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The Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait / off East Greenland – 2010.

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 has been assessed as a single population by evaluation of fishery dependent data only, until this year, where survey data for the period 2008-2010 became available. The stock is managed by catch quotas in the Greenlandic zone. There is 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. Since then catches have decreased to 2 800 tons in 2008, the lowest level since 1980. 2009 catches were close to 4500 tons and 2010 catches are expected to be at the same level. 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. In 2010 the biomass index is back to the level seen since the beginning of the 2000s. 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 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. Until this year the assessment was based on fishery dependent data only, and was largely done by evaluation of trends in biomass indices. Surveys have been performed since 2008 and the result is presented this year (Siegstad 2010).

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 15 000 tons during the following 10-year period. Total catches fluctuated around 12 000 tons from 1994 to 2003 (Table 1, Fig. 2A), and have been decreasing since then, reaching a record-low catch of 2 800 tons in 2008. The fishery was originally conducted north of 65°N on both sides of the territorial midline between Greenland and Iceland. 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 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 CPUE 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. From 1998 approximately 40% of all hauls were performed with double trawl and since 2004 more than 60% of all hauls were performed with doubletrawl. The 2010 assessment included both single and double trawl in the standardized catch rates calculations. The catches in the Greenland EEZ were corrected for “overpacking” according to Hvingel 2003.

Catches and corresponding effort were compiled by year and by areas north and south of 65°N. 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 unstandardised CPUE by statistical units of 7.5' latitude and 15' longitude (fig. 4).

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 the Greenland Fishery and Licence Control (GFLK), 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:

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

Where $CPUE_{miki}$ 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_{miki} 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 78 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 2-11 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 3) 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). 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 (appendix 2) and the year coefficients from the Icelandic zone model (appendix 3). 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-Stredbank area on both sides of the territorial midline between Greenland and Iceland and on the slopes of Storfjord Deep. In 1993 a fishery was also initiated in various smaller areas extending south to the Cap Farewell.

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. 1A, Table 1 and 2). Following the area expansion of the fishery south of 65°N in 1993 catches increased again reaching 11 900 tons in 1994. From 1994 to 2003 catches fluctuated between 11 500 and 14 000 tons (Fig. 1A). In 2004 the catches started dropping, from 10 000 tons in 2004 to a low of 2800 tons in 2008. In 2009 the

catch rose to 4500 tons and the same level is expected for this year.

In the northern area the amount caught declined by about 85% from 1988 to 2001, i.e. from 15 000 tons to 2 200 tons (Fig. 1A, Table 2). Catches more than doubled in the period 2002-2004 (Table 2, Fig. 1A), but have been decreasing since then.

Catches in the southern area increased from 1 900 tons in 1993 (the first year of fishery in this area) to about 11 700 tons in 2001 (Fig. 1A). Since 2001 catches in the southern area has declined, being below 600 tons since 2008.

From 1996 to 2005 catches in the area south of 65°N accounted for between 50% and 85% of the total catch (Fig. 1A). Since then catches in the area south of 65°N has been decreasing. The proportion of the catch taken in the southern area has been around 10% since 2008.

Fishing effort

The high increase in catches during the first ten-year period was mainly driven by increased fishing effort (Fig. 1B, Table 2). Between 1981 and 1989, total effort increased from about 20 000 hr's to a peak of nearly 120 000 hours and has declined since (Table 2, Fig. 1B).

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 10 000 hours in 1993 to 25 000 hours in 1997. In 1999 it reached a low of 7 500 hr's but increased again to 20 000 hr's in 2001. Since then effort in the southern area has been declining (Fig. 1B, Table 2).

According to Greenlandic skippers the reduced effort spent was due to reduced catch rates of large shrimp, which is the primary target of the Greenlandic fishery in East Greenland.

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. 1C, Table 2). Since then the catch rate has been around 400 kg/hr except for 2009, where the catch rate was 640 kg/hr, the highest value ever obtained.

In the southern areas CPUE increased from 204 kg/hr in 1993 to 925 kg/hour in 1999. Until 2008 the mean CPUE in this area fluctuated between 450 and 700 kg/hr. In 2009 the catch rate reached 989 kg/hr and preliminary data for 2010 indicates a CPUE even higher.

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 1995-2002 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. In 2009 the catch rate reached a value of 607kg/hr, the highest value ever obtained. Part year data for 2010 indicates that the catch rate is back to the level obtained in 2003-2007.

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 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. 2, Table 3) indicated that the stock was more than halved during the period 1987-1993. Since then it has been rebuilding reaching the level of 1987 in the mid 1990's. The mean index values increased thereafter and stabilized at a level one third above that of 1987. In 2009 the index more than doubled compared

to 1987, but is back to the 1987 level in 2010.

The CPUE index series of the northern areas (Fig. 2, 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 started increasing reaching a record high level in 2009. The 2010 value is back to the level seen in 2004-2007.

The CPUE index series of the southern area (Fig. 3, Table 3) increased until 1999, with stability until 2007. In 2008 it dropped down to a low of 2.32, the lowest value obtained since 1997. In 2009 the index obtained the highest value ever obtained, whereas the value for 2010 is back to the level from 2000-2007.

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. 3) reaching its lowest levels in 2008 and 2009. The separate indices for the Northern and Southern areas are also shown in Fig. 3 and they follow the trend seen for the total area.

Conclusions

Total catches fluctuated around 12000 tons from 1994 to 2003 (Table 1, Fig. 1A). Catches decreased thereafter to 2 800 tons in 2008. Catches doubled in 2009 compared to 2008 and the catch level for 2010 is expected to be at the same level as in 2009.

A combined standardized catch-rate index for the total area decreased steadily from 1987 to 1993 (Fig. 2), showed an increasing trend until 2000, and has fluctuated at this level until today, except for a record high value in 2009.

Since the mid 1990s exploitation rate index (standardized effort) has decreased, reaching the lowest levels seen in the time series from 2008-2010.

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 the 2000s and has fluctuated at this level until 2009, where an increase was seen. The standardized CPUE in 2010 is back to the level seen in the period from 2000-2008. However, 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.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 ¹
North of 65°N																					
EU (DK,EST,LTU)	476	450	199	138	250	302	26	85	401	793	459	72	816	861	482	304	618	421	389	892	1299
Faeroe Islands	1029	1265	1355	689	462	931	995	635	1268	867	956	214	1029	1062	894	615	342	319	612	1325	782
France	62	148	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-
Greenland	7580	5283	2496	1771	1326	2390	359	105	646	614	115	650	638	695	578	454	223	802	14	844	599
Iceland	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1231	703	411	29	0	0	0	0	0
Norway	3052	3146	3102	1831	2180	2402	1544	797	1628	1783	2759	1291	1630	2861	2700	2614	2704	1771	1514	883	875
Total	12480	10757	8901	6982	5731	7176	3490	4478	5364	4827	4420	2237	5344	6183	5065	4016	3887	3314	2529	3945	3556
South of 65°N																					
Denmark (EU)	-	-	-	60	613	731	1167	1657	1300	1095	1900	2473	2309	1827	1022	644	683	431	251	28	268
Faeroe Island	-	-	-	280	974	295	402	656	138	453	340	2402	1013	303	255	176	227	169	14	28	0
Greenland	-	-	-	1141	3603	2667	5295	4701	3950	4966	5235	4943	4333	4194	3488	2737	316	639	0	447	238
Norway	-	-	-	424	1011	720	1590	2261	670	378	157	1855	1098	197	186	180	76	48	0	107	0
Total	-	-	-	1904	6201	4412	8453	9276	6057	6893	7632	11674	5985	6522	4951	3737	1302	1286	266	610	505
Total area																					
EU (DK,EST,LTU)	476	450	199	198	863	1033	1193	1742	1701	1888	2358	2545	2548	2688	1504	948	1301	852	640	920	1567
Faeroe Islands	1029	1265	1355	968	1436	1225	1397	1292	1406	1321	1296	2616	1322	1365	1149	791	569	488	627	1354	782
France	62	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	7580	5283	2496	2912	4929	5057	5655	4806	4595	5581	5349	5593	4484	4890	4066	3191	539	1441	14	1292	837
Iceland	281	465	1750	2553	1514	1151	566	2856	1421	769	132	10	1231	703	411	29	0	0	0	0	0
Norway	3052	3146	3102	2255	3190	3122	3133	3059	2298	2160	2917	3147	1743	3059	2886	2794	2780	1819	1514	990	875
Total	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11329	12705	10016	7753	5189	4600	2794	4555	4061
Total all areas	12480	10757	8901	8886	11932	11588	11944	13754	11422	11719	12053	13911	11242	12637	9985	7753	5189	4600	2794	4555	4061
Advised TAC	100003	100003	8000	5000	5000	5000	5000	5000	5000	9600	9600	9600	9600	9600	12400	12400	12400	12400	12400	12400	12400
Effective TAC ^c	14100	14500	13000	9563	9563	9563	9563	9563	9563	10600	12600	10600	10600	10600	15043	12400	12400	12400	12400	12835	11835

¹Catch in 2010 until October

^cFor Greenland zone only; no restrictions in Iceland zone

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.

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	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	2529	6106	414	266	585	454	2794	6691	418
2009	3945	6500	607	610	617	989	4555	7117	640
2010*	3556	11005	323	505	401	1261	4061	11657	348

*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.

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	0.88	0.08	1.16	0.11					0.85	0.06	1.20	0.00
1989	0.62	0.06	1.40	0.13					0.58	0.04	1.48	0.10
1990	0.61	0.06	1.35	0.13					0.58	0.04	1.43	0.10
1991	0.52	0.05	1.37	0.13					0.48	0.03	1.48	0.10
1992	0.42	0.04	1.40	0.14					0.39	0.03	1.51	0.11
1993	0.34	0.03	1.35	0.14	1.00	-	1.00	-	0.37	0.03	1.61	0.12
1994	0.80	0.09	0.48	0.05	2.25	0.18	1.45	0.11	0.96	0.07	0.83	0.06
1995	0.66	0.07	0.72	0.07	1.90	0.19	1.22	0.11	0.71	0.05	1.08	0.08
1996	0.60	0.07	0.39	0.05	2.65	0.22	1.67	0.13	0.98	0.08	0.81	0.06
1997	0.80	0.10	0.37	0.05	2.52	0.22	1.93	0.16	1.08	0.09	0.85	0.07
1998	1.03	0.13	0.35	0.04	2.83	0.28	1.12	0.10	1.15	0.10	0.66	0.06
1999	0.89	0.11	0.36	0.05	3.67	0.44	0.99	0.11	1.16	0.11	0.67	0.06
2000	1.08	0.12	0.27	0.03	3.60	0.34	1.11	0.10	1.26	0.10	0.63	0.05
2001	0.96	0.13	0.15	0.02	2.75	0.22	2.23	0.17	1.29	0.10	0.72	0.06
2002	0.99	0.13	0.36	0.05	3.39	0.30	0.93	0.08	1.41	0.12	0.53	0.04
2003	0.96	0.11	0.43	0.05	2.83	0.26	1.21	0.11	1.09	0.09	0.78	0.06
2004	1.31	0.14	0.26	0.03	2.74	0.30	0.95	0.10	1.23	0.10	0.54	0.04
2005	1.33	0.16	0.20	0.02	3.46	0.39	0.57	0.06	1.42	0.13	0.36	0.03
2006	1.38	0.17	0.19	0.02	3.30	0.46	0.21	0.03	1.38	0.13	0.25	0.02
2007	1.22	0.15	0.18	0.02	3.64	0.56	0.19	0.03	1.25	0.12	0.24	0.02
2008	1.54	0.20	0.11	0.01	2.32	0.65	0.06	0.01	1.40	0.16	0.13	0.01
2009	2.25	0.28	0.12	0.01	4.47	1.16	0.07	0.02	2.07	0.22	0.15	0.02
2010*	1.17	0.14	0.20	0.02	3.34	1.50	0.08	0.03	1.11	0.12	0.24	0.03

* Until Oct.

Figure 1. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall. (Data for 2010 is part-years data, until October).

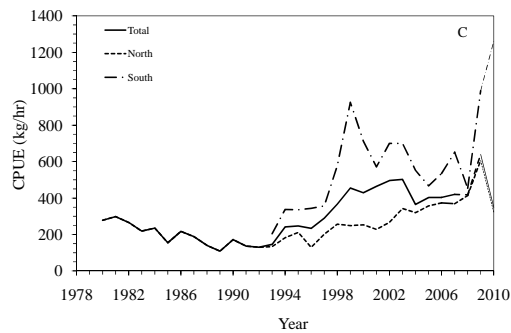
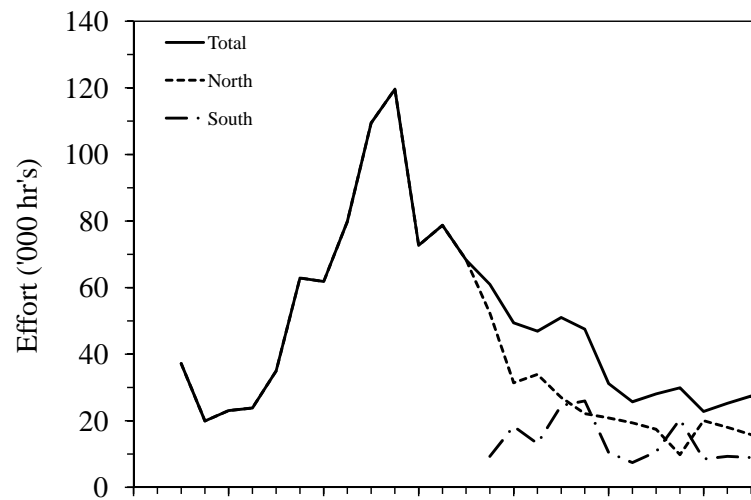
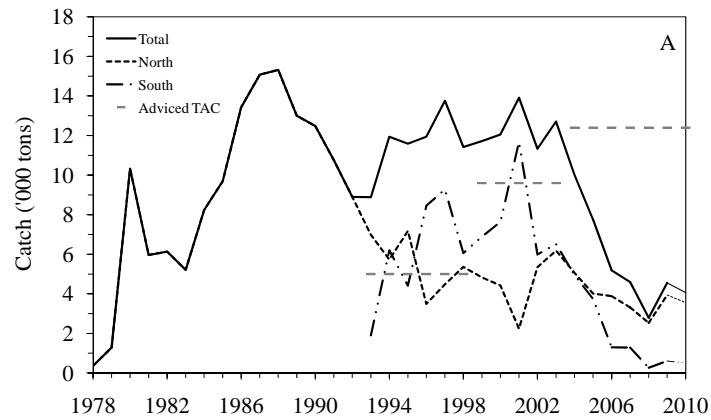


Figure 2. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas south of 65°N, in Iceland EEZ, overall fishery north of 65°N (both in Greenland and Iceland EEZ), and overall standardized CPUE for the stock (Estimates for 2010 are based on data until October).

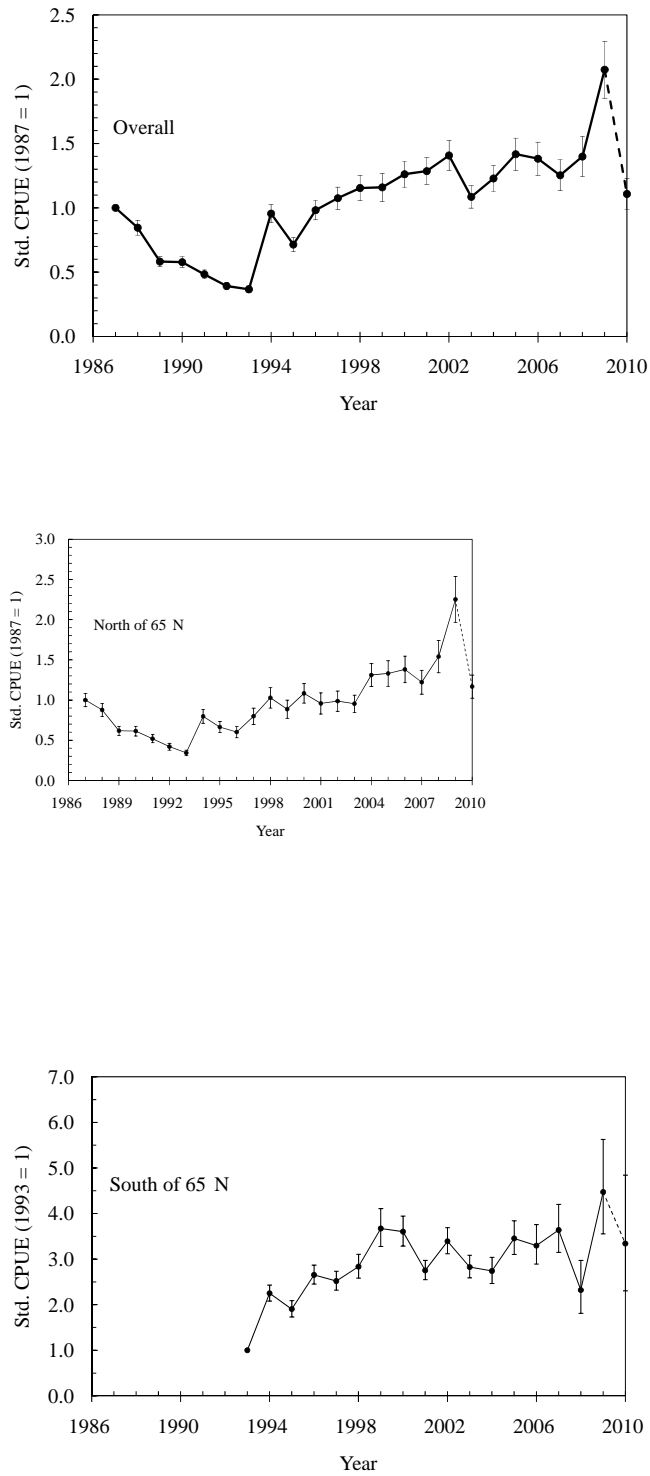


Figure 3. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall (Estimates for 2010 are based on data until October).

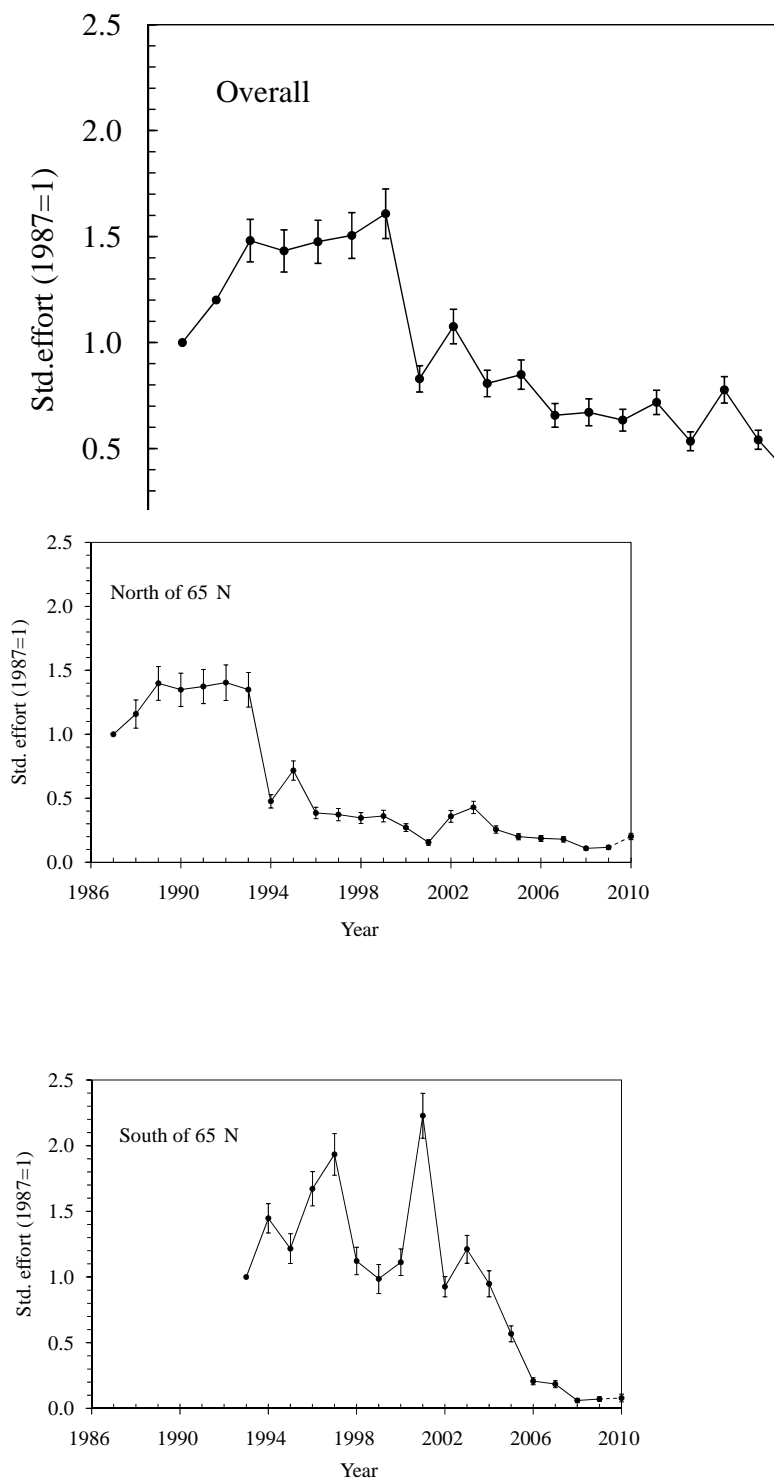


Figure 4a. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland 2006.

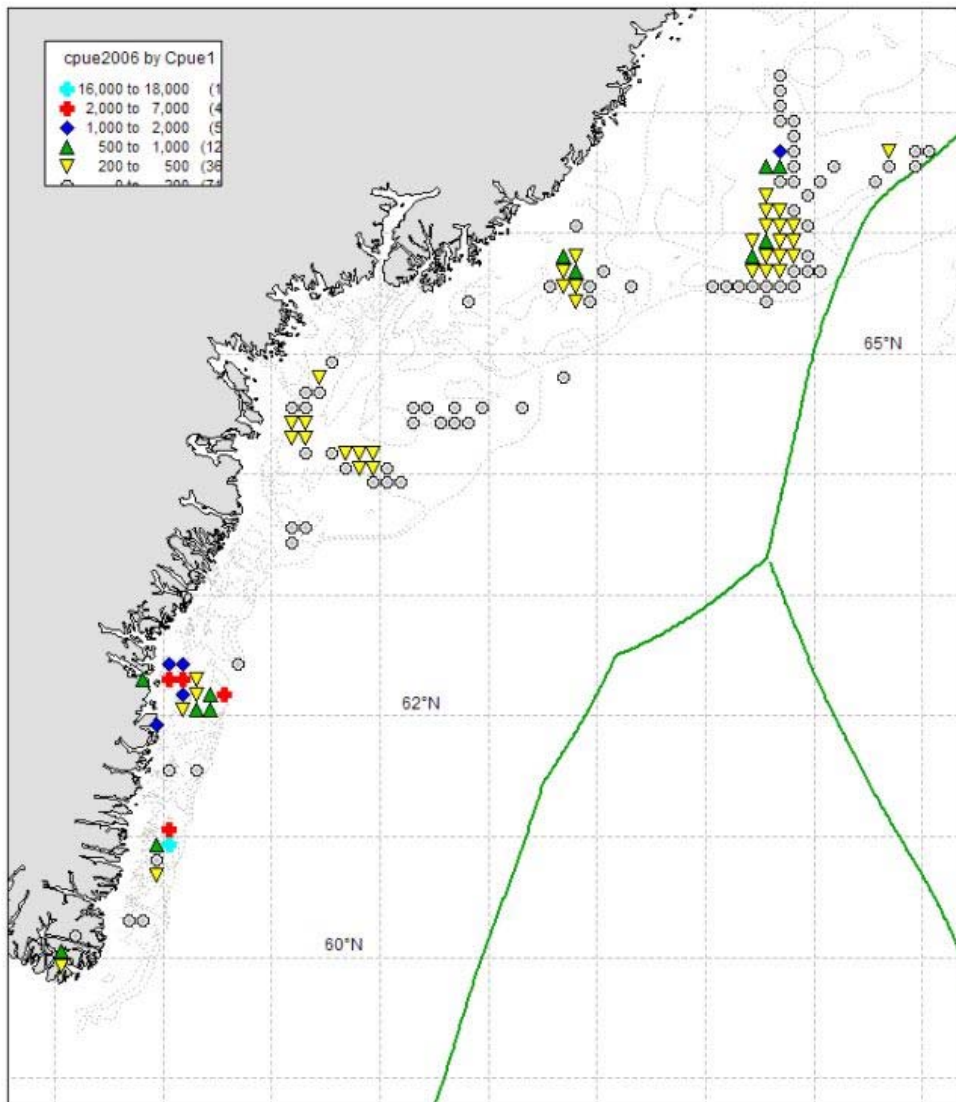


Figure 4b. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland 2007.

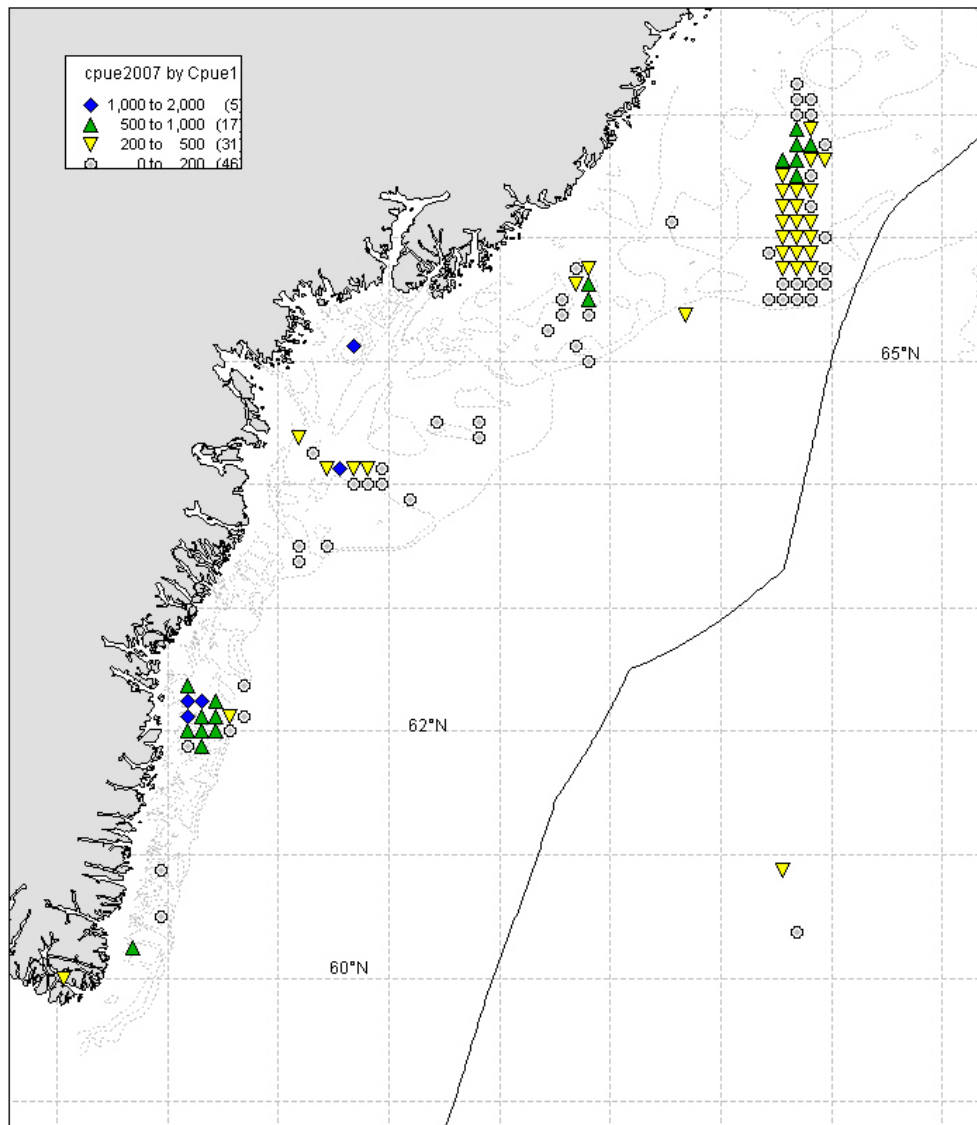


Figure 4c. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland 2008.

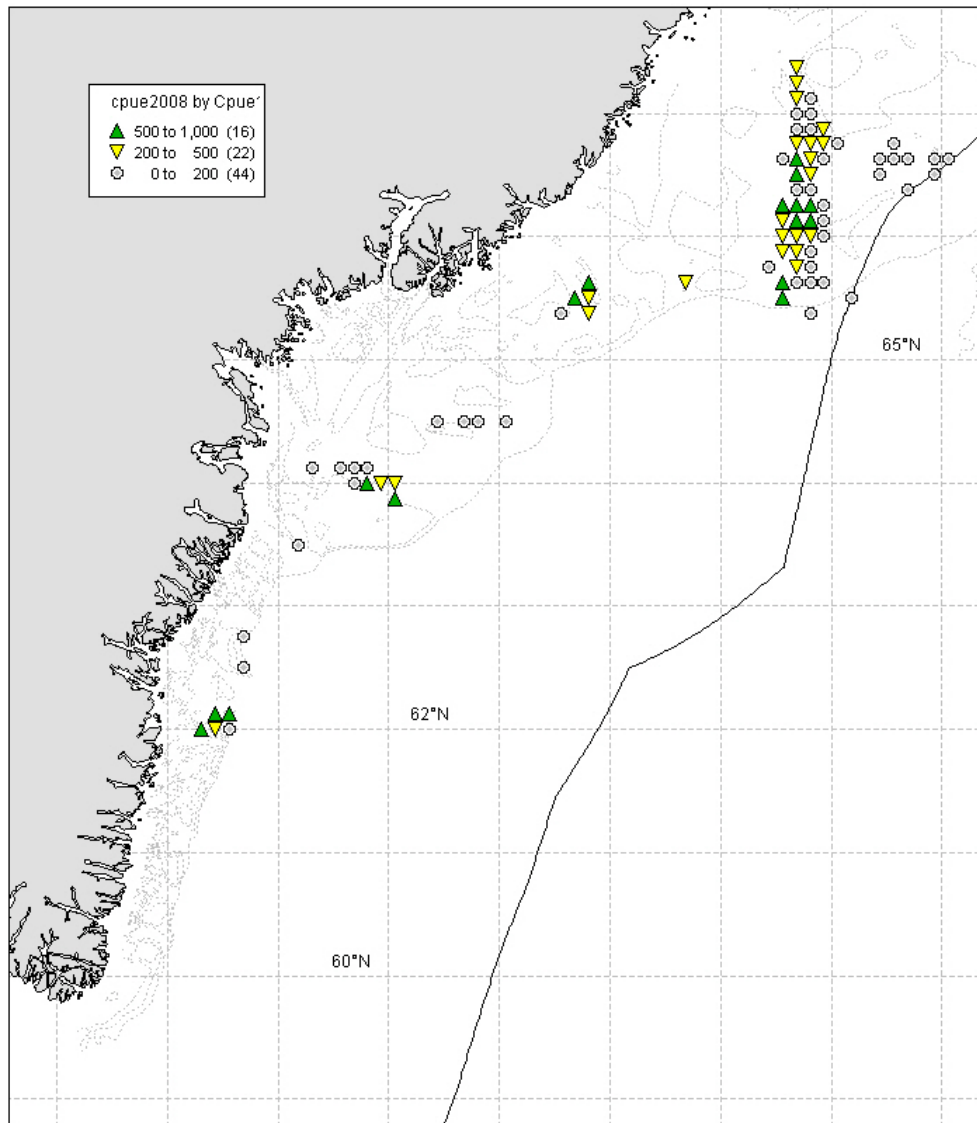


Figure 4d. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland 2009.

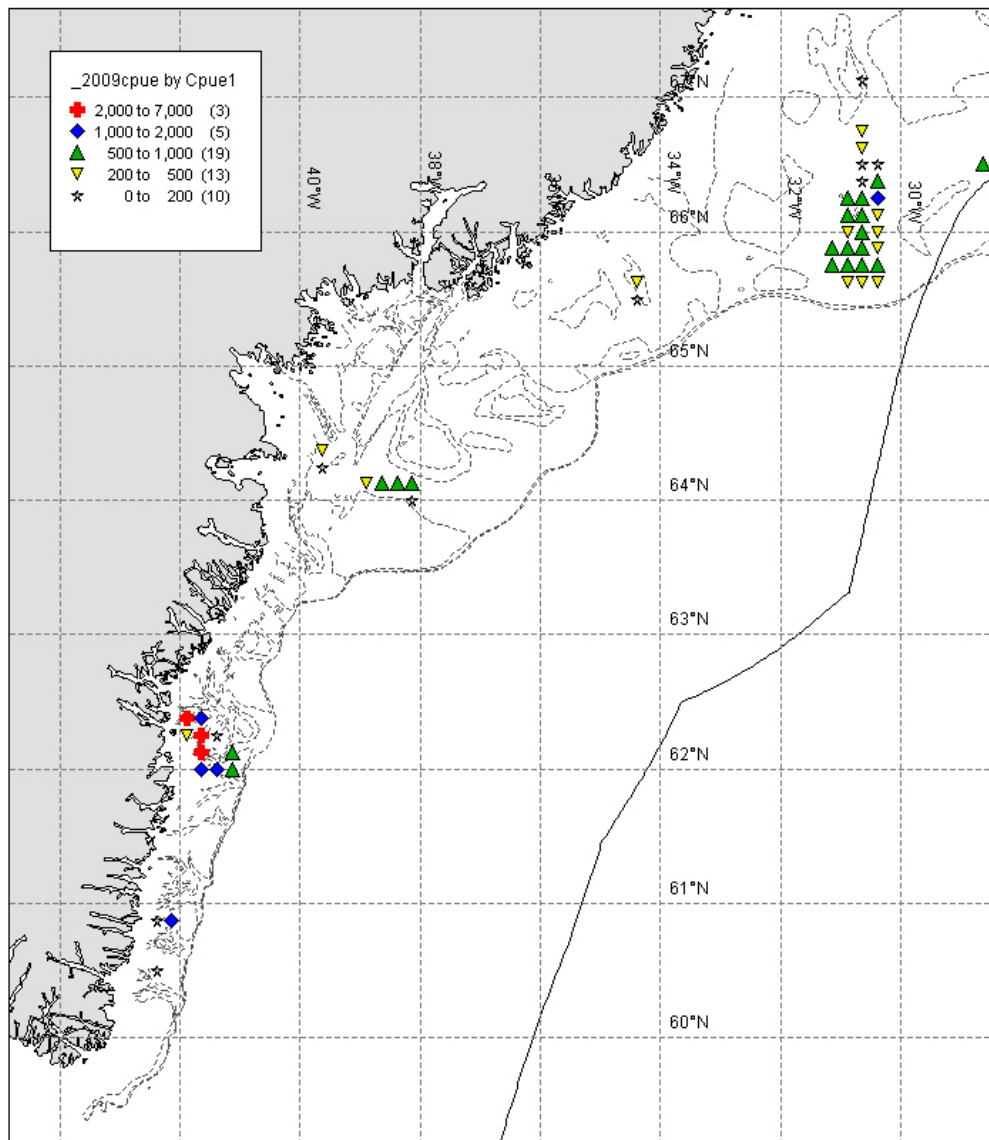
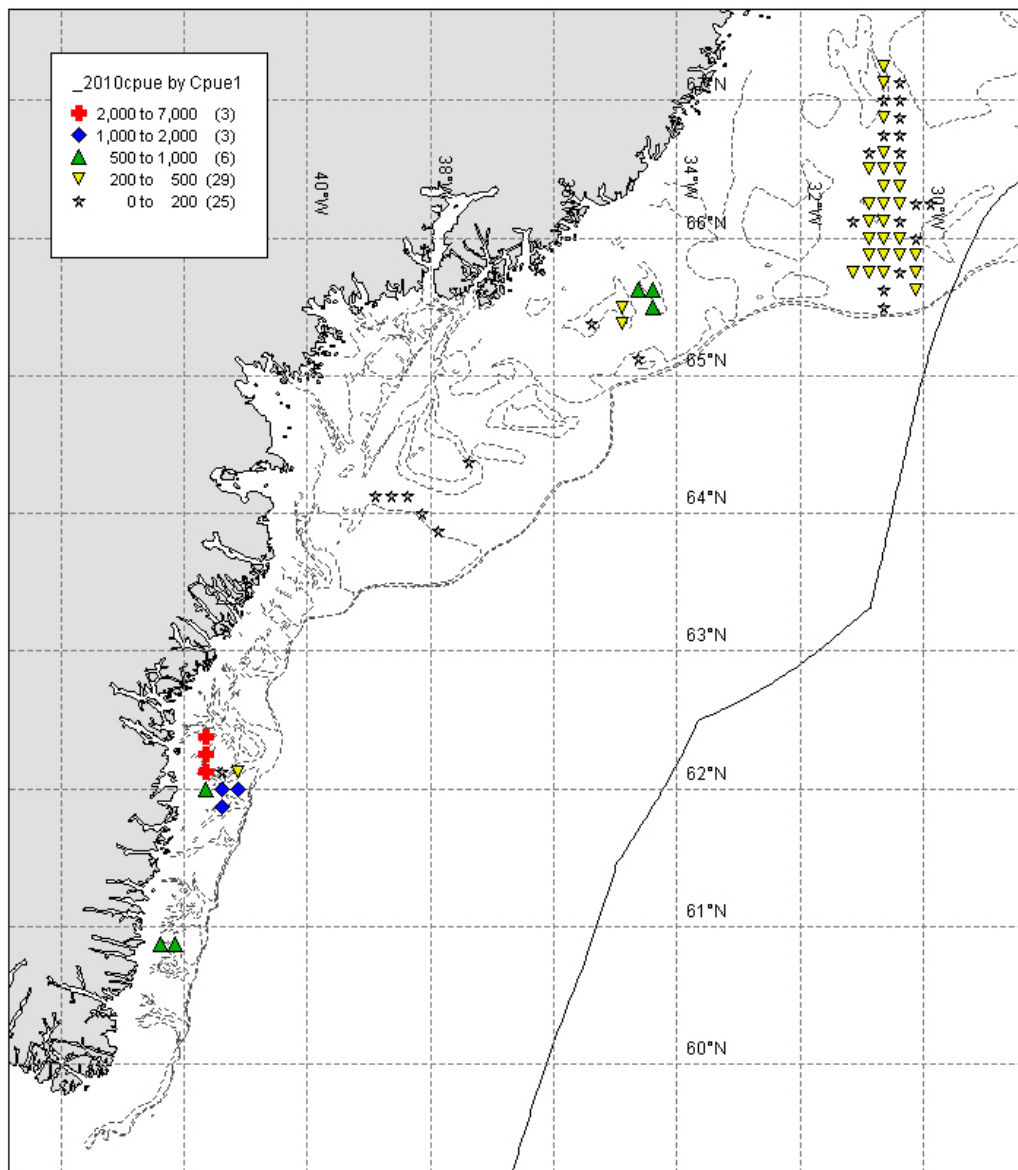


Figure 4e. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland 2010 (until October).



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 SAS System

3

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.

Appendix 2. Results and diagnostical outputs from GLM run of model without area interaction for standardising CPUE in Greenlandic zone. Data from Greenlandic, Faeroese, Norway and EUvessels.

The SAS System

October 11, 2010

The GLM Procedure

Class Level Information

Class	Levels	Values
BAAD	18	E005 E010 E013 E018 E024 E028 E030 E033 E043 E048 E057 E062 E067 E069 E075 E076 E077 E078
YEAR	24	88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111
MONTH	9	1 2 4 5 6 7 8 11 12
HOLD	2	2 9

Number of Observations Read	3185
Number of Observations Used	3185

The SAS System

13:55 Monday, October 11, 2010 10

The GLM Procedure

Dependent Variable: LNCPUE

Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	49	47823.47317	975.98925	111.83	<.0001
Error	3135	27360.34849	8.72738		
Corrected Total	3184	75183.82166			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.636087	269.0051	2.954215	1.098200

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	17	23329.39965	1372.31763	157.24	<.0001
YEAR	23	21048.03715	915.13205	104.86	<.0001
MONTH	8	3445.20430	430.65054	49.34	<.0001
HOLD	1	0.83208	0.83208	0.10	0.7575

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	17	11700.11901	688.24229	78.86	<.0001
YEAR	23	19119.11336	831.26580	95.25	<.0001
MONTH	8	3443.12808	430.39101	49.32	<.0001
HOLD	1	0.83208	0.83208	0.10	0.7575

Parameter		Standard Estimate	Error	t Value	Pr > t
Intercept		1.019254227 B	0.12971554	7.86	<.0001
BAAD	E005	-0.485945278 B	0.13626436	-3.57	0.0004
BAAD	E010	-0.330297931 B	0.13153318	-2.51	0.0121
BAAD	E013	-0.250615824 B	0.13408136	-1.87	0.0617
BAAD	E018	-0.179693315 B	0.13303157	-1.35	0.1769
BAAD	E024	-0.063338981 B	0.12978454	-0.49	0.6256
BAAD	E028	-0.003081595 B	0.12958169	-0.02	0.9810
BAAD	E030	0.116330084 B	0.13029467	0.89	0.3720
BAAD	E033	0.156716724 B	0.13165760	1.19	0.2340
BAAD	E043	0.182184559 B	0.12768808	1.43	0.1537
BAAD	E048	0.280378928 B	0.13341930	2.10	0.0357
BAAD	E057	0.360156176 B	0.12926520	2.79	0.0054
BAAD	E062	0.515055932 B	0.12918047	3.99	<.0001
BAAD	E067	0.585243001 B	0.12763995	4.59	<.0001
BAAD	E069	0.714823742 B	0.13292638	5.38	<.0001
BAAD	E075	0.863917212 B	0.13888721	6.22	<.0001
BAAD	E076	-0.016541319 B	0.21884476	-0.08	0.9398
BAAD	E077	0.311448021 B	0.19176045	1.62	0.1044
BAAD	E078	0.000000000 B	.	.	.
YEAR	88	-0.198943843 B	0.04758964	-4.18	<.0001
YEAR	89	-0.602277295 B	0.04663108	-12.92	<.0001
YEAR	90	-0.600873979 B	0.04678607	-12.84	<.0001
YEAR	91	-0.800738975 B	0.04657178	-17.19	<.0001
YEAR	92	-1.015079970 B	0.05124873	-19.81	<.0001
YEAR	93	-1.079847918 B	0.05138245	-21.02	<.0001
YEAR	94	-0.098422470 B	0.05472379	-1.80	0.0722
YEAR	95	-0.390936952 B	0.05518743	-7.08	<.0001
YEAR	96	-0.053616961 B	0.05660558	-0.95	0.3436
YEAR	97	0.058059366 B	0.06292217	0.92	0.3562
YEAR	98	0.167664109 B	0.06902648	2.43	0.0152
YEAR	99	0.163151041 B	0.07941366	2.05	0.0400
YEAR	100	0.197236343 B	0.06031700	3.27	0.0011
YEAR	101	0.208194569 B	0.05874436	3.54	0.0004
YEAR	102	0.291934694 B	0.06484005	4.50	<.0001
YEAR	103	0.047932935 B	0.06071085	0.79	0.4299
YEAR	104	0.170121997 B	0.06329394	2.69	0.0072
YEAR	105	0.298200608 B	0.06874509	4.34	<.0001
YEAR	106	0.272100460 B	0.07455053	3.65	0.0003
YEAR	107	0.172791702 B	0.07750149	2.23	0.0258
YEAR	108	0.277535821 B	0.09385598	2.96	0.0031
YEAR	109	0.673801960 B	0.08857631	7.61	<.0001
YEAR	110	0.047714808 B	0.08642881	0.55	0.5809
YEAR	111	0.000000000 B	.	.	.
MONTH	1	0.284133269 B	0.03170895	8.96	<.0001
MONTH	2	0.264929518 B	0.03160719	8.38	<.0001
MONTH	4	0.178928200 B	0.03062828	5.84	<.0001
MONTH	5	0.124525399 B	0.04444692	2.80	0.0051
MONTH	6	0.088730579 B	0.08359032	1.06	0.2885
MONTH	7	0.481917906 B	0.07537160	6.39	<.0001
MONTH	8	0.201657222 B	0.05487910	3.67	0.0002
MONTH	11	-0.202305673 B	0.03323948	-6.09	<.0001
MONTH	12	0.000000000 B	.	.	.
HOLD	2	-0.009615363 B	0.03114055	-0.31	0.7575
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

Appendix 3. 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

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.

