006 level (Fig. 2B).

The historic development of fishing effort spent in the northern areas follow closely the one described for the total area – except for 2001, when a lot of effort shifted to the south. 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 had been declining to less than 2.300 hr's in 2006 - the 2007-value is expected to be at the 2006 level (Fig. 2B, Table 2).

Catch rate

Catch rates (total area) decreased from 278 kg/hr to 109 kg/hr in the period 1980-1989, but has shown an increasing trend since then reaching about 502 kg/hr in 2003 (Fig. 2C, Table 2). The catch rates in the last four years (2004 to 2007) are down at 400 kg/hr.

In the southern areas CPUE increased from 204 kg/hr in 1993 to 925 kg per hour in 1999. During the following years the mean CPUE obtained in this area fluctuated between 500 and 700 kg/hr. Preliminary data from 2007 indicate an increase to 870 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 of 129 kg/hr in 1996. Since 2002 annual mean CPUE was above 300 kg/hr, with 373 kg/hr estimated for 2006 and 2007.

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 68% and 78%, respectively. The model-diagnostic 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 CPUE index series of the northern areas (Fig. 3) declined from 1987 to 1993 thereafter an increasing trend was observed and by the turn of the century the index values had reached the level seen at the offset of the time series. For the recent four years the mean index values have stabilized at a level one third above that of 1987. The CPUE index series of the southern area (Fig. 3) increased until 1999, with stability thereafter.

The combined index for the total area (Fig. 3) indicated that the stock was more than halved during the period 1987-1993. After that it has been rebuilding at a corresponding rate reaching the level of 1987 in the late 1990's. The mean index values increased thereafter and have stabilized at a level one third above that of 1987.

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

Indices of harvest rate

The standardised effort, i.e. the index of harvest rate, showed a decreasing trend since 1993 for the total area (Fig. 4). The separate indices for the northern and southern areas are also shown in Fig. 4. As mentioned in the previous section the development in the harvest rate indices might be too optimistic. Furthermore, the index of 2007 also depends on the precision with which the catch is projected to the end of the year.

Conclusions

Total catches fluctuated around 12000 tons from 1994 to 2003 (Table 1, Fig. 2A). Catches decreased thereafter to 5107 tons in 2006. Preliminary data indicate that catches will stay at that level in 2007.

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.

Indices of harvest rate have shown a decreasing trend since 1993.

State of the stock: Standardized CPUE data for all the areas combined indicate an increasing trend in the fishable biomass from 1993 to beginning of 2000s and fluctuated at this level after. However, part of the fishing fleet has decreased their effort in recent years, which gives some uncertainty on whether recent values is 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 2007. Values for the fishery in the Greenland EEZ by EU-Denmark, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel 2003.

Area/Nation	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004 ^{1,3}	2005 ¹	2006 ¹	2007 ^{1,2}
North of 65°N																								
EU (DK,EST,LTU)	554	442	626	703	554	454	476	450	199	138	250	302	26	85	401	793	459	72	744	785	439	267	619	495
Faroe Islands	836	843	910	754	847	738	1029	1265	1355	689	462	931	995	635	1268	867	956	214	1029	1063	894	616	342	319
France	626	803	976	1305	616	472	62	148	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
Greenland	2815	3248	7232	8396	9304	7408	7580	5283	2496	1771	1326	2390	359	105	646	614	115	650	638	696	578	446	188	721
Iceland	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1231	703	411	29	0	0
Norway	2662	2566	2535	2586	2561	2601	3052	3146	3102	1831	2180	2402	1544	797	1628	1783	2759	1291	1630	2861	2700	2624	2705	1946
Total	8235	9696	13428	15073	15313	12999	12480	10757	8901	6982	5731	7176	3490	4478	5364	4827	4420	2237	5273	6108	5023	3981	3854	3480
South of 65°N																								
Denmark (EU)	-	-	-	-	-	-	-	-	-	60	613	731	1167	1657	1300	1095	1900	2473	2309	1903	1065	646	685	120
Faroe Island	-	-	-	-	-	-	-	-	-	280	974	295	402	656	138	453	340	2402	1013	303	255	175	227	169
Greenland	-	-	-	-	-	-	-	-	-	1141	3603	2667	5295	4701	3950	4966	5235	4943	4333	4194	3488	2687	265	573
Norway	-	-	-	-	-	-	-	-	-	424	1011	720	1590	2261	670	378	157	1855	1098	197	186	181	76	56
Total	-	-	-	-	-	-	-	-	-	1904	6201	4412	8453	9276	6057	6893	7632	11674	6055	6597	4993	3690	1253	919
Total area																								
EU (DK,EST,LTU)	554	442	626	703	554	454	476	450	199	198	863	1033	1193	1742	1701	1888	2358	2545	2548	2688	1504	913	1304	615
Faroe Islands	836	843	910	754	847	738	1029	1265	1355	968	1436	1225	1397	1292	1406	1321	1296	2616	1322	1365	1149	791	569	488
France	626	803	976	1305	616	472	62	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	2815	3248	7232	8396	9304	7408	7580	5283	2496	2912	4929	5057	5655	4806	4595	5581	5349	5593	4484	4890	4066	3133	453	1294
Iceland	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1231	703	411	29	0	0
Norway	2662	2566	2535	2586	2561	2601	3052	3146	3102	2255	3190	3122	3133	3059	2298	2160	2917	3147	1743	3059	2886	2805	2781	2002
Total	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11329	12705	10016	7671	5107	4399
Total all areas	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12637	9985	7671	5107	4399
Advised TAC	4200	5000	-	-	-	100003	100003	100003	8000	5000	5000	5000	5000	5000	5000	9600	9600	9600	9600	9600	12400	12400	12400	12400
Effective TAC ⁵	5245	6090	75255	75255	87255	90255	14100	14500	13000	9563	9563	9563	9563	9563	9563	10600	12600	10600	10600	10600	15043	12400	12400	12400

PROVISIONAL

Catch in 2007 per Sep. 11.

For Greenland zone only; no restrictions in Iceland zone

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.

Year	Area north			Area south			Total area		
	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	4419	17470	253	7633	10706	713	12053	28096	429
2001	2230	9792	228	11681	20447	571	13911	29933	465
2002	5273	19787	267	5968	8523	700	11242	22668	496
2003	6108	17836	342	6529	9327	700	12637	25160	502
2004	5023	15718	320	4962	8991	552	9985	27365	365
2005	3981	11256	354	3682	7886	467	7663	19124	401
2006	3854	10324	373	1253	2345	535	5107	12646	404
2007*	3480	9321	373	919	1056	870	4399	10220	430

*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 2007.

Year	Area north				Area south				Total			
	Std.CPUE		Std. Effort		Std.CPUE		Std. Effort		Std.CPUE		Std. Effort	
	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se
1987	1.00	-	1.00	-					1.00	-	1.00	-
1988	0.86	0.08	1.18	0.11					0.84	0.06	1.21	0.09
1989	0.60	0.06	1.43	0.13					0.57	0.04	1.51	0.11
1990	0.60	0.06	1.37	0.13					0.57	0.04	1.45	0.11
1991	0.51	0.05	1.40	0.14					0.48	0.03	1.49	0.11
1992	0.42	0.04	1.42	0.14					0.39	0.03	1.52	0.11
1993	0.35	0.04	1.34	0.14	1.00	-	1.00	-	0.37	0.03	1.59	0.12
1994	0.80	0.09	0.48	0.05	2.33	0.19	1.40	0.11	0.99	0.08	0.80	0.06
1995	0.66	0.07	0.72	0.08	1.93	0.19	1.20	0.11	0.72	0.06	1.07	0.09
1996	0.60	0.07	0.39	0.05	2.61	0.22	1.70	0.13	0.96	0.08	0.82	0.07
1997	0.77	0.10	0.38	0.05	2.50	0.22	1.95	0.16	1.05	0.09	0.87	0.07
1998	1.02	0.12	0.35	0.04	2.86	0.28	1.11	0.10	1.16	0.10	0.65	0.06
1999	0.88	0.11	0.36	0.05	3.71	0.45	0.98	0.11	1.17	0.11	0.67	0.06
2000	1.09	0.12	0.27	0.03	3.73	0.36	1.07	0.10	1.30	0.11	0.61	0.05
2001	0.97	0.14	0.15	0.02	2.77	0.22	2.22	0.17	1.31	0.11	0.70	0.06
2002	1.03	0.13	0.34	0.04	3.54	0.32	0.89	0.08	1.48	0.13	0.50	0.04
2003	1.01	0.11	0.40	0.04	2.98	0.28	1.15	0.10	1.16	0.09	0.72	0.06
2004	1.37	0.15	0.24	0.03	2.91	0.33	0.90	0.10	1.31	0.12	0.50	0.04
2005	1.35	0.16	0.20	0.02	3.65	0.42	0.53	0.06	1.46	0.13	0.35	0.03
2006	1.48	0.18	0.17	0.02	3.47	0.49	0.19	0.03	1.53	0.15	0.22	0.02
2007	1.30	0.16	0.18	0.02	4.16	0.82	0.12	0.02	1.34	0.13	0.22	0.02

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

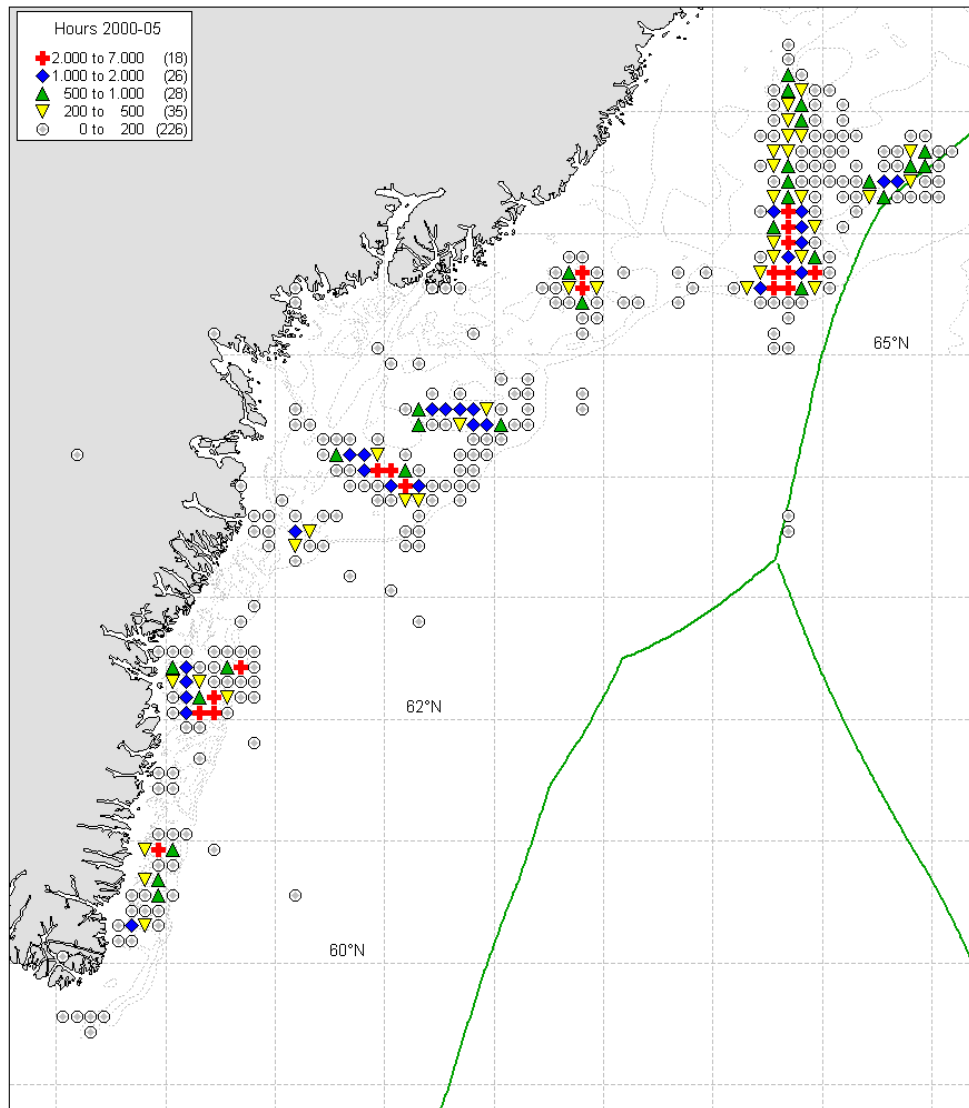


Figure 2. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall.

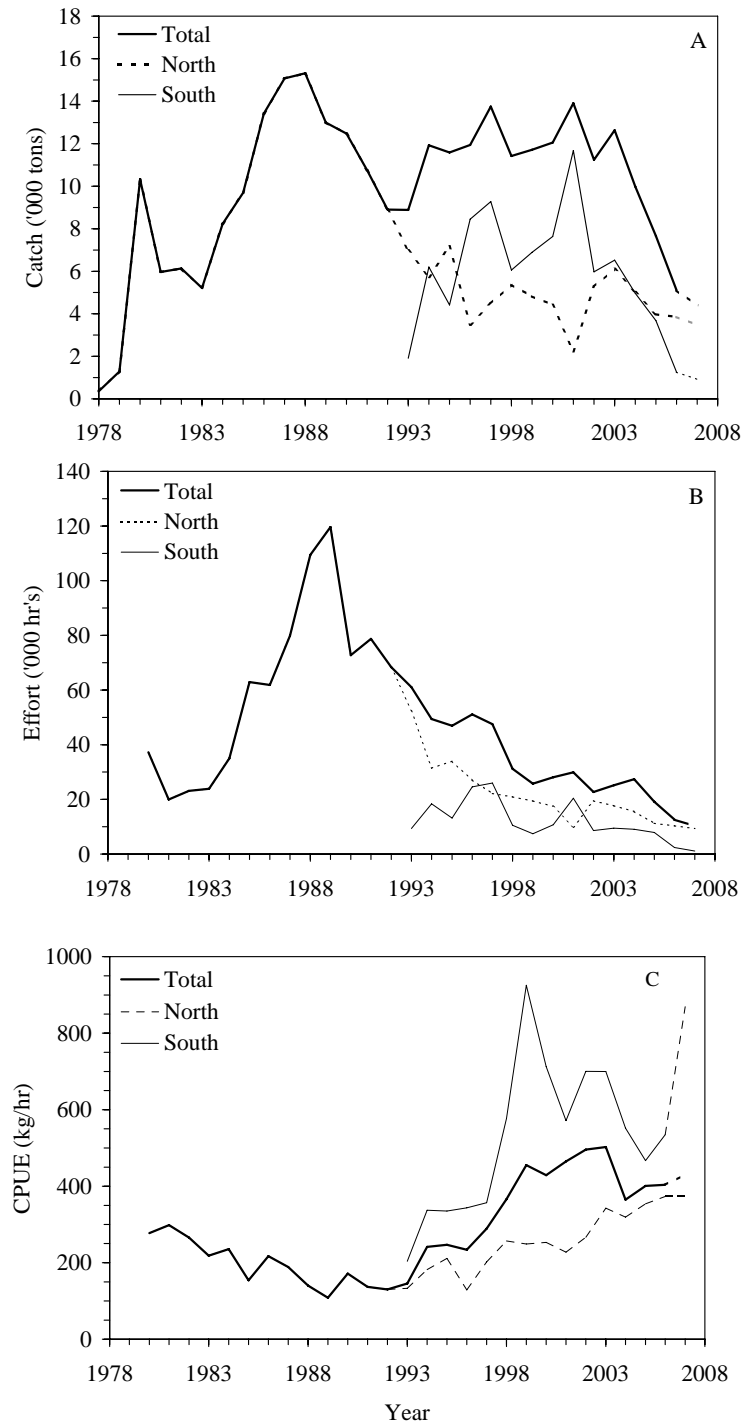


Figure 3. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas south of 65°N, in Iceland EEZ, overall fishery north of 65°N (both in Greenland and Iceland EEZ), and overall standardized CPUE for the stock. Estimates are based on data until October 2007.

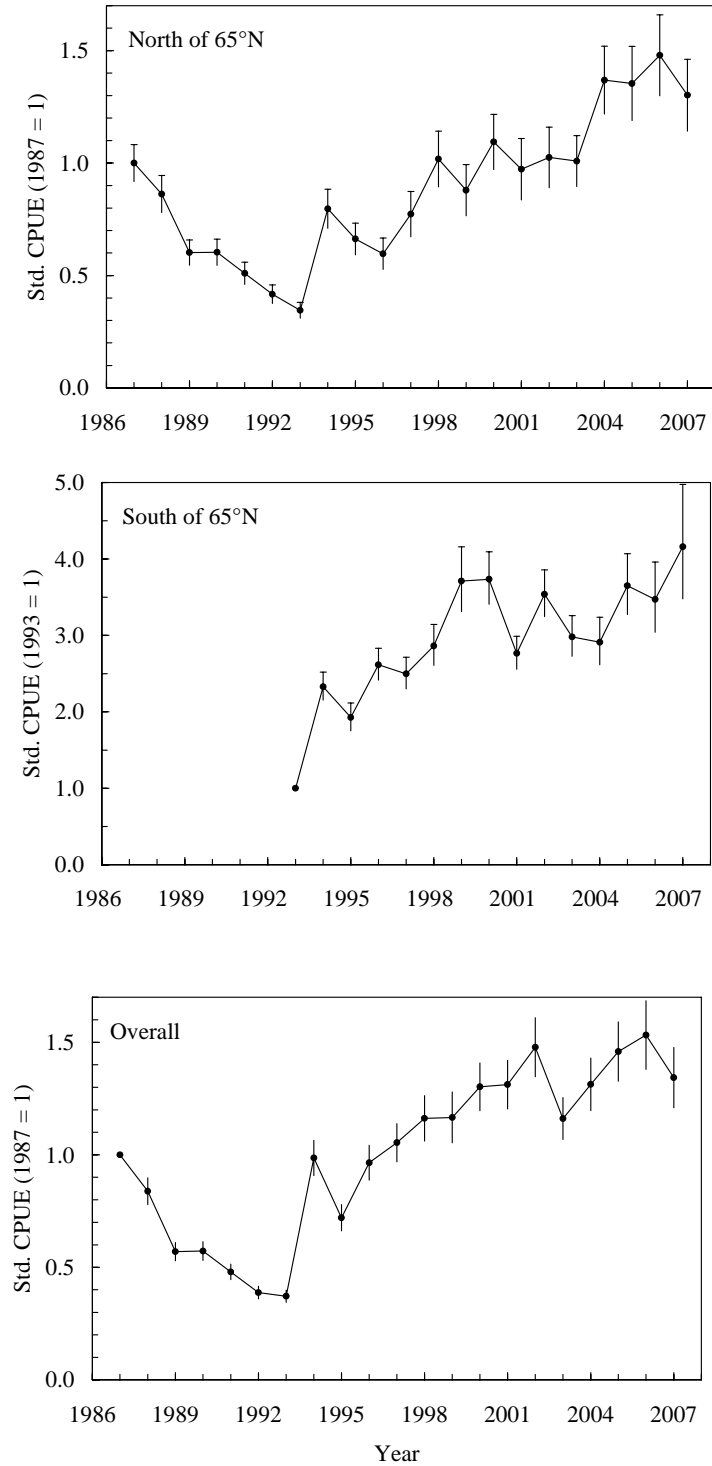


Figure 4. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until October 2007.

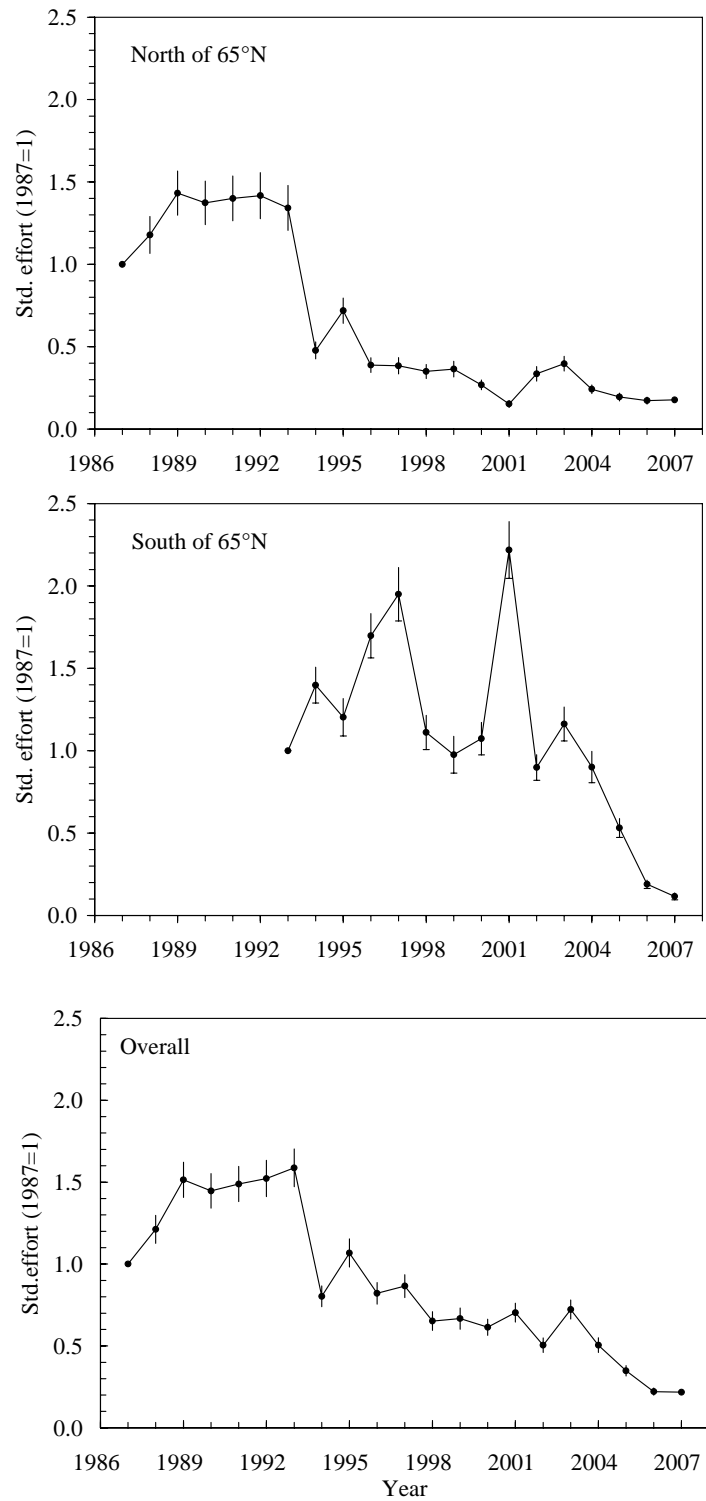


Figure 5a. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2005.

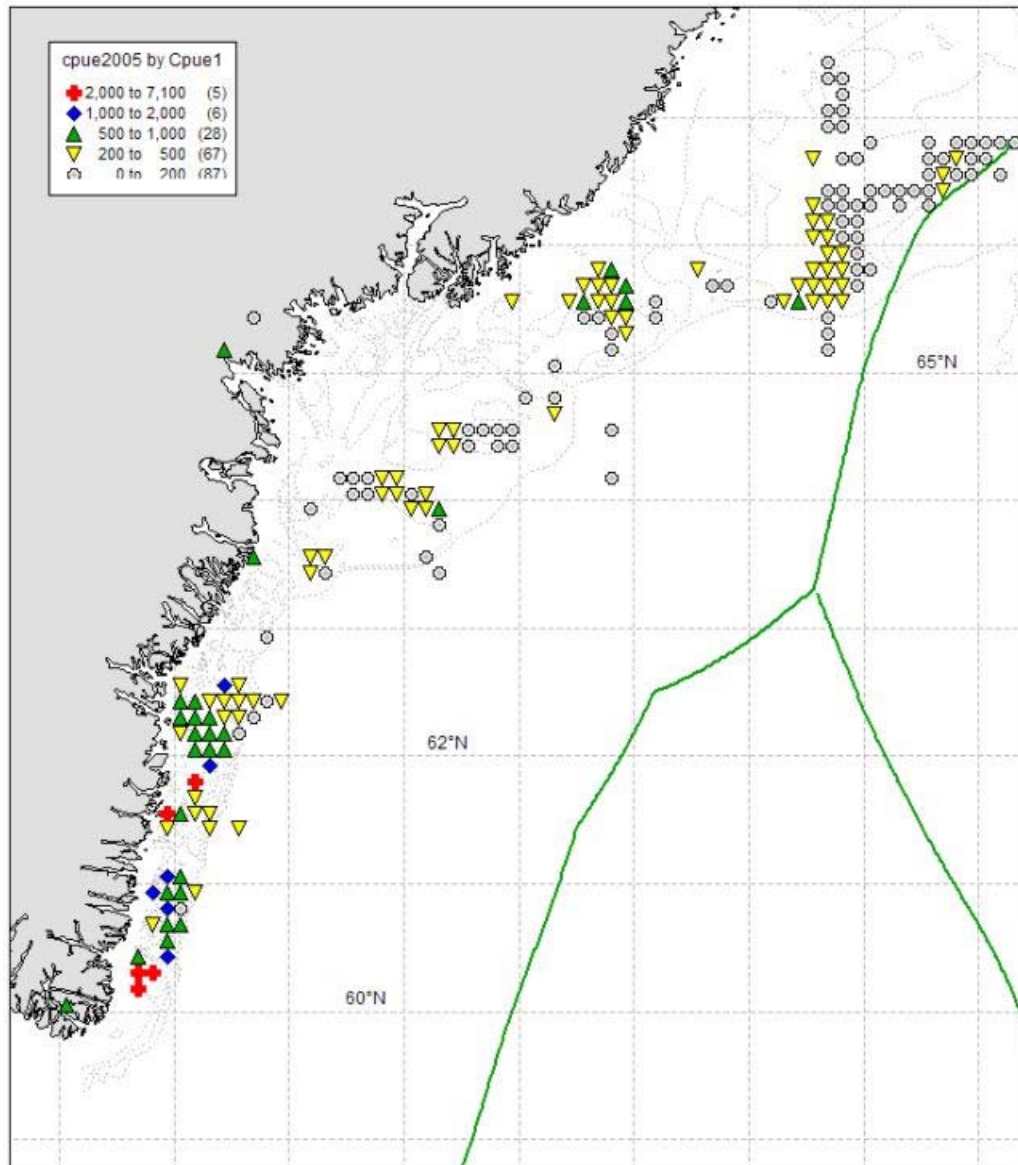


Figure 5b. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2006.

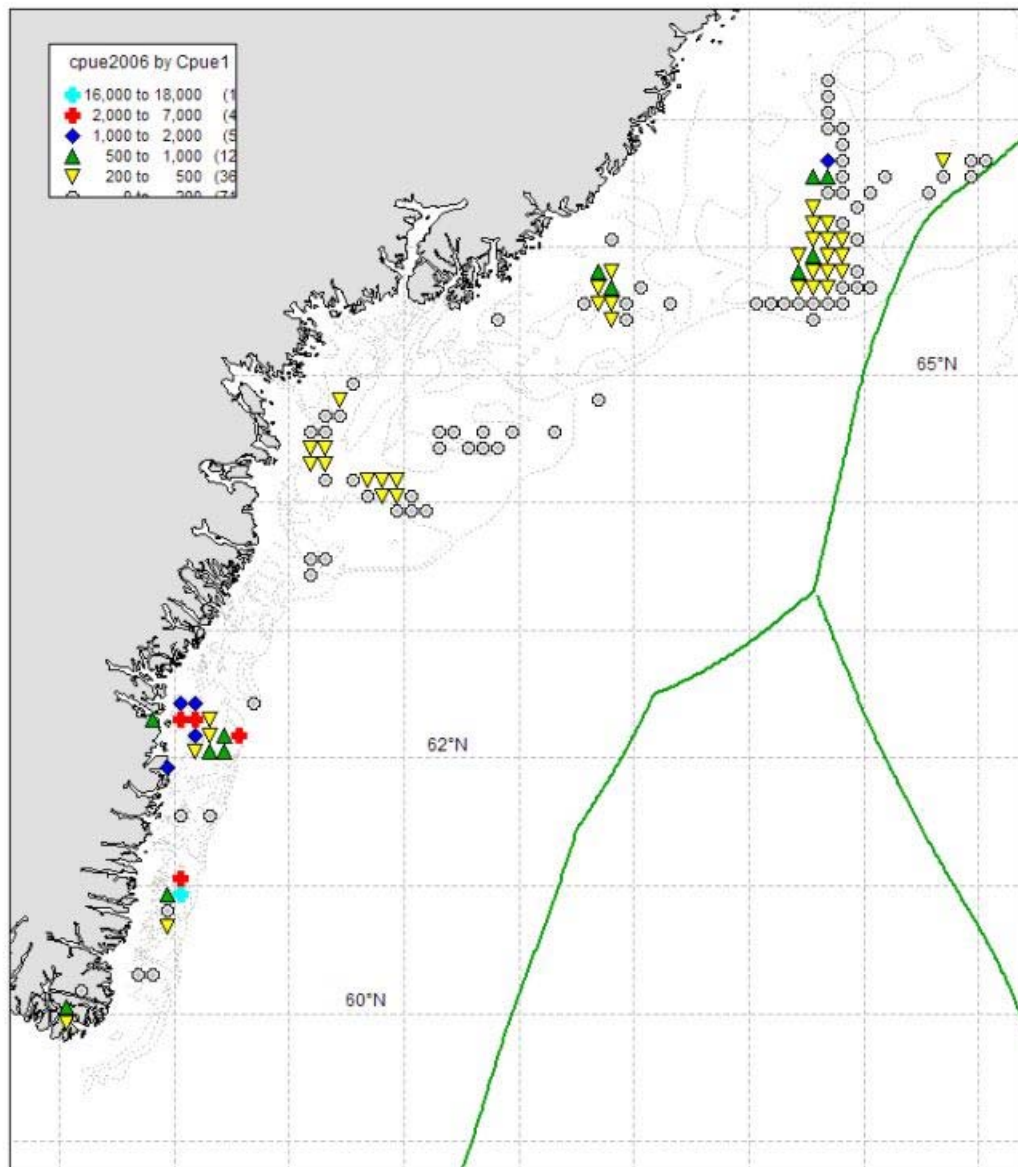
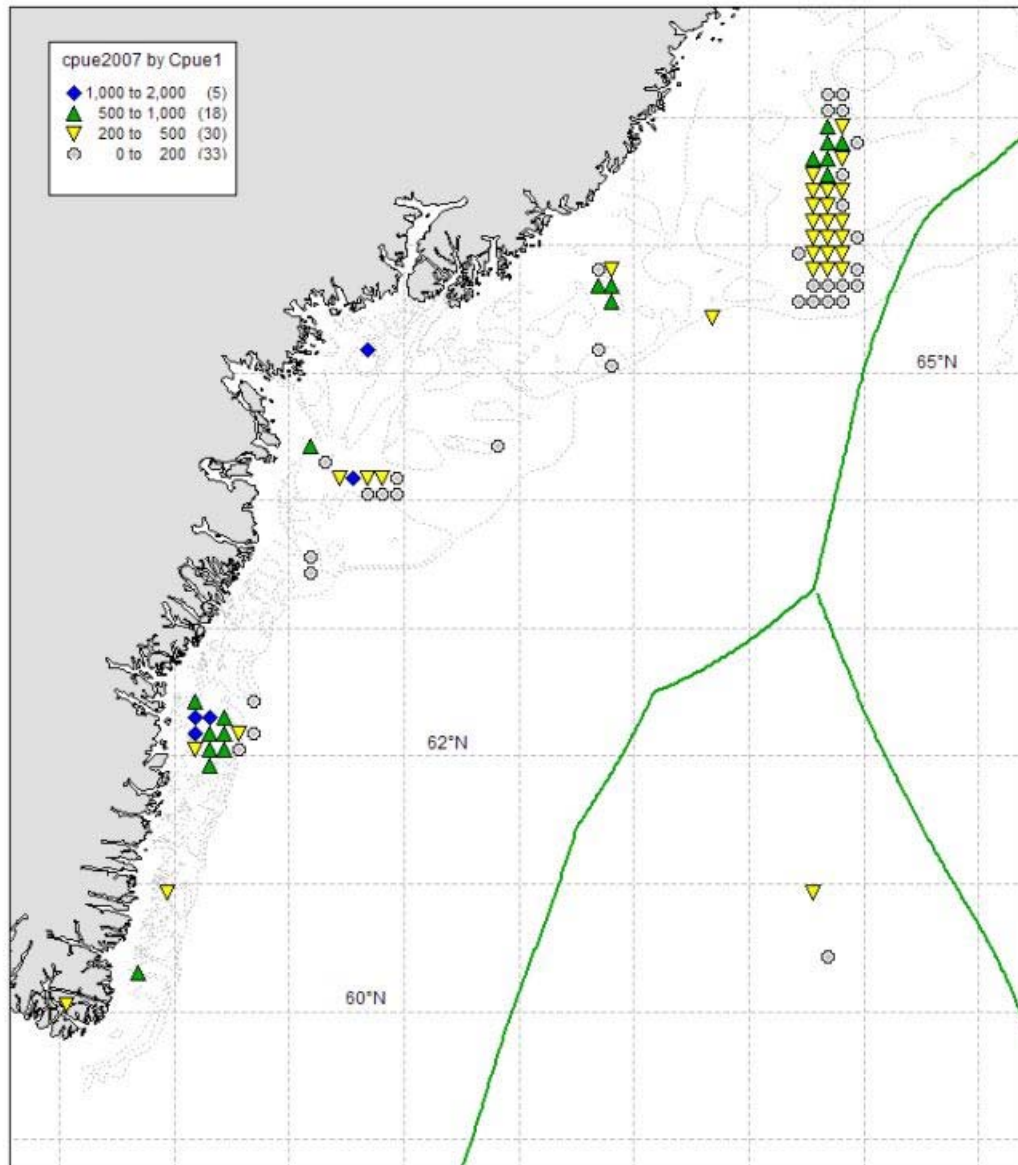


Figure 5c. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2007 (until October).



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

Class	Levels	Values
BAAD	14	AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH IIII JJJJ KKKK LLLL MMMM XXXX
YEAR	21	87 88 89 90 91 92 94 95 96 97 98 99 100 101 102 103 104 105 106 107 111
MONTH	5	1 4 7 9 12
AREA	2	21 22
HOLD	2	2 9

Number of Observations Read 2971
 Number of Observations Used 2971

Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	46490.71457	877.18329	110.54	<.0001
Error	2917	23147.66809	7.93544		
Corrected Total	2970	69638.38266			

R-Square 0.667602
 Coeff Var 263.4069
 Root MSE 2.816991
 LNCPUE Mean 1.069444

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	13	19531.65194	1502.43476	189.33	<.0001
YEAR*AREA	35	23462.19285	670.34837	84.48	<.0001
MONTH	4	3492.43929	873.10982	110.03	<.0001
AREA	0	0.00000	.	.	.
HOLD	1	4.43049	4.43049	0.56	0.4550

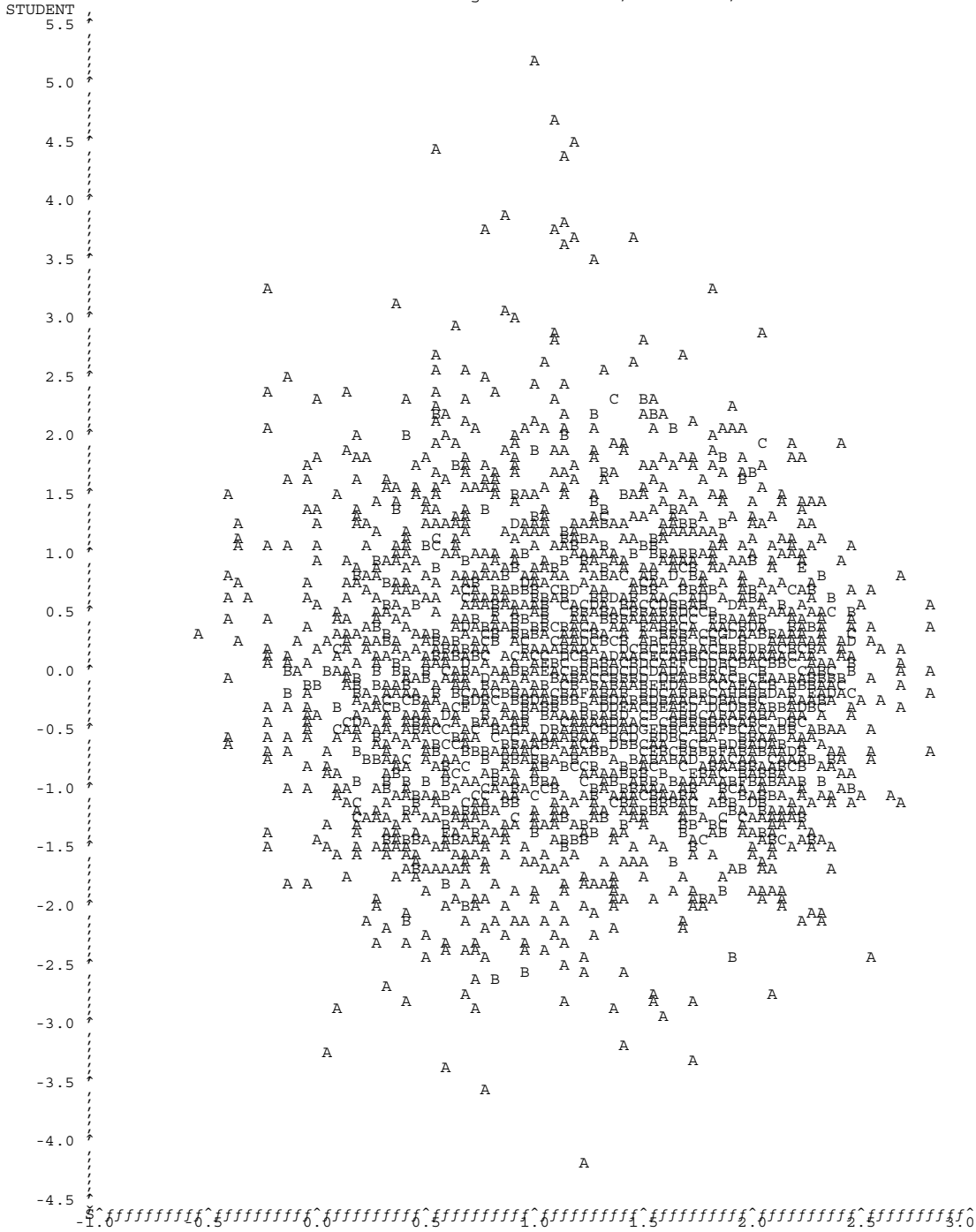
Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	13	8702.94991	669.45769	84.36	<.0001
YEAR*AREA	34	14085.73093	414.28620	52.21	<.0001
MONTH	4	3478.74529	869.68632	109.60	<.0001
AREA	1	4039.97590	4039.97590	509.11	<.0001
HOLD	1	4.43049	4.43049	0.56	0.4550

Parameter	Estimate	Standard Error	t Value	Pr > t
Intercept	0.806417969 B	0.18356751	4.39	<.0001
BAAD AAAA	-0.834914654 B	0.17467885	-4.78	<.0001
BAAD BBBB	-0.647382151 B	0.17408208	-3.72	0.0002
BAAD CCCC	-0.486433395 B	0.17347959	-2.80	0.0051
BAAD DDDD	-0.367894912 B	0.17366512	-2.12	0.0342
BAAD EEEE	-0.296026076 B	0.17344825	-1.71	0.0880
BAAD FFFF	-0.259509504 B	0.17348517	-1.50	0.1348
BAAD GGGG	-0.165568512 B	0.17459999	-0.95	0.3431
BAAD HHHH	-0.117335412 B	0.17640385	-0.67	0.5060
BAAD IIII	-0.035890191 B	0.17319979	-0.21	0.8359
BAAD JJJJ	0.044790181 B	0.17388245	0.26	0.7967
BAAD KKKK	0.086361257 B	0.17408993	0.50	0.6199
BAAD LLLL	0.154305181 B	0.17507500	0.88	0.3782
BAAD MMMM	0.292808738 B	0.18724361	1.56	0.1180
BAAD XXXX	0.000000000 B	.	.	.
YEAR*AREA 87 21	0.702815765 B	0.07234324	9.72	<.0001
YEAR*AREA 88 21	0.501044925 B	0.06829907	7.34	<.0001
YEAR*AREA 89 21	0.097573871 B	0.06739513	1.45	0.1478
YEAR*AREA 90 21	0.099069519 B	0.06737695	1.47	0.1416
YEAR*AREA 91 21	-0.103825563 B	0.06655141	-1.56	0.1188
YEAR*AREA 92 21	-0.309011907 B	0.06975574	-4.43	<.0001
YEAR*AREA 94 21	0.355376511 B	0.08518644	4.17	<.0001
YEAR*AREA 94 22	0.845546415 B	0.07816595	10.82	<.0001
YEAR*AREA 95 21	0.181883958 B	0.07687501	2.37	0.0180
YEAR*AREA 95 22	0.655535092 B	0.09411320	6.97	<.0001
YEAR*AREA 96 21	0.076834875 B	0.09270717	0.83	0.4073

YEAR*AREA 96 22	0.961174906 B	0.07926574	12.13	<.0001
YEAR*AREA 97 21	0.365705538 B	0.11405823	3.21	0.0014
YEAR*AREA 97 22	0.915442316 B	0.08311007	11.01	<.0001
YEAR*AREA 98 21	0.741959667 B	0.10588072	7.01	<.0001
YEAR*AREA 98 22	1.051895132 B	0.09360832	11.24	<.0001
YEAR*AREA 99 21	0.538754620 B	0.10932924	4.93	<.0001
YEAR*AREA 99 22	1.310871501 B	0.11404792	11.49	<.0001
YEAR*AREA 100 21	0.709961148 B	0.08339230	8.51	<.0001
YEAR*AREA 100 22	1.317568856 B	0.09162936	14.38	<.0001
YEAR*AREA 101 21	0.576820999 B	0.11568279	4.99	<.0001
YEAR*AREA 101 22	1.017147205 B	0.07773736	13.08	<.0001
YEAR*AREA 102 21	0.574968266 B	0.11215967	5.13	<.0001
YEAR*AREA 102 22	1.263709131 B	0.08614312	14.67	<.0001
YEAR*AREA 103 21	0.635479745 B	0.08636222	7.36	<.0001
YEAR*AREA 103 22	1.092164314 B	0.08889695	12.29	<.0001
YEAR*AREA 104 21	0.947306065 B	0.08291530	11.42	<.0001
YEAR*AREA 104 22	1.068253653 B	0.10611783	10.07	<.0001
YEAR*AREA 105 21	0.903535393 B	0.09221694	9.80	<.0001
YEAR*AREA 105 22	1.294511060 B	0.10866800	11.91	<.0001
YEAR*AREA 106 21	0.992409080 B	0.09351463	10.61	<.0001
YEAR*AREA 106 22	1.243997378 B	0.13229558	9.40	<.0001
YEAR*AREA 107 21	0.864069901 B	0.09693285	8.91	<.0001
YEAR*AREA 107 22	1.425395931 B	0.17903249	7.96	<.0001
YEAR*AREA 111 21	-0.500099270 B	0.07292329	-6.86	<.0001
YEAR*AREA 111 22	0.000000000 B	.	.	.
MONTH 1	0.280743233 B	0.02811595	9.99	<.0001
MONTH 4	0.132826427 B	0.02931852	4.53	<.0001
MONTH 7	0.177905748 B	0.06008175	2.96	0.0031
MONTH 9	-0.216242601 B	0.03147299	-6.87	<.0001
MONTH 12	0.000000000 B	.	.	.
AREA 21	0.000000000 B	.	.	.
AREA 22	0.000000000 B	.	.	.
HOLD 2	0.024005344 B	0.03212679	0.75	0.4550
HOLD 9	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.



Appendix 2. Results and diagnostical outputs from GLM run of model for standardising CPUE in Icelandic 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

Source	DF	Sum of 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 0.781967
Coeff Var 4129.035
Root MSE 29.16498
LNCPUE Mean 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

Parameter	Estimate	Standard 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 ,

