Northwest Atlantic Fisheries Organization

Serial No. N5328 **NAFO SCR Doc. 06/78**

NAFO/ICES WG *PANDALUS* MEETING – OCTOBER/NOVEMBER 2006

An Assessment of the Shrimp Stock in Denmark Strait/off East Greenland – 2006

by

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Abstract

Northern shrimp (*Pandalus borealis*) occurs off East Greenland from Cape Farewell to about 70°N in depths down to about 800 m. North of 65°N the stock spans the adjacent Greenlandic and Icelandic economic zones. The stock is assessed as a single population by evaluation of fishery dependent data only. The stock is managed by catch quotas in the Greenlandic zone. There are no management related restrictions on the fishery in the Icelandic zone.

A multinational fleet of large factory trawlers exploits the stock taking annual catches close to 12 000 tons from 1994 to 2003. Catches decreased to 8 100 tons in 2005 and preliminary data indicate that catches will decrease further in 2006. 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 are 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 1970s initiated by Icelandic trawlers. It soon became a multinational fishery with annual catches increasing rapidly to more than 15 000 tons during the following 10-year period. Total catches fluctuated around 12 000 tons from 1994 to 2003 (Table 1, Fig. 2A). Catches decreased to 8 100 in 2005 and preliminary data indicate that catches will decrease further in 2006. 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, Denmark, the Faroe Islands and Norway have participated in the fishery in the Greenlandic zone. Annual catches in this area accounts for around 70-98% of the total and the fishery is managed by a Total Allowable Catch (TAC). Icelandic vessels operate exclusively in the Icelandic EEZ and the fishery is unrestricted by management initiatives. Vessels taking part in the fishery on both sides of the national midline are large factory trawlers

in the range of 1 000-4 000 GRT.

This paper presents and analyses data from the shrimp fishery in Denmark Strait/off East Greenland to provide a basis for the assessment of the shrimp stock in this area i.e. time series of catch, fishing effort, geographical distribution 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 preformed with double trawl and the 2006 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 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(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:

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

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 mth area; S_j is the effect of the jth month; V_k is the effect of the kth vessel; Y_i is the effect of the ith year; e_{mjki} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ where n is the number of observations in the cell. The standardised CPUE indices are the antilog of the year coefficient.

Parameter estimates of the vessel, month and area variable from a first run of the model were compared. Levels within each variable were combined in subsequent analyses if the parameter estimates did not differ by more than 5%. This was done to reduce the number of empty cells in the models.

For the model pertaining to the Greenlandic zone 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 since 1987. Almost no fishery has been conducted in 2005 (21 tons) and 2006 (0 tons). 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 2006 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 ${\sigma_{pi}}^2$. 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, ${\sigma_{pi}}^2$ 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 15 000 tons in 1987-88, but declined thereafter to about 9 000 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 13 700 tons in 1997. Catches from 1998 to 2004 have been between 10-14 000 tons (Fig. 2A). The 2005 catch decreased to 8 000 tons and catches in 2006 are projected to be lower than the 2005 level (projected from October)

In the northern area the amount caught has declined by about 75%, i.e. from 15 000 tons in 1988 to about 2 000 tons in 2002 (Fig. 2A). According to Greenlandic skippers the reduced effort spent was due to reduced catch rates of large shrimp, which was the primary target of the Greenlandic fishery. However increasing effort has been spent in the northern areas has since 2004.

Catches in the southern area increased from 1900 tons in 1993 - the first year of fishery in this area - to about 9 300 tons in 1997 (Fig. 2A). They then decreased somewhat to about 6-7 000 tons in 1998-2000. In 2001 catches reached 11 700 tons declined to 9 000 tons in 2002-2003. In 2004 and 2005 catches from the southern area was reported to less than 4 000 tons. 2006 figures are expected to lower than the 2005 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 20 000 hr's to a peak of more than 119 000 hr's and then declined again to a low of less than 20 000 hr's in 2002. Since then total effort had been less than 25 000 hr's - the 2006-value is expected to be at lower than the 2005-value (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 10 000 hours in 1993 to 21 000 hours in 1997. In 1999 it reached a low of 7 500 hr's but increased again to 27 000 hr's in 2001. For 2002-2003 effort in the southern areas was down to approx. 11 000 hrs. The 2004 value declined to a historic low at 4 500 hr's. In 2005 effort increased again to 6 000 hr's, but the 2006 level is expected to decrease again (Fig. 2B, Table 2).

Catch rate

Catch rates (total area) decreased from 278 kg/hr to 109 kg/hr in the period 1980-1989, but has shown an increasing trend since then reaching about 586 kg/hr in 2003 (Fig. 2C, Table 2). The catch rates for 2004 are and 2005 is down at 400 kg/hr and preliminary data from 2006 indicate a further decrease to 280 kg/hr

In the southern areas CPUE increased from 204 kg/hr in 1993 to 950 kg per hour in 1999. During the following two years the mean CPUE obtained in this area was halved reaching 432 kg/hr in 2001. However CPUE was back at 780 kg/hr in 2002 and 2003. For 2004 and 2005 CPUE is on 600 kg/hr, and preliminary data from 2006 CPUE indicate a decrease to 400 kg/hr.

Catch rates in the northern area follow the same trend as the overall figures until 1993 as the fishery in the southern areas had not yet been initiated. From 1994-2001 CPUE's have fluctuated around 225 kg/hr except for an extreme of 146 kg/hr in 1996. Since 2002 annual mean CPUE was above 300 kg/hr, with 270 kg/hr estimated for 2006.

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 66% 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 CPUE index series of the northern areas (Fig. 3) declined from 1987 to 1993 thereafter an increasing trend was observed and by the turn of the century the index values had reached the level seen at the offset of the time series. For the recent three years the mean index values have stabilized at a level a little 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 1990s. The index values indicate that the stock biomass have stayed at or around this level since then.

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

Indices of harvest rate

The standardised effort, i.e. the index of harvest rate, showed a decreasing trend since 1993 for the total area (Fig. 4). The separate indices for the northern and southern areas are also shown in Fig. 4. As mentioned in the previous section the development in the harvest rate indices might be to optimistic. Furthermore, the index of 2006 also depends on the precision with which the catch is projected to the end of the year.

Conclusions

Total catches fluctuated around 12 000 tons from 1994 to 2003 (Table 1, Fig. 2A). Catches decreased to 8 100 in 2005 and preliminary data indicate that catches will decrease further in 2006.

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 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 2006. 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	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998[1]	1999[1]	2000[1]	2001[1]	2002[1]	2003[1]	2004[1,5]	2005[1,2]	2006[1,2]
North of 65°N																										
EU (DK,EST,LTU)	727	926	255	554	442	626	703	554	454	476	450	199	138	250	302	26	85	401	793	459	72	238	538	812	304	729
Faroe Islands	892	922	554	836	843	910	754	847	738	1029	1265	1355	689	462	931	995	635	1268	867	956	214	309	744	1115	639	586
France	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	1771	1326	2390	359	105	646	614	115	650	152	292	2299	733	0
Iceland	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1144	635	380	21	0
Norway	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	1831	2180	2402	1544	797	1628	1783	2759	1291	645	2569	2511	2611	2683
Total	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	6982	5731	7176	3490	4478	5364	4827	4420	2237	2488	4778	7116	4307	3999
South of 65°N																										
Denmark (EU)	-	-	-	-	-	-	-	-	-	-	-	-	60	613	731	1167	1657	1300	1095	1900	2473	2309	2151	692	645	313
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	280	974	295	402	656	138	453	340	2402	1013	621	34	567	129
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	1141	3603	2667	5295	4701	3950	4966	5235	4943	4333	4597	1767	2400	253
Norway	-	-	-	-	-	-	-	-	-	-	-	-	424	1011	720	1590	2261	670	378	157	1855	1098	489	375	194	0
Total	-	-	-	-	-	-	-	-	-	-	-	-	1904	6201	4412	8453	9276	6057	6893	7632	11674	8753	7858	2869	3807	694
Total area																										
EU (DK,EST,LTU)	727	926	255	554	442	626	703	554	454	476	450	199	198	863	1033	1193	1742	1701	1888	2358	2545	2548	2688	1504	949	1042
Faroe Islands	892	922	554	836	843	910	754	847	738	1029	1265	1355	968	1436	1225	1397	1292	1406	1321	1296	2616	1322	1365	1149	1206	715
France	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	2912	4929	5057	5655	4806	4595	5581	5349	5593	4484	4890	4066	3133	253
Iceland	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1144	635	380	21	0
Norway	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	2255	3190	3122	3133	3059	2298	2160	2917	3147	1743	3059	2886	2805	2683
Total	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12637	9985	8114	4693
Total all areas	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12637	9985	8114	4693
Advised TAC	-	4200	4200	4200	5000	-	-	-	10000[3]	10000[3]	10000[3]	8000	5000	5000	5000	5000	5000	5000	9600	9600	9600	9600	9600	12400	12400	12400
Effective TAC[4]	8000	4500	5725	5245	6090	7525[5]	7525[5]	8725[5]	9025[5]	14100	14500	13000	9563	9563	9563	9563	9563	9563	10600	12600	10600	10600	10600	15043	12400	12400

[1]Provisional

[2]Catch in 2006 per Oct. 11.

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

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

[5]Not including Greenland fishery north of 66°30'N

Table 2. Catch (tons), effort (hr's) and Catch-Per-Unit-Effort (kg/hr) by trawlers fishing in Denmark Strait/off East Greenland in areas north and south of 65°N.

	Area north			Area south			Total area		
Year	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
1980	10325	37198	278				10325	37198	278
1981	5964	19986	298				5964	19986	298
1982	6133	23081	266				6133	23081	266
1983	5212	23855	219				5212	23855	219
1984	8235	34983	235				8235	34983	235
1985	9696	62911	154				9696	62911	154
1986	13428	61863	217				13428	61863	217
1987	15073	79881	189				15073	79881	189
1988	15313	109455	140				15313	109455	140
1989	12999	119629	109				12999	119629	109
1990	12480	94044	133				12480	94044	133
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	25444	225	6201	16361	379	11932	39725	300
1995	7176	34021	211	4412	11328	389	11588	43574	266
1996	3490	23966	146	8453	20136	420	11944	39480	303
1997	4478	19273	232	9276	18481	502	13754	37498	367
1998	5364	21379	251	6057	10231	592	11422	29524	387
1999	4827	20736	233	6893	7256	950	11719	24809	472
2000	4420	17474	253	7632	10385	735	12053	27955	431
2001	2237	9822	228	11674	26241	445	13911	36407	382
2002	2488	9337	267	8753	11638	752	11242	22587	498
2003	4778	15887	301	7858	10057	781	12637	26611	475
2004	7116	22020	323	2869	4454	644	9985	26612	375
2005	4307	13179	327	3807	6170	617	8114	19617	414
2006*	3999	14824	270	694	1894	367	4693	16532	284

*until Oct.

Table 3. Means 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 until October 2006.

	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	0,86	0,08	1,19	0,11					0,84	0,06	1,21	0,08
1989	0,60	0,06	1,44	0,14					0,56	0,03	1,54	0,09
1990	0,60	0,06	1,38	0,14					0,57	0,03	1,46	0,09
1991	0,51	0,05	1,40	0,14					0,47	0,03	1,53	0,09
1992	0,41	0,04	1,43	0,14					0,38	0,02	1,57	0,09
1993	0,34	0,03	1,36	0,14	1,00	-	1,00	-	0,36	0,02	1,64	0,09
1994	0,80	0,09	0,48	0,05	2,32	0,19	1,40	0,11	0,98	0,08	0,81	0,06
1995	0,66	0,07	0,72	0,08	1,93	0,19	1,20	0,11	0,71	0,05	1,08	0,07
1996	0,59	0,07	0,39	0,05	2,59	0,21	1,72	0,14	0,96	0,08	0,83	0,07
1997	0,77	0,10	0,39	0,05	2,47	0,21	1,97	0,16	1,04	0,09	0,88	0,08
1998	1,00	0,13	0,36	0,04	2,83	0,28	1,13	0,11	1,11	0,11	0,68	0,07
1999	0,85	0,11	0,38	0,05	3,63	0,44	1,00	0,11	1,11	0,12	0,70	0,08
2000	1,09	0,12	0,27	0,03	3,67	0,35	1,09	0,10	1,28	0,13	0,62	0,06
2001	0,97	0,14	0,15	0,02	2,75	0,22	2,23	0,17	1,31	0,13	0,70	0,07
2002	1,04	0,13	0,16	0,02	3,52	0,32	1,31	0,11	1,49	0,17	0,50	0,06
2003	1,00	0,11	0,32	0,04	2,91	0,27	1,42	0,13	1,15	0,11	0,73	0,07
2004	1,28	0,15	0,37	0,04	2,86	0,32	0,53	0,06	1,24	0,13	0,54	0,05
2005	1,26	0,16	0,23	0,03	3,66	0,40	0,55	0,06	1,45	0,18	0,37	0,05
2006	1,35	0,20	0,20	0,03	2,03	0,48	0,18	0,04	1,30	0,21	0,24	0,04

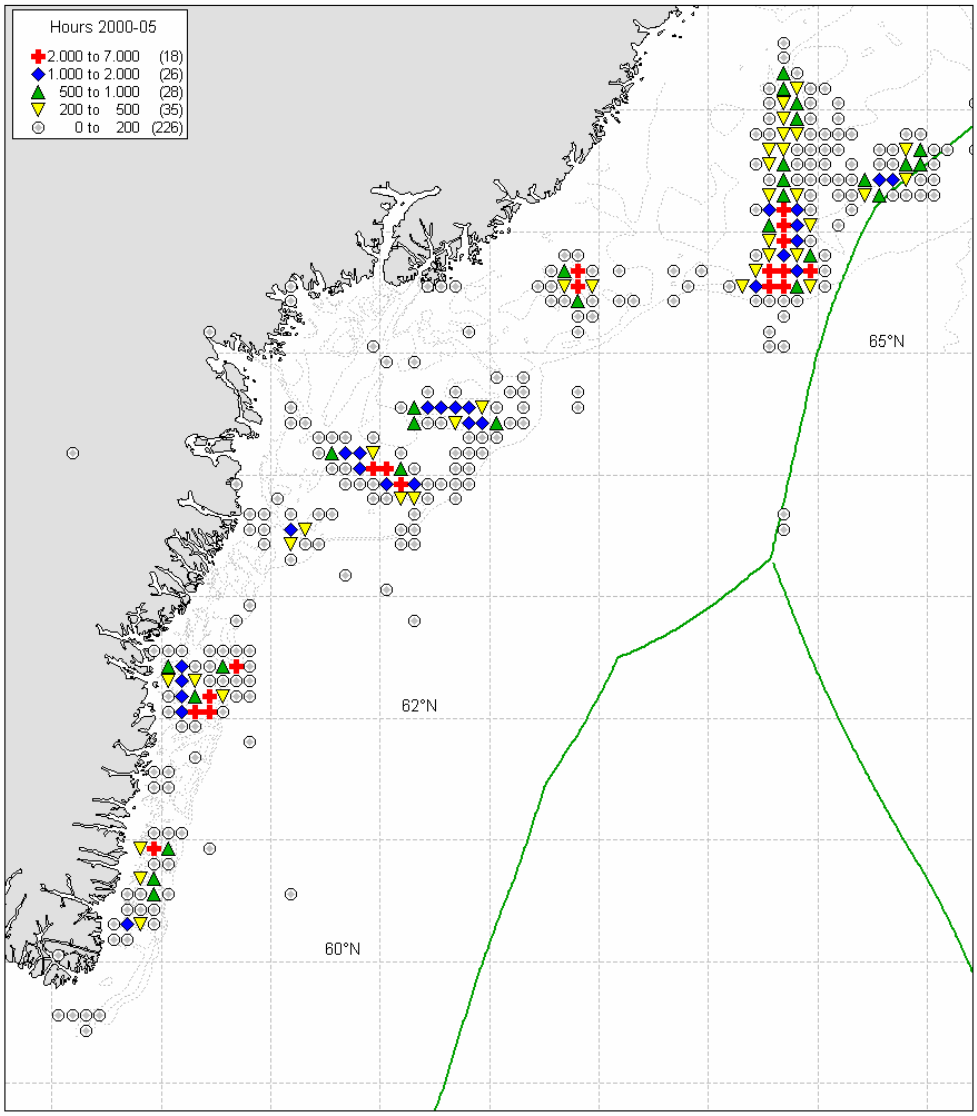


Fig. 1. Thematic mapping of different value of effort (in hours) in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2000-2005.

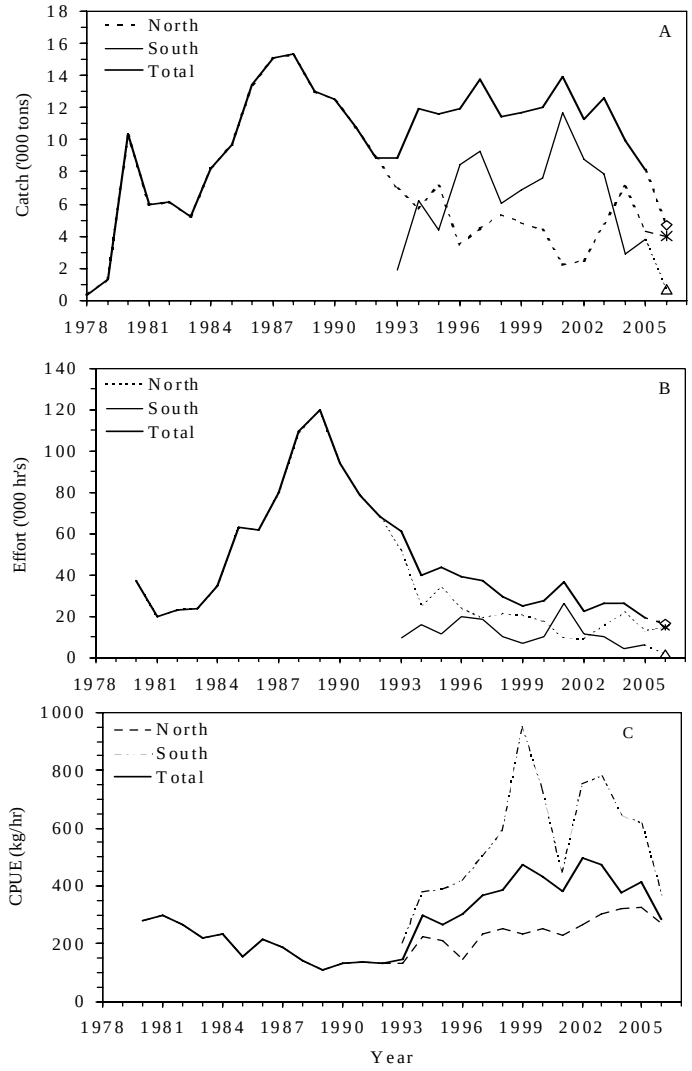


Fig. 2. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall.

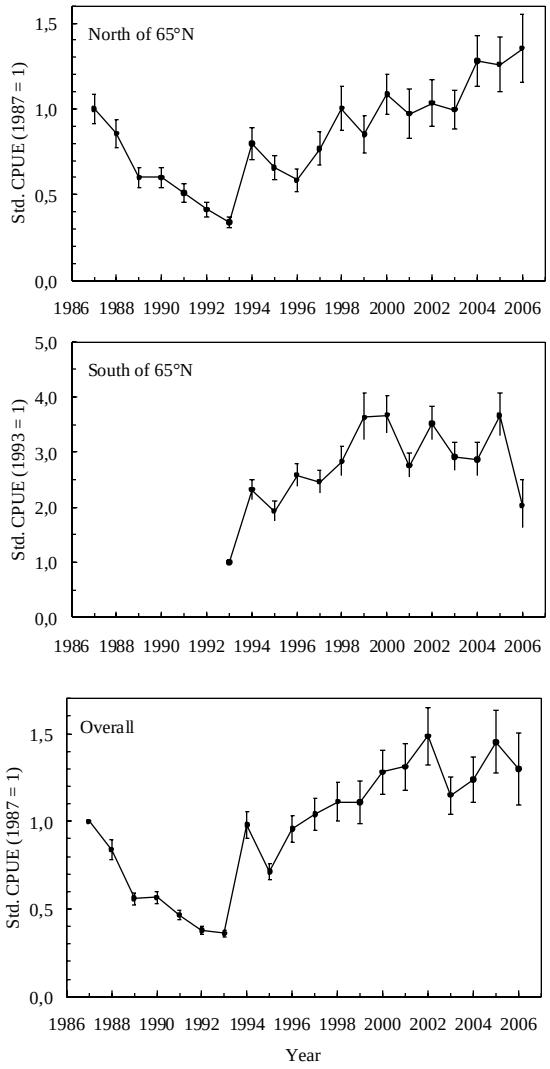


Fig. 3. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas south of 65°N, in Iceland EZZ, overall fishery north of 65°N (both in Greenland and Iceland EEZ), and overall standardized CPUE for the stock. Estimates are based on data until October 2006.

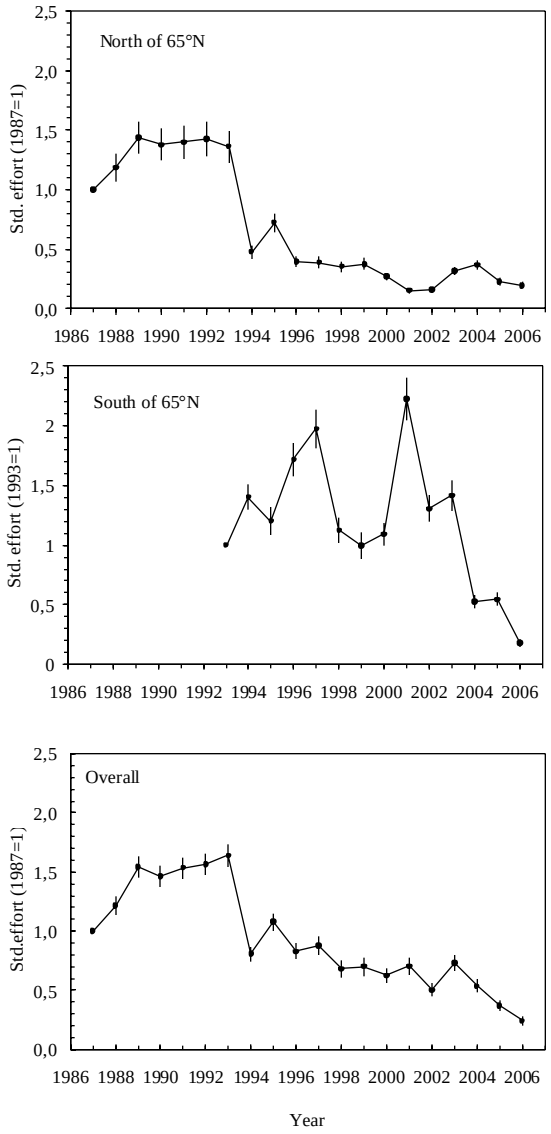


Fig. 4. Standardized effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall. Estimates are based on data until October 2006.

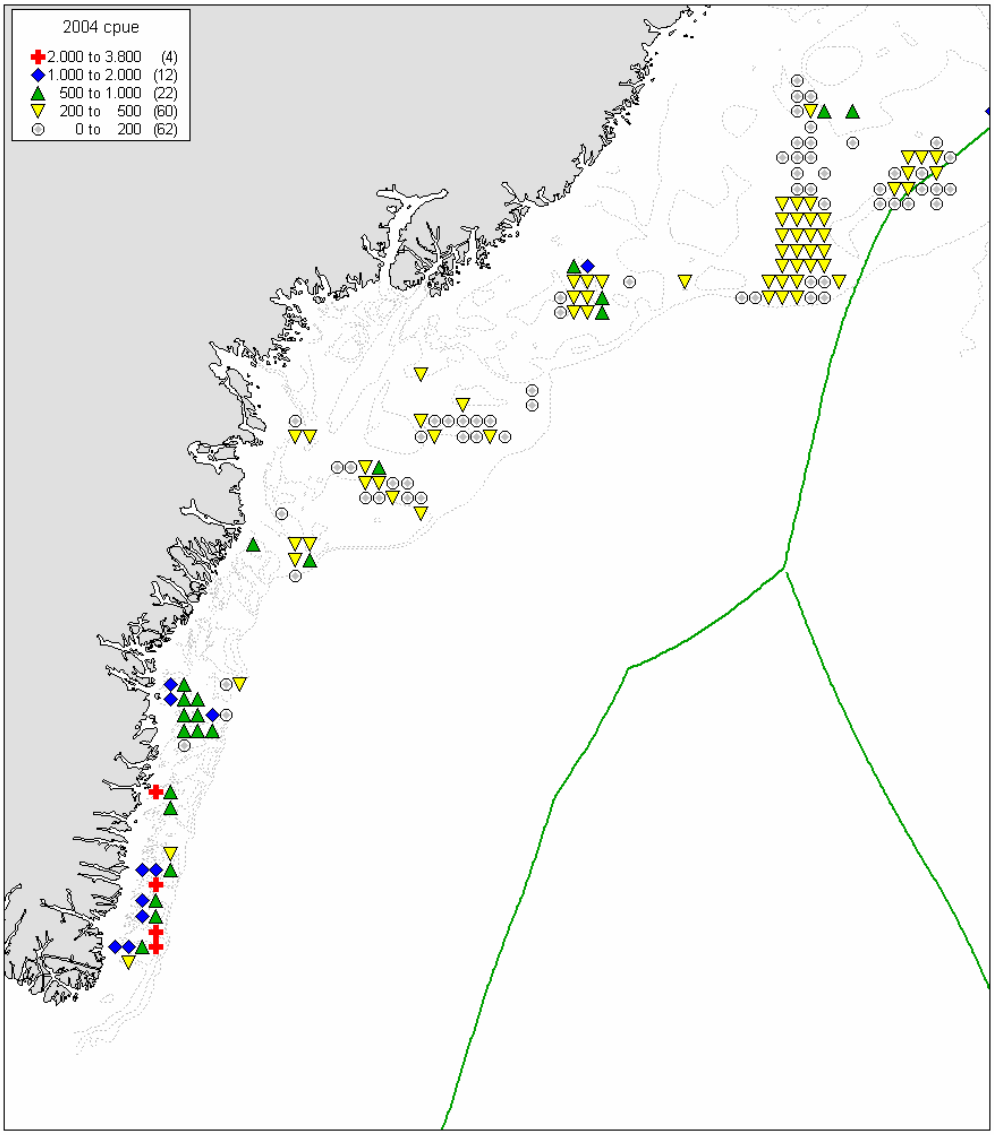


Fig. 5a. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2004.

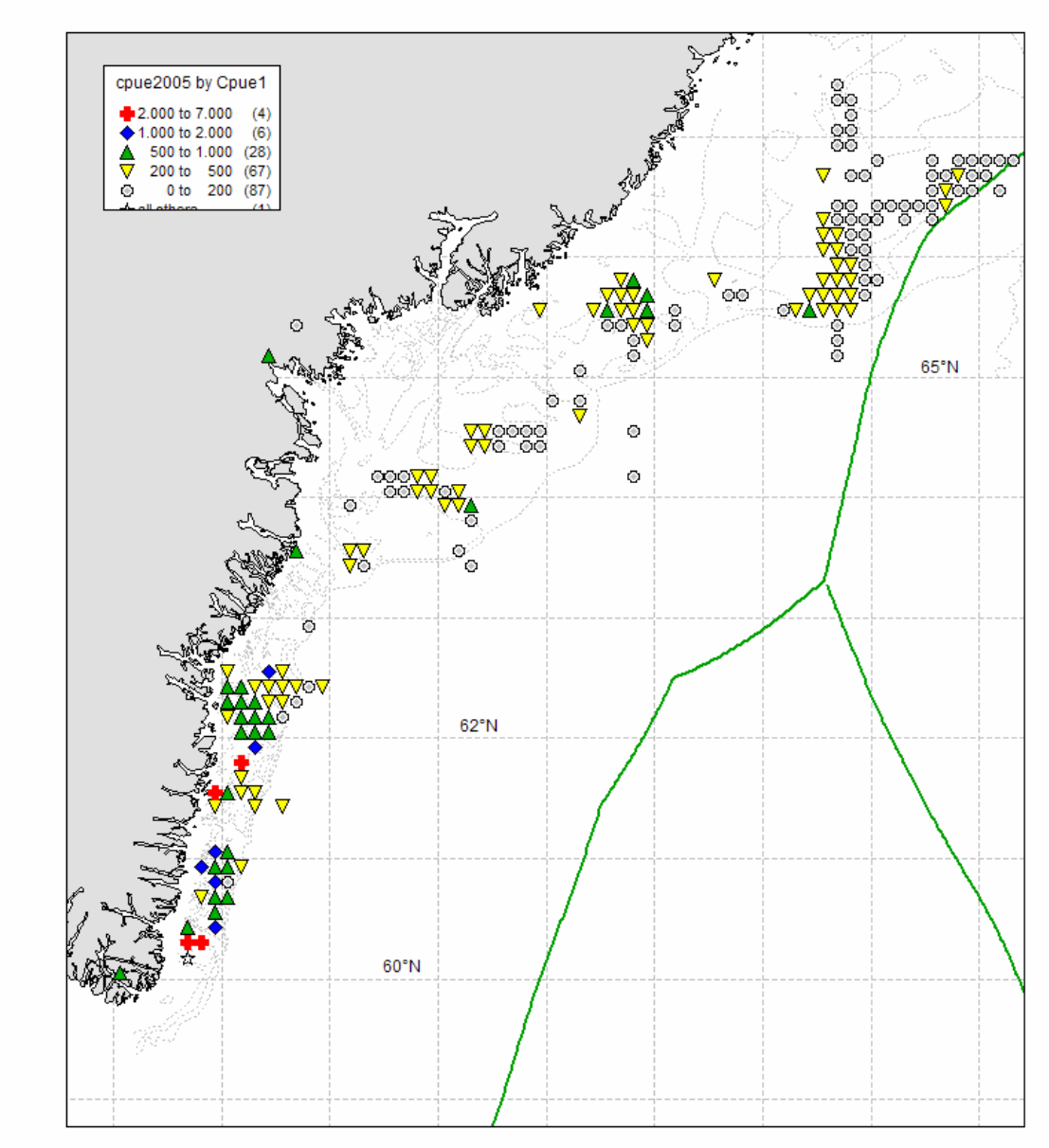


Fig. 5b. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2005.

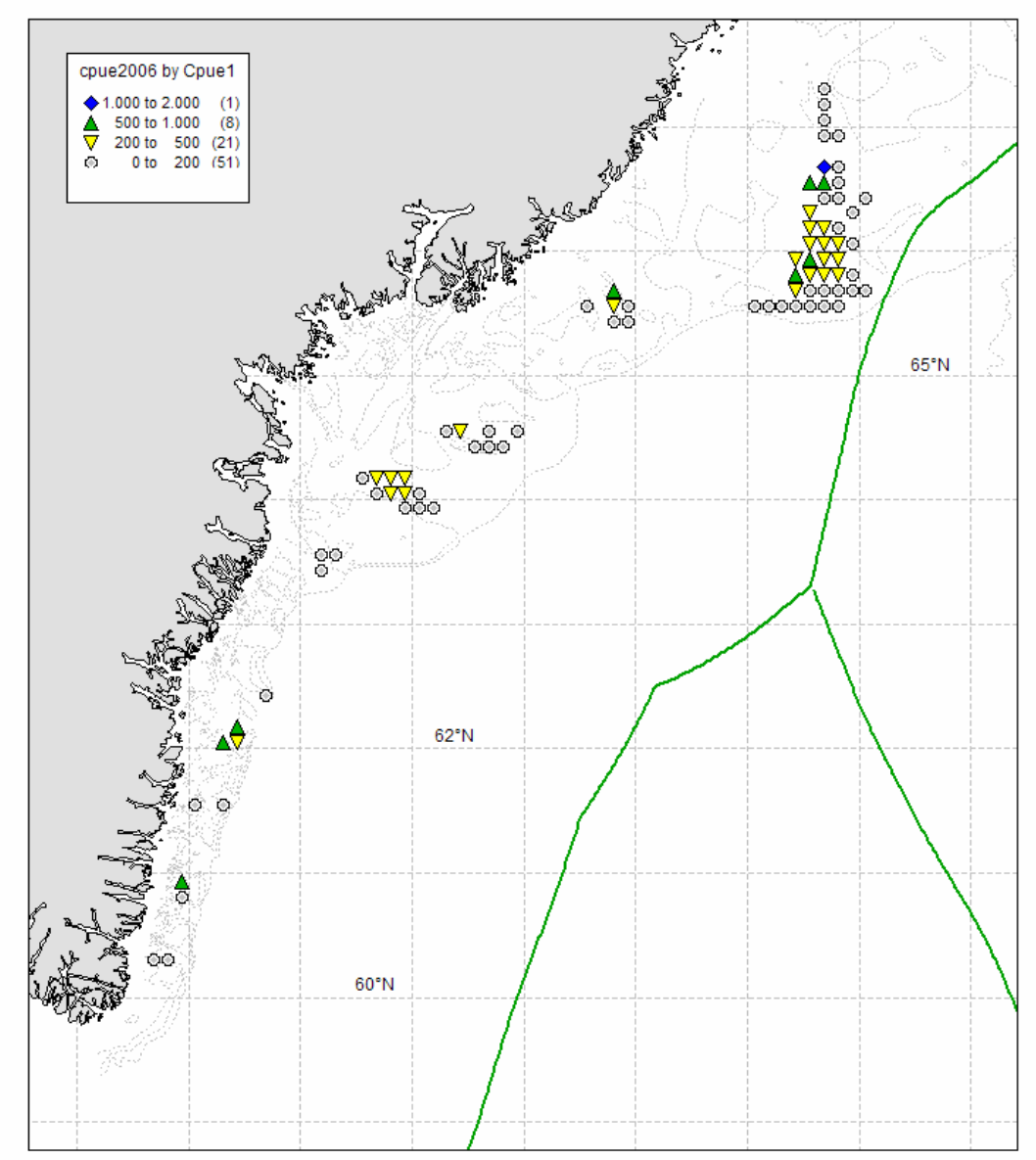
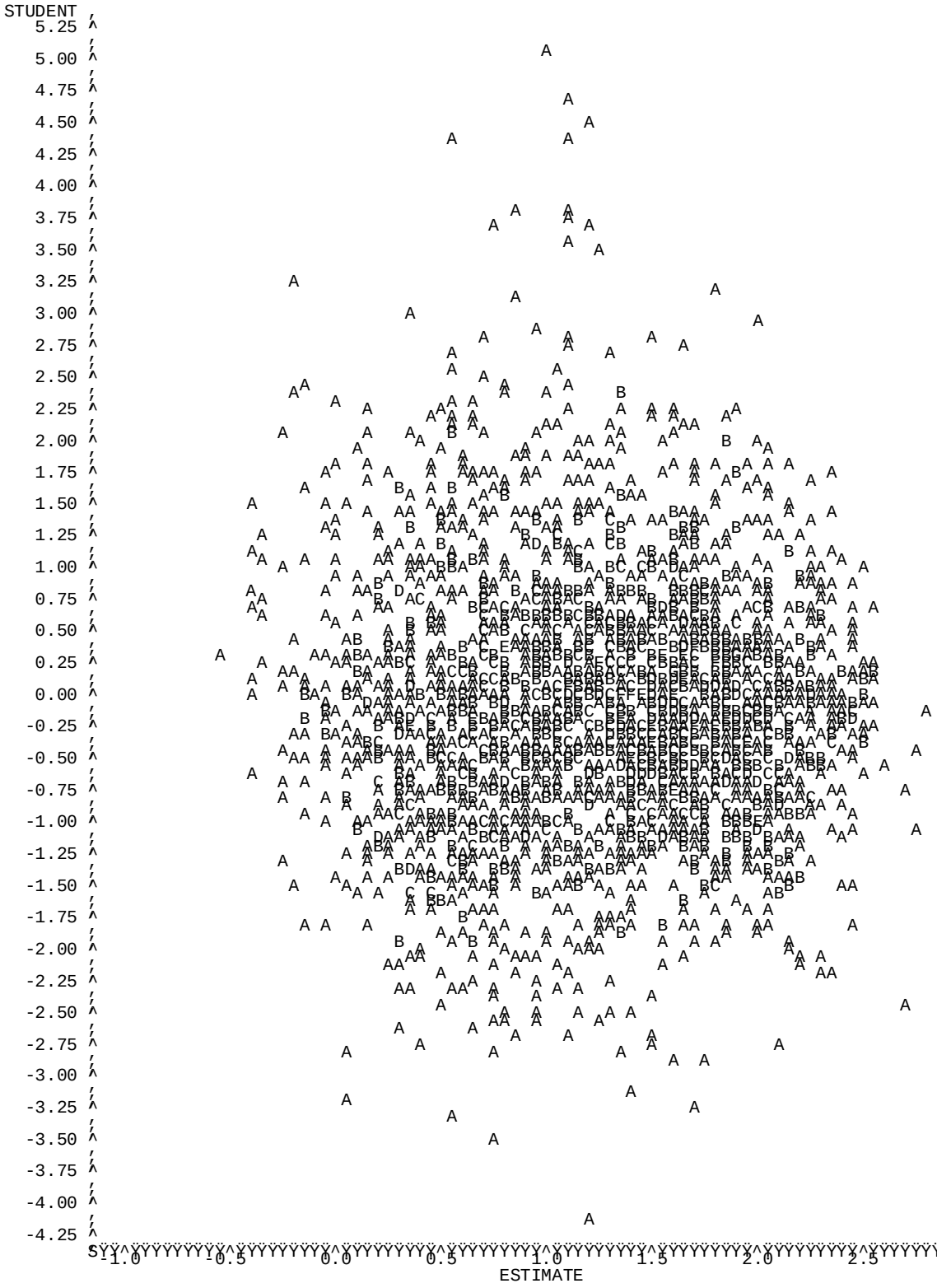


Fig. 5c. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland by Greenlandic, Faeroese and Danish trawlers 2006 (until October).

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
 VESSEL           14    AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH IIII JJJJ KKKK LLLL MMMM XXXX
 YEAR             19    87 88 89 90 91 92 94 95 96 97 98 99 101 102 103 104 105 106 111
 MONTH             5    1 4 7 9 12
 AREA              2    21 22
 HOLD              2    2 9
                            Number of Observations Read        2647
                            Number of Observations Used        2647
 Weight: Hauls
                                                 Sum of
       Source                        DF          Squares     Mean Square    F Value    Pr > F
       Model                         49      41746.48458       851.96907     105.02    <.0001
       Error                       2597      21068.73847         8.11272
       Corrected Total             2646      62815.22305
                     R-Square     Coeff Var      Root MSE    LNCPUE Mean
                     0.664592      279.4414      2.848284       1.019278
       Source                        DF        Type I SS     Mean Square    F Value    Pr > F
       VESSEL                        13      17196.14859      1322.78066     163.05    <.0001
       YEAR*AREA                     31      20981.74384       676.83045      83.43    <.0001
       MONTH                          4       3527.88489       881.97122     108.71    <.0001
       AREA                           0          0.00000               .          .         .
       HOLD                           1         40.70726        40.70726       5.02    0.0252

       Source                        DF       Type III SS     Mean Square    F Value    Pr > F
       VESSEL                        13       8774.42587       674.95584      83.20    <.0001
       YEAR*AREA                     30      11742.59905       391.41997      48.25    <.0001
       MONTH                          4       3508.87779       877.21945     108.13    <.0001
       AREA                           1       2819.14819      2819.14819     347.50    <.0001
       HOLD                           1         40.70726        40.70726       5.02    0.0252
                                                      Standard
           Parameter                  Estimate             Error    t Value    Pr > |t|
           Intercept               0.941482581 B      0.22875823       4.12      <.0001
           VESSEL    AAAA         -0.960072728 B      0.22146957      -4.34      <.0001
           VESSEL    BBBB         -0.780117713 B      0.22121865      -3.53      0.0004
           VESSEL    CCCC         -0.615196152 B      0.22060549      -2.79      0.0053
           VESSEL    DDDD         -0.517585577 B      0.22087340      -2.34      0.0192
           VESSEL    EEEE         -0.429153551 B      0.22075227      -1.94      0.0520
           VESSEL    FFFF         -0.383117348 B      0.22076605      -1.74      0.0828
           VESSEL    GGGG         -0.294897593 B      0.22323380      -1.32      0.1866
           VESSEL    HHHH         -0.249537875 B      0.22299524      -1.12      0.2632
           VESSEL    IIII         -0.135497932 B      0.22044547      -0.61      0.5388
           VESSEL    JJJJ         -0.078328071 B      0.22102915      -0.35      0.7231
           VESSEL    KKKK         -0.037327397 B      0.22104146      -0.17      0.8659
           VESSEL    LLLL          0.038896804 B      0.22228769       0.17      0.8611
           VESSEL    MMMM          0.284463949 B      0.23708388       1.20      0.2303
           VESSEL    XXXX          0.000000000 B               .          .         .
           YEAR*AREA 87 21         0.693319179 B      0.07328751       9.46      <.0001
           YEAR*AREA 88 21         0.490339664 B      0.06920241       7.09      <.0001
           YEAR*AREA 89 21         0.089641221 B      0.06827425       1.31      0.1893
           YEAR*AREA 90 21         0.089132800 B      0.06823479       1.31      0.1916
           YEAR*AREA 91 21        -0.111284155 B      0.06735043      -1.65      0.0986
           YEAR*AREA 92 21        -0.315767113 B      0.07060028      -4.47      <.0001
           YEAR*AREA 94 21         0.349333414 B      0.08621152       4.05      <.0001
           YEAR*AREA 94 22         0.838596221 B      0.07913854      10.60      <.0001
           YEAR*AREA 95 21         0.166663541 B      0.07785882       2.14      0.0324
           YEAR*AREA 95 22         0.650567748 B      0.09527483       6.83      <.0001
           YEAR*AREA 96 21         0.046795590 B      0.09402975       0.50      0.6188
           YEAR*AREA 96 22         0.940401777 B      0.08038955      11.70      <.0001
           YEAR*AREA 97 21         0.343538261 B      0.11554209       2.97      0.0030
           YEAR*AREA 97 22         0.888531730 B      0.08427839      10.54      <.0001
           YEAR*AREA 98 21         0.717215365 B      0.10723117       6.69      <.0001
           YEAR*AREA 98 22         1.026267294 B      0.09483286      10.82      <.0001
           YEAR*AREA 99 21         0.485914056 B      0.11109868       4.37      <.0001
           YEAR*AREA 99 22         1.276768306 B      0.11558867      11.05      <.0001
           YEAR*AREA 101 21        0.563137814 B      0.12085830       4.66      <.0001
           YEAR*AREA 101 22        0.995451952 B      0.07946165      12.53      <.0001
           YEAR*AREA 102 21        0.576977274 B      0.11626824       4.96      <.0001
           YEAR*AREA 102 22        1.243712780 B      0.08756937      14.20      <.0001
           YEAR*AREA 103 21        0.605782578 B      0.09101741       6.66      <.0001
           YEAR*AREA 103 22        1.050738218 B      0.09057343      11.60      <.0001
           YEAR*AREA 104 21        0.852751269 B      0.08682875       9.82      <.0001
           YEAR*AREA 104 22        1.024947405 B      0.10886965       9.41      <.0001
           YEAR*AREA 105 21        0.803065927 B      0.09726020       8.26      <.0001
           YEAR*AREA 105 22        1.270291600 B      0.10608297      11.97      <.0001
           YEAR*AREA 106 21        0.863325888 B      0.12453495       6.93      <.0001
           YEAR*AREA 106 22        0.675385751 B      0.21366328       3.16      0.0016
           YEAR*AREA 111 21       -0.513911389 B      0.07383290      -6.96      <.0001
           YEAR*AREA 111 22        0.000000000 B               .          .         .
           MONTH     1             0.295423359 B      0.02935736      10.06      <.0001
           MONTH     4             0.122906935 B      0.03076618       3.99      <.0001
           MONTH     7             0.175327843 B      0.06567661       2.67      0.0076
           MONTH     9            -0.222033759 B      0.03305787      -6.72      <.0001
           MONTH     12            0.000000000 B               .          .         .
           AREA      21            0.000000000 B               .          .         .
           AREA      22            0.000000000 B               .          .         .
           HOLD      2             0.082180940 B      0.03668753       2.24      0.0252
           HOLD      9             0.000000000 B               .          .         .
```


Plot of STUDENT*ESTIMATE. Legend: A = 1 obs, B = 2 obs, etc.
STUDENT
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
-2.00
-2.25
-2.50
-2.75
-3.00
-3.25
-3.50
-3.75
-4.00
-4.25
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
ESTIMATE

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

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

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

rce                          DF       Type I SS     Mean Square    F Value    Pr > F
TH                            5     1876847.067      375369.413     441.30    <.0001
P                             7      264825.858       37832.265      44.48    <.0001
R                            17      320504.417       18853.201      22.16    <.0001
                              1        2734.659        2734.659       3.21    0.0733

rce                          DF     Type III SS     Mean Square    F Value    Pr > F
TH                            5     213264.7800      42652.9560      50.14    <.0001
P                             7     206529.8841      29504.2692      34.69    <.0001
R                            17     321650.1454      18920.5968      22.24    <.0001
                              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.