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The Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait / off East Greenland 1978 - 2017.

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 2011, where data from an annual survey series starting in 2008 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. The fishery in the Icelandic zone ceased in 2006.

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 2004 annual catches have decreased and reached a low of 49 tons in 2016. 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. From 2009 to 2014 the biomass index has been declining. In the last years there have been an increasing trend in the biomass index but at the same time fishing effort has been very low. The index of harvest rate has declined since 1993 and recent levels are the lowest of the time series.

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 2011the assessment was based on fishery dependent data only, and was largely done by evaluation of trends in biomass indices. Surveys has been performed since 2008 (Siegstad 2016).

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. The catch in 2016 was 49 tons and in 2017 until July was 557 tons. 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 south of 65°N extending south to the Cap Farewell. At any time access to fishing grounds depends on ice conditions.

Since 1994 fleets from Greenland, EU, 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 since 1980 and from Norway since 2000 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 double trawl. The 2017 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:

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

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,σ^2/n), where n is the number of observations in the cell. The standardised CPUE indices are the antilog of the year coefficient.

For the model pertaining to the Greenlandic zone 82 of 118 vessels met the criteria for inclusion in the analysis (at least three years of fishing in the area). The 82 vessels qualifying for the index were collapsed into 16 groups

consisting of 2 -9 vessels. 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 was unsuitable to further analyses and therefore not included. This analysis has not been repeated since 2006 (Siegstad and Hvingel 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 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 (Siegstad and Hvingel 2006). 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. In 1993 a fishery was also initiated south of 65°N in various smaller areas extending south to the Cap Farewell. Since 2008 most of

the fishery (more than 90 %) has been conducted north of 65°N (Table 2, Fig. 1). Since 2013 no fishery has been conducted south of 65°N.

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 decreasing, from 10 000 tons in 2004 to a low of 49 tons in 2016. The catch until July 2017 was 557 tons.

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 then catches in the area south of 65°N has been decreasing. No fishing has been conducted in the southern area since 2013. From 1996 to 2005 catches in the area south of 65°N accounted for between 50% and 85% of the total catch (Fig. 1A).

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 hours to a peak of nearly 120 000 hours and has declined since (Table 2, Fig. 1B). In 2016 total effort was the lowest ever seen, being 327 hours.

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).

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). From 2004 to 2008 the catch rate was between 365 and 420 kg/hr. In 2009 the catch rate was 640 kg/hr, the highest value ever obtained. Since 2009 catch rates has been decreasing reaching a low in 2014-2016 around 135 kg/hour. In 2017 catch rate is increasing (based on half years data).

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. Since then catch rates has been decreasing until 2017 where an increase was seen.

In the southern area CPUE increased from 204 kg/hr in 1993 to 925 kg/hr in 1999. Until 2008 the mean CPUE in this area fluctuated between 450 and 700 kg/hr with a mean of 600 kg/hr. Since then catch rates has increased reaching a high of 2 136 kg/hr in 2011. –However only 7 hauls were conducted in the southern area in 2011. The catch rate in 2012 fell to 1267 kg/hr, but is based on only 60 hauls. No fishery has been conducted in the southern area since then.

Standardised catch rate indices

The CPUEs for the southern area since 2011 were omitted from the GLMs because of the low number of hauls conducted in this area during the last years.

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.

The combined CPUE index for the total area (Fig. 2, Table 3) indicated that the stock 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 then increased until the end of the 1990s, and stabilized at a level one third above that of 1987. Since then the biomass index has been fluctuating without a trend until 2009 where the index more than doubled compared to 1987. Since then the combined index has been declining and reached a low level in 2014-2015. Since then there has been an increasing trend.

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 stabilised at a level one third above that of 1987. In 2008 the index started increasing reaching a record high level in 2009. The index went down until 2014/2015 but has shown an increasing trend since then.
The fishing fleet has decreased the effort in recent years which gives some uncertainty to whether recent CPUE indices are a true reflection on stock biomass.

The CPUE index series of the southern area (Fig. 3, Table 3) increased until 1999 and has since then fluctuated without a trend. No index for the southern has been calculated since 2011.

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 from 2008 to 2014. The separate indices for the Northern and Southern areas are shown in Fig. 3 and they follow the trend seen for the total area. No standardised effort for the southern area has been calculated since 2010.

Conclusions

Total catches fluctuated around 12000 tons from 1994 to 2003 and has decreased since then to a low of 49 tons in 2016. The catch until July 2017 was 557 tons.

The combined CPUE index for the total area was stable from 1998 to 2008 and reached a record high value in 2009. It decreased from 2009 to 2013, was at a low level from 2013 to 2015 and has shown an increase in 2016 and 2017, but the estimate is uncertain since the fishing fleet has decreased the effort in recent years.

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

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Table 1. Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland from 1978 to July 2017. Values for the fishery in the Greenland EEZ by EU, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel 2003.

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
North of 65°N																				
EU (DK,EST,LTU)	-	0	878	727	926	255	554	442	626	703	554	454	476	450	199	138	250	302	26	85
Faroe Islands	-	0	5296	892	922	554	836	843	910	754	847	738	1029	1265	1355	689	462	931	995	635
France	-	0	63	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0	0
Greenland	-	0	250	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	1771	1326	2390	359	105
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856
Norway	-	1001	3079	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	1831	2180	2402	1544	797
Total	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	6982	5731	7176	3490	4478
South of 65°N																				
Denmark (EU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	613	731	1167	1657
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	280	974	295	402	656
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1141	3603	2667	5295	4701
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	424	1011	720	1590	2261
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1904	6201	4412	8453	9276
Total area																				
EU (DK,EST,LTU, GBR)	-	0	878	727	926	255	554	442	626	703	554	454	476	450	199	198	863	1033	1193	1742
Faroe Islands	-	0	5296	892	922	554	836	843	910	754	847	738	1029	1265	1355	968	1436	1225	1397	1292
France	-	0	63	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0	0
Greenland	-	0	250	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	2912	4929	5057	5655	4806
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566	2856
Norway	-	1001	3079	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	2255	3190	3122	3133	3059
Total	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754
Total all areas	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944	13754
Advised TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	100003	100003	100003	8000	5000	5000	5000	5000	5000
Effective TAC[1]	-	-	-	8000	4500	5725	5245	6090	75255	75255	87255	90255	14100	14500	13000	9563	9563	9563	9563	9563

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

Table 1 (continued). Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland from 1978 to July 2017. Values for the fishery in the Greenland EEZ by EU, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel 2003.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[2]
North of 65°N																				
EU (DK,EST,LTU)	401	793	459	72	816	861	482	304	618	421	389	892	1345	927	1411	1540	442	402	49	174
Faroe Islands	1268	867	956	214	1029	1062	894	615	342	319	612	1325	781	0	0	0	0	0	0	0
France	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenland	646	614	115	650	638	695	578	454	223	802	14	844	426	183	481	174	180	174	0	383
Iceland	1421	769	132	10	1231	703	411	29	0	0	0	0	0	0	0	0	0	0	0	0
Norway	1628	1783	2759	1291	1630	2861	2700	2613	2704	1771	1514	883	770	36	2	0	0	0	0	0
Total	5364	4827	4420	2237	5344	6183	5065	4015	3887	3313	2529	3945	3323	1145	1893	1714	622	576	49	557
South of 65°N																				
Denmark (EU)	1300	1095	1900	2473	2309	1827	1022	644	683	431	251	28	101	0	0	0	0	0	0	0
Faroe Island	138	453	340	2402	1013	303	255	176	227	169	14	28	0	0	0	0	0	0	0	0
Greenland	3950	4966	5235	4943	4333	4194	3488	2737	316	638	0	447	178	53	215	3	0	0	0	0
Norway	670	378	157	1855	1098	197	186	180	76	48	0	107	0	0	0	0	0	0	0	0
Total	6057	6893	7632	11674	5985	6522	4951	3737	1302	1286	266	610	280	53	215	3	0	0	0	0
Total area																				
EU (DK,EST,LTU, GBR)	1701	1888	2358	2545	2548	2688	1504	948	1301	852	640	920	1446	927	1411	1540	442	402	49	174
Faroe Islands	1406	1321	1296	2616	1322	1365	1149	791	569	488	627	1354	782	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	4595	5581	5349	5593	4484	4890	4066	3191	539	1440	14	1292	605	236	696	177	180	174	0	383
Iceland	1421	769	132	10	1231	703	411	29	0	0	0	0	0	0	0	0	0	0	0	0
Norway	2298	2160	2917	3147	1743	3059	2886	2793	2780	1819	1514	990	770	36	2	0	0	0	0	0
Total	11422	11719	12053	13911	11329	12705	10016	7752	5189	4599	2794	4555	3602	1199	2109	1717	622	576	49	557
Total all areas	11422	11719	12053	13911	11242	12637	9985	7752	5189	4599	2794	4555	3602	1199	2109	1717	622	576	49	557
Advised TAC	5000	9600	9600	9600	9600	9600	12400	12400	12400	12400	12400	12400	12400	12400	12400	12400	2000	2000	2000	2000
Effective TAC[1]	9563	10600	12600	10600	10600	10600	15043	12400	12400	12400	12400	12835	11835	12400	12400	12400	8300	6100	5300	5000

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

[2]Catch until July

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 and total area.

	Area north			Area south			Total area		
Year	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
1980	10325	37198	278				10325	37198	278
1981	5964	19986	298				5964	19986	298
1982	6133	23081	266				6133	23081	266
1983	5212	23855	219				5212	23855	219
1984	8235	34983	235				8235	34983	235
1985	9696	62911	154				9696	62911	154
1986	13428	61863	217				13428	61863	217
1987	15073	79881	189				15073	79881	189
1988	15313	109455	140				15313	109455	140
1989	12999	119629	109				12999	119629	109
1990	12480	72736	172				12480	72736	172
1991	10757	78714	137				10757	78714	137
1992	8901	68349	130				8901	68349	130
1993	6982	52381	133	1904	9335	204	8886	61003	146
1994	5731	31417	182	6201	18371	338	11932	49428	241
1995	7176	33953	211	4412	13157	335	11588	46927	247
1996	3490	27029	129	8453	24589	344	11944	51049	234
1997	4478	22175	202	9276	25992	357	13754	47519	289
1998	5364	20881	257	6057	10498	577	11422	31205	366
1999	4827	19388	249	6893	7449	925	11719	25742	455
2000	4420	17474	253	7632	10705	713	12053	28096	429
2001	2237	9822	228	11674	20435	571	13911	29933	465
2002	5344	20052	267	5985	8546	700	11329	22843	496
2003	6183	18053	342	6522	9317	700	12705	25295	502
2004	5065	15848	320	4951	8972	552	10016	27450	365
2005	4015	11249	357	3737	8003	467	7752	19255	403
2006	3887	10414	373	1302	2436	534	5189	12851	404
2007	3313	8976	369	1286	1974	651	4599	10949	420
2008	2529	6106	414	266	585	454	2794	6691	418
2009	3945	6500	607	610	617	989	4555	7117	640
2010	3323	10286	323	280	263	1062	3602	10550	341
2011	1145	3301	347	53	25	2136	1199	3326	360
2012	1893	6343	298	215	170	1267	2109	6513	324
2013	1714	8162	210	3	75	45	1717	8235	208
2014	622	4364	142	0	-	-	622	4374	142
2015	576	4573	126	0	-	-	576	4905	117
2016	49	327	150	0	-	-	49	327	150
2017*	557	1574	354	0	-	-	557	1574	354

*until July

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.

	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	0.90	0.08	1.13	0.10					0.94	0.09	1.08	0.11
1989	0.64	0.06	1.35	0.13					0.65	0.06	1.33	0.13
1990	0.63	0.06	1.30	0.12					0.65	0.06	1.27	0.13
1991	0.54	0.05	1.33	0.13					0.55	0.06	1.29	0.13
1992	0.44	0.04	1.35	0.13					0.45	0.05	1.32	0.13
1993	0.36	0.04	1.30	0.13	1.00	-	1.00	-	0.42	0.04	1.39	0.14
1994	0.84	0.09	0.45	0.05	2.26	0.18	1.44	0.11	1.17	0.12	0.68	0.07
1995	0.69	0.07	0.69	0.07	1.89	0.18	1.23	0.11	0.92	0.10	0.84	0.09
1996	0.63	0.07	0.37	0.04	2.63	0.21	1.69	0.13	1.16	0.12	0.68	0.07
1997	0.83	0.10	0.36	0.05	2.50	0.21	1.95	0.16	1.44	0.15	0.64	0.07
1998	1.07	0.13	0.33	0.04	2.86	0.27	1.11	0.10	1.51	0.17	0.50	0.06
1999	0.92	0.11	0.35	0.04	3.68	0.43	0.98	0.11	1.71	0.20	0.45	0.05
2000	1.11	0.12	0.26	0.03	3.56	0.33	1.13	0.10	1.77	0.19	0.45	0.05
2001	0.97	0.13	0.15	0.02	2.69	0.21	2.28	0.17	1.76	0.19	0.53	0.06
2002	1.01	0.13	0.35	0.04	3.31	0.29	0.95	0.08	2.02	0.22	0.37	0.04
2003	0.97	0.11	0.42	0.05	2.79	0.25	1.23	0.11	1.56	0.17	0.54	0.06
2004	1.35	0.14	0.25	0.03	2.71	0.29	0.96	0.10	1.71	0.18	0.39	0.04
2005	1.35	0.16	0.20	0.02	3.45	0.38	0.57	0.06	2.02	0.23	0.26	0.03
2006	1.41	0.16	0.18	0.02	3.25	0.45	0.21	0.03	1.89	0.22	0.18	0.02
2007	1.24	0.15	0.18	0.02	3.58	0.55	0.19	0.03	1.63	0.20	0.19	0.02
2008	1.54	0.20	0.11	0.01	2.29	0.63	0.06	0.01	1.92	0.26	0.10	0.01
2009	2.29	0.28	0.11	0.01	4.37	1.11	0.07	0.02	2.68	0.35	0.11	0.01
2010	1.18	0.14	0.19	0.02	3.50	1.40	0.04	0.01	1.44	0.17	0.17	0.02
2011	1.28	0.20	0.06	0.01	-	-	-	-	1.46	0.25	0.05	0.01
2012	1.00	0.13	0.13	0.02	-	-	-	-	1.22	0.17	0.11	0.02
2013	0.60	0.08	0.19	0.02	-	-	-	-	0.74	0.11	0.15	0.02
2014	0.42	0.10	0.10	0.02	-	-	-	-	0.54	0.14	0.08	0.02
2015	0.47	0.08	0.08	0.01	-	-	-	-	0.60	0.11	0.06	0.01
2016	0.67	0.34	0.005	0.002	-	-	-	-	0.93	0.52	0.004	0.002
2017	1.40	0.32	0.026	0.006	-	-	-	-	1.56	0.38	0.024	0.006

* Until July

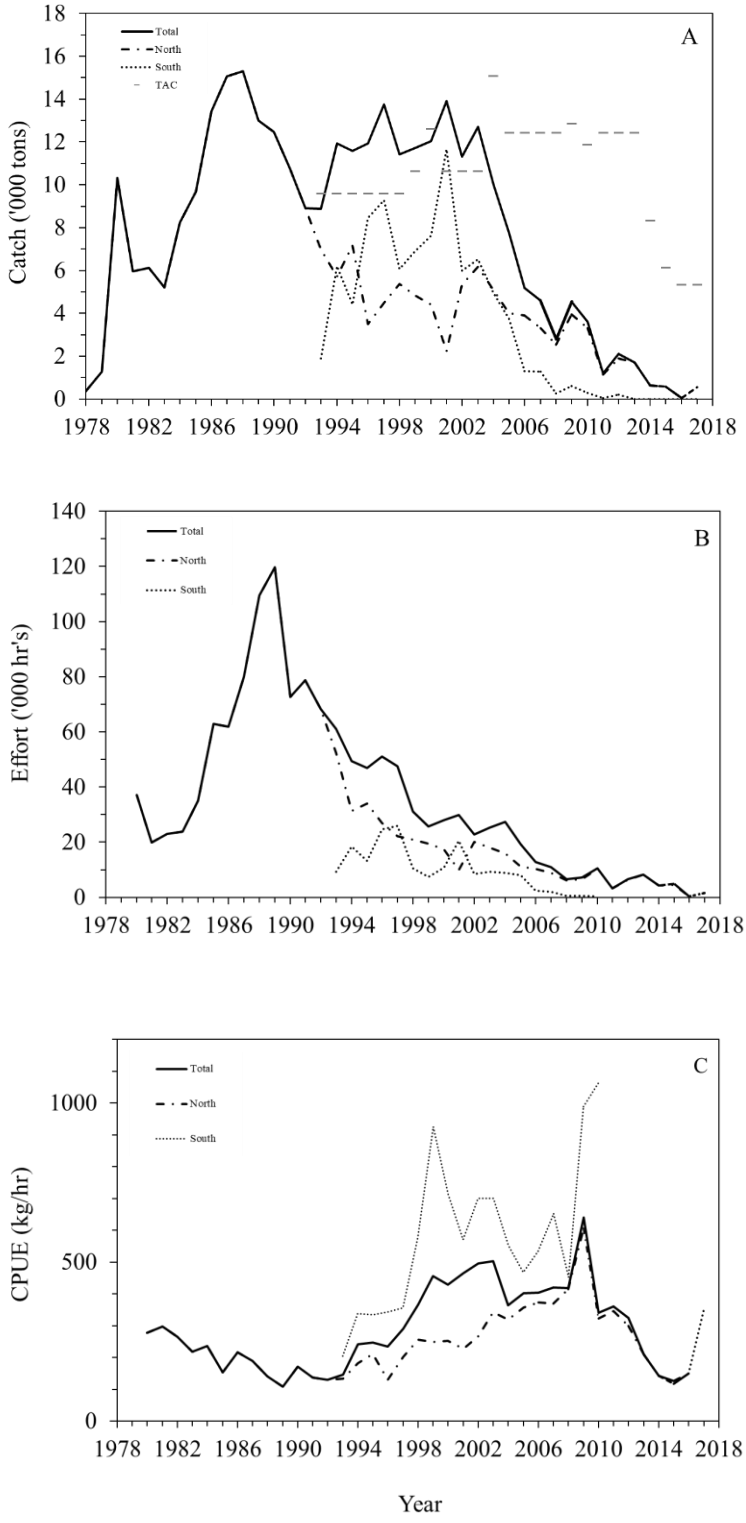

Fig. 1. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall. (Data for 2017 is part-years data, until July).

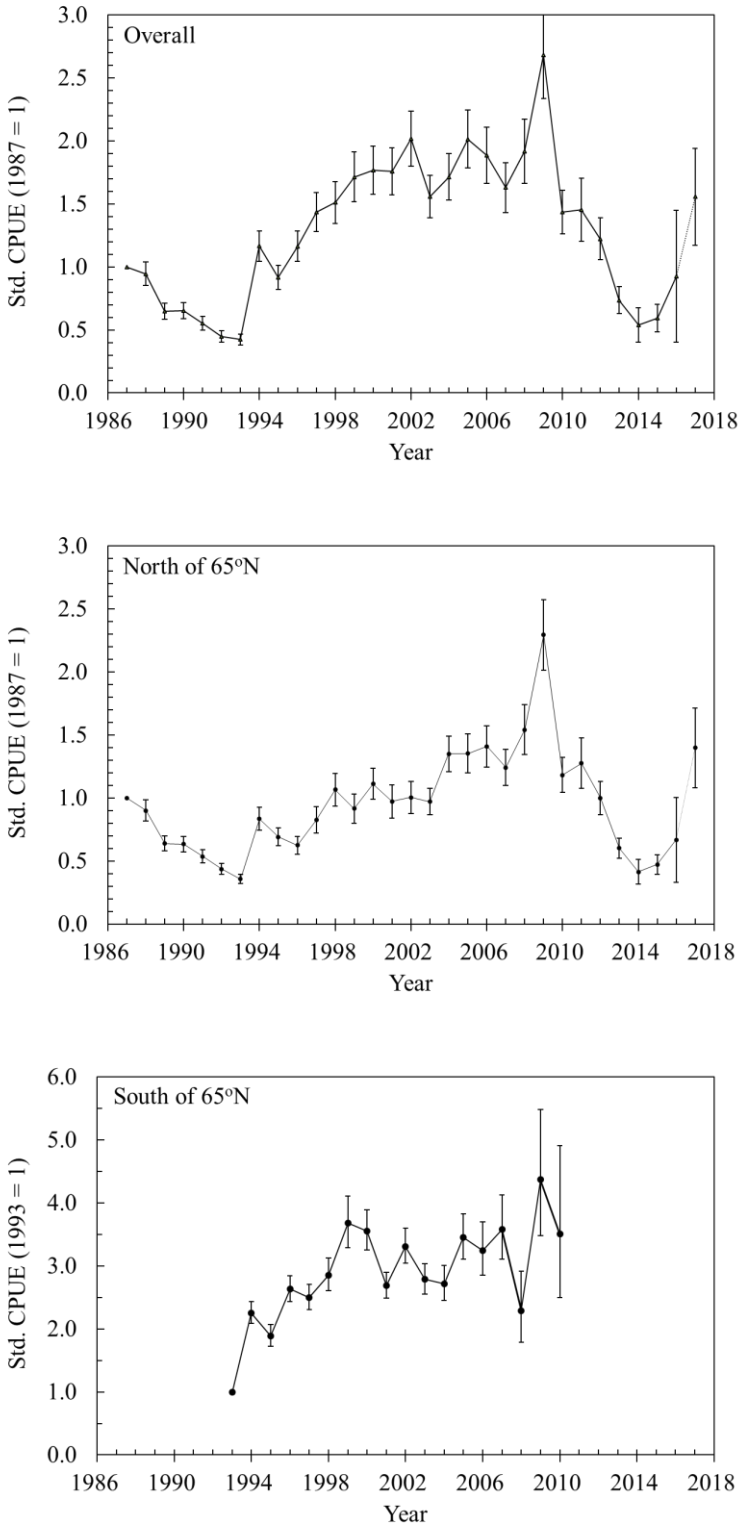

Fig. 2. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas south of 65°N, overall fishery north of 65°N (both in Greenland and Iceland EEZ), and overall standardized CPUE for the stock (Estimates for 2017 are based on data until July). No index for the southern area was calculated since 2010 due to a low number of hauls.

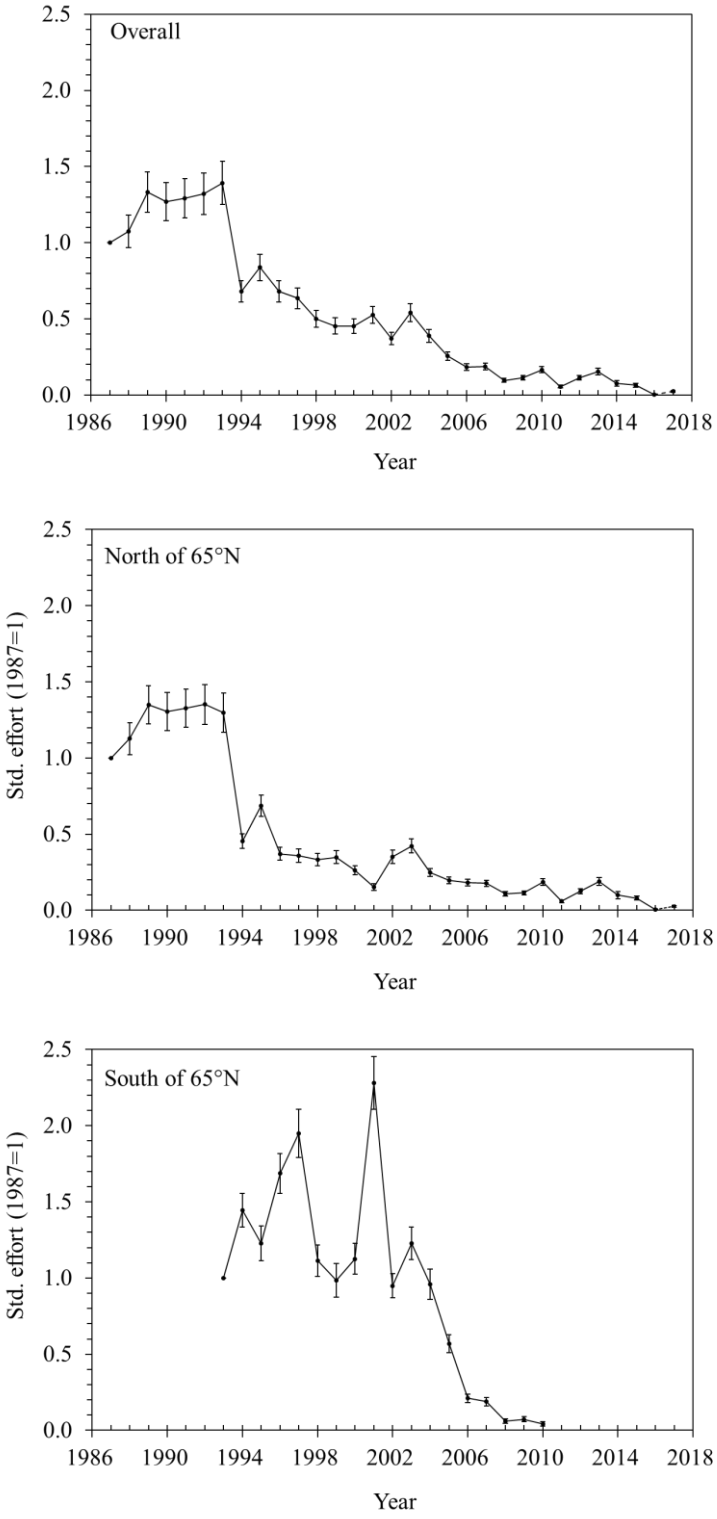

Fig. 3. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall (Estimates for 2017 are based on data until July).

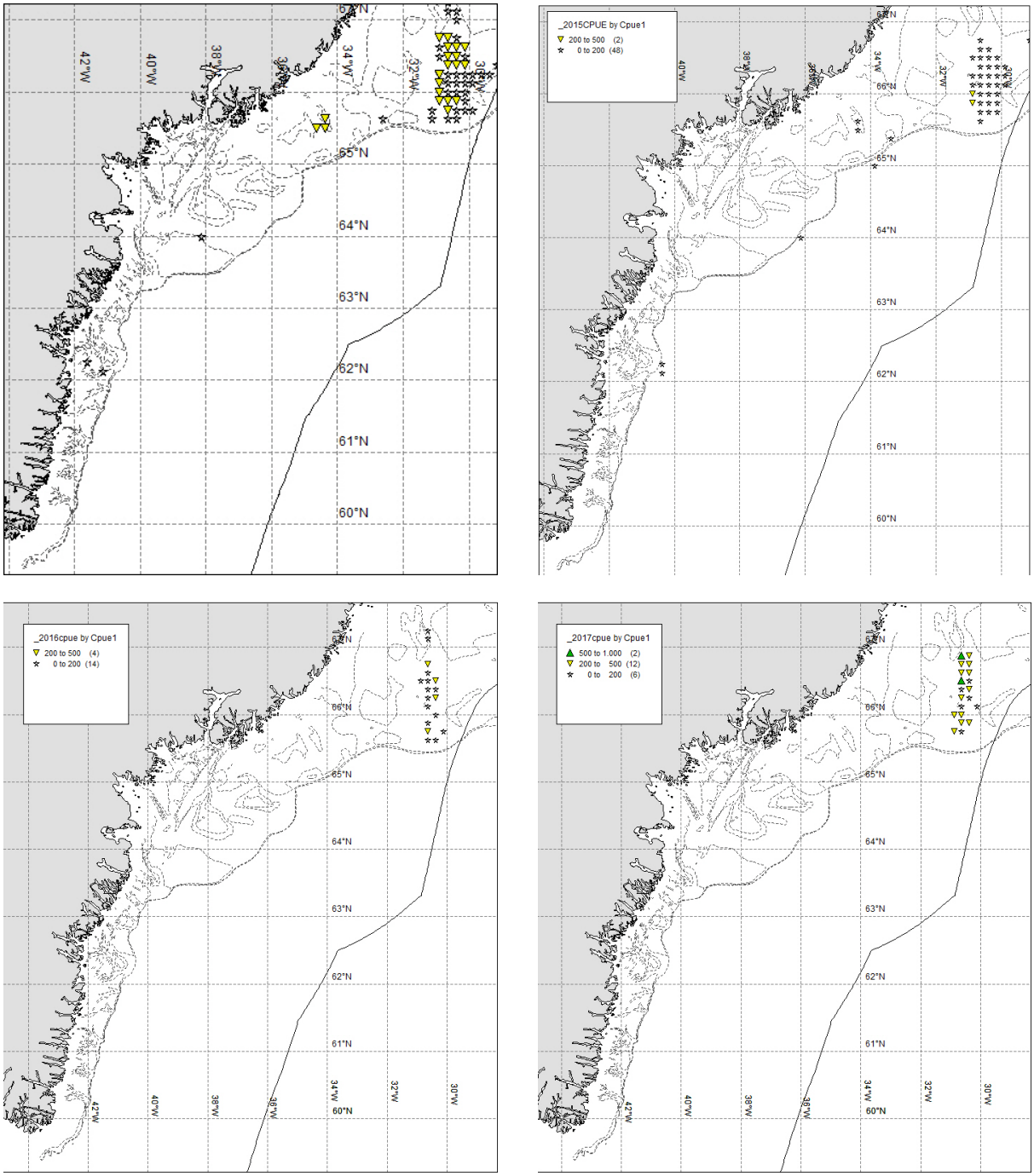

Fig. 4. Thematic mapping of different levels of CPUE in the shrimp fishery in Denmark Strait/off East Greenland 2014-2017 (2017 until July).

Appendix 1. Results and diagnostical outputs from GLM run of model for standardising CPUE in the Greenlandic zone including the area effect. Data from Greenlandic, Faeroese, Norway and EU vessels.

The GLM Procedure

Class Level Information

Class	Levels	Values
BAAD	16	E005 E008 E013 E020 E025 E031 E033 E042 E046 E052 E059 E066 E072 E074 E079 E082
YEAR	31	87 88 89 90 91 92 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 999
MONTH	9	1 2 4 5 6 7 8 11 12
AREA	2	21 22
HOLD	2	2 9

Number of Observations Read 3355
Number of Observations Used 3355

Dependent Variable: LNCPUE
Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	73	52161.45094	714.54042	94.54	<.0001
Error	3281	24797.94326	7.55804		
Corrected Total	3354	76959.39420			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.677779	248.1640	2.749190	1.107812

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	15	23281.61264	1552.10751	205.36	<.0001
YEAR*AREA	49	24494.77188	499.89330	66.14	<.0001
MONTH	8	4361.46131	545.18266	72.13	<.0001
AREA	0	0.00000			
HOLD	1	23.60510	23.60510	3.12	0.0773

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	15	8895.89366	593.05958	78.47	<.0001
YEAR*AREA	48	16432.01337	342.33361	45.29	<.0001
MONTH	8	4331.01222	541.37653	71.63	<.0001
AREA	1	1833.80054	1833.80054	242.63	<.0001
HOLD	1	23.60510	23.60510	3.12	0.0773

Parameter	Estimate	StandardError	t Value	Pr > |t|
Intercept	1.071351896 B	0.11025216	9.72	<.0001
BAAD E005	-1.165659670 B	0.10142428	-11.49	<.0001
BAAD E008	-1.070581379 B	0.09731001	-11.00	<.0001
BAAD E013	-0.970633439 B	0.09844882	-9.86	<.0001
BAAD E020	-0.883749232 B	0.09575127	-9.23	<.0001
BAAD E025	-0.787727080 B	0.09438218	-8.35	<.0001
BAAD E031	-0.720948789 B	0.09330443	-7.73	<.0001

BAAD E033		-0.658806469 B	0.09454069	-6.97	<.0001
BAAD E042		-0.566972346 B	0.09188939	-6.17	<.0001
BAAD E046		-0.524902877 B	0.09326804	-5.63	<.0001
BAAD E052		-0.454892215 B	0.09638902	-4.72	<.0001
BAAD E059		-0.386920632 B	0.09350052	-4.14	<.0001
BAAD E066		-0.304807703 B	0.09049651	-3.37	0.0008
BAAD E072		-0.231732433 B	0.09174688	-2.53	0.0116
BAAD E074		-0.187198530 B	0.09352429	-2.00	0.0454
BAAD E079		-0.111591129 B	0.09347338	-1.19	0.2326
BAAD E082		0.000000000 B	. . .		
YEAR*AREA87	21	0.694628329 B	0.07058048	9.84	<.0001
YEAR*AREA88	21	0.493719514 B	0.06657403	7.42	<.0001
YEAR*AREA89	21	0.108447009 B	0.06573239	1.65	0.0991
YEAR*AREA90	21	0.100010026 B	0.06565318	1.52	0.1278
YEAR*AREA91	21	-0.100987601 B	0.06493892	-1.56	0.1200
YEAR*AREA92	21	-0.307460307 B	0.06804875	-4.52	<.0001
YEAR*AREA94	21	0.350061743 B	0.08326054	4.20	<.0001
YEAR*AREA94	22	0.813630348 B	0.07634268	10.66	<.0001
YEAR*AREA95	21	0.174036805 B	0.07504136	2.32	0.0204
YEAR*AREA95	22	0.635657424 B	0.09214307	6.90	<.0001
YEAR*AREA96	21	0.070507661 B	0.09078655	0.78	0.4374
YEAR*AREA96	22	0.967732874 B	0.07743839	12.50	<.0001
YEAR*AREA97	21	0.389524412 B	0.11174261	3.49	0.0005
YEAR*AREA97	22	0.915517809 B	0.08096290	11.31	<.0001
YEAR*AREA98	21	0.728397110 B	0.10270035	7.09	<.0001
YEAR*AREA98	22	1.049472926 B	0.09110382	11.52	<.0001
YEAR*AREA99	21	0.525361923 B	0.10672813	4.92	<.0001
YEAR*AREA99	22	1.302038586 B	0.11122075	11.71	<.0001
YEAR*AREA100	21	0.675668884 B	0.08153601	8.29	<.0001
YEAR*AREA100	22	1.269213494 B	0.08966854	14.15	<.0001
YEAR*AREA101	21	0.528575549 B	0.11049297	4.78	<.0001
YEAR*AREA101	22	0.988208145 B	0.07560188	13.07	<.0001
YEAR*AREA102	21	0.502682223 B	0.10766287	4.67	<.0001
YEAR*AREA102	22	1.197566125 B	0.08328588	14.38	<.0001
YEAR*AREA103	21	0.537714145 B	0.08377489	6.42	<.0001
YEAR*AREA103	22	1.025075863 B	0.08656310	11.84	<.0001
YEAR*AREA104	21	0.876384210 B	0.07978484	10.98	<.0001
YEAR*AREA104	22	0.998705890 B	0.10313697	9.68	<.0001
YEAR*AREA105	21	0.850162404 B	0.08825159	9.63	<.0001
YEAR*AREA105	22	1.238899935 B	0.10416186	11.89	<.0001
YEAR*AREA106	21	0.893209650 B	0.09145395	9.77	<.0001
YEAR*AREA106	22	1.178273506 B	0.12934736	9.11	<.0001
YEAR*AREA107	21	0.767271051 B	0.09200912	8.34	<.0001
YEAR*AREA107	22	1.275333278 B	0.14199039	8.98	<.0001
YEAR*AREA108	21	0.978532021 B	0.10341590	9.46	<.0001
YEAR*AREA108	22	0.826515871 B	0.24361829	3.39	0.0007
YEAR*AREA109	21	1.376614439 B	0.09796217	14.05	<.0001
YEAR*AREA109	22	1.475262489 B	0.22689797	6.50	<.0001
YEAR*AREA110	21	0.716640155 B	0.08829984	8.12	<.0001
YEAR*AREA110	22	1.254045837 B	0.33671913	3.72	0.0002
YEAR*AREA111	21	0.779787002 B	0.13425872	5.81	<.0001
YEAR*AREA112	21	0.545691330 B	0.10451504	5.22	<.0001
YEAR*AREA112	22	1.595072524 B	0.37348334	4.27	<.0001
YEAR*AREA113	21	0.037368387 B	0.10763552	0.35	0.7285
YEAR*AREA114	21	-0.394307000 B	0.20987949	-1.88	0.0604
YEAR*AREA115	21	-0.220071714 B	0.14103070	-1.56	0.1187

YEAR*AREA116	21	-0.164597708 B	0.44577808	-0.37	0.7120
YEAR*AREA117	21	0.823239548 B	0.20251646	4.07	<.0001
YEAR*AREA999	21	-0.516123134 B	0.07087403	-7.28	<.0001
YEAR*AREA999	22	0.000000000 B	. . .		
MONTH 1		0.321146659 B	0.02953472	10.87	<.0001
MONTH 2		0.290742495 B	0.02942706	9.88	<.0001
MONTH 4		0.158884242 B	0.02843973	5.59	<.0001
MONTH 5		0.096549224 B	0.04066219	2.37	0.0176
MONTH 6		-0.040852662 B	0.07729921	-0.53	0.5972
MONTH 7		0.343936846 B	0.07087935	4.85	<.0001
MONTH 8		0.061400751 B	0.05168196	1.19	0.2349
MONTH 11		-0.257835025 B	0.03118171	-8.27	<.0001
MONTH 12		0.000000000 B	. . .		
AREA 21		0.000000000 B	. . .		
AREA 22		0.000000000 B	. . .		
HOLD 2		0.050541179 B	0.02859876	1.77	0.0773
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 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 GLM Procedure

Class Level Information

Class	Levels	Values
BAAD	16	E001 E005 E012 E015 E022 E032 E042 E050 E054 E061 E064 E069 E073 E078 E081 E082
YEAR	31	88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 999
MONTH	8	2 3 4 6 7 8 11 12
HOLD	2	2 9

Number of Observations Read 3883
Number of Observations Used 3883

Dependent Variable: LNCPUE
Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	58572.66531	1105.14463	124.36	<.0001
Error	3829	34028.17329	8.88696		
Corrected Total	3882	92600.83860			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.632528	253.3530	2.981101	1.176659

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	15	23811.46798	1587.43120	178.62	<.0001
YEAR	30	31843.33085	1061.44436	119.44	<.0001
MONTH	7	2841.92984	405.98998	45.68	<.0001
HOLD	1	75.93664	75.93664	8.54	0.0035

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	15	15157.61530	1010.50769	113.71	<.0001
YEAR	30	29391.60314	979.72010	110.24	<.0001
MONTH	7	2874.19626	410.59947	46.20	<.0001
HOLD	1	75.93664	75.93664	8.54	0.0035

Parameter	Estimate	StandardError	t Value	Pr > |t|
Intercept	2.149066352 B	0.10058940	21.36	<.0001
BAAD E001	-1.992900724 B	0.16535709	-12.05	<.0001
BAAD E005	-1.581110239 B	0.10479856	-15.09	<.0001
BAAD E012	-1.456032979 B	0.09654983	-15.08	<.0001
BAAD E015	-1.336190839 B	0.10164701	-13.15	<.0001
BAAD E022	-1.244520825 B	0.09505984	-13.09	<.0001
BAAD E032	-1.137893530 B	0.09330896	-12.19	<.0001
BAAD E042	-1.014718050 B	0.09401486	-10.79	<.0001
BAAD E050	-0.930633253 B	0.09202685	-10.11	<.0001
BAAD E054	-0.860442001 B	0.09849635	-8.74	<.0001
BAAD E061	-0.701408880 B	0.09253646	-7.58	<.0001
BAAD E064	-0.624871830 B	0.10228327	-6.11	<.0001
BAAD E069	-0.536016994 B	0.09335292	-5.74	<.0001
BAAD E073	-0.477085360 B	0.09372095	-5.09	<.0001
BAAD E078	-0.374063375 B	0.09486835	-3.94	<.0001
BAAD E081	-0.260759557 B	0.10696463	-2.44	0.0148
BAAD E082	0.000000000 B	. . .		

YEAR 88	-0.193945856 B	0.04776373	-4.06	<.0001
YEAR 89	-0.602049142 B	0.04718992	-12.76	<.0001
YEAR 90	-0.581583113 B	0.04726407	-12.30	<.0001
YEAR 91	-0.769376839 B	0.04719084	-16.30	<.0001
YEAR 92	-0.988429892 B	0.05204996	-18.99	<.0001
YEAR 93	-1.035242836 B	0.05217244	-19.84	<.0001
YEAR 94	0.003583684 B	0.05377633	0.07	0.9469
YEAR 95	-0.235382058 B	0.05357492	-4.39	<.0001
YEAR 96	0.017759838 B	0.05497483	0.32	0.7467
YEAR 97	0.254934940 B	0.05998217	4.25	<.0001
YEAR 98	0.343572989 B	0.06594414	5.21	<.0001
YEAR 99	0.465221028 B	0.07360455	6.32	<.0001
YEAR 100	0.439192597 B	0.05826314	7.54	<.0001
YEAR 101	0.421432868 B	0.05766091	7.31	<.0001
YEAR 102	0.567243910 B	0.06275254	9.04	<.0001
YEAR 103	0.320367047 B	0.05903862	5.43	<.0001
YEAR 104	0.412836643 B	0.06264242	6.59	<.0001
YEAR 105	0.551835026 B	0.06831692	8.08	<.0001
YEAR 106	0.483874541 B	0.07468702	6.48	<.0001
YEAR 107	0.336703441 B	0.07757675	4.34	<.0001
YEAR 108	0.492835075 B	0.09345421	5.27	<.0001
YEAR 109	0.834225761 B	0.08902148	9.37	<.0001
YEAR 110	0.208771018 B	0.07855200	2.66	0.0079
YEAR 111	0.203010186 B	0.13614251	1.49	0.1360
YEAR 112	0.044413123 B	0.09949370	0.45	0.6553
YEAR 113	-0.468019903 B	0.10491857	-4.46	<.0001
YEAR 114	-0.836728560 B	0.22145712	-3.78	0.0002
YEAR 115	-0.692889538 B	0.14474753	-4.79	<.0001
YEAR 116	-0.609954300 B	0.48058726	-1.27	0.2045
YEAR 117	0.220424126 B	0.21449255	1.03	0.3042
YEAR 999	0.000000000 B	. . .		
MONTH 2	0.191200236 B	0.02728994	7.01	<.0001
MONTH 3	0.085635122 B	0.03145945	2.72	0.0065
MONTH 4	0.150768994 B	0.03685554	4.09	<.0001
MONTH 6	0.040613454 B	0.04023550	1.01	0.3128
MONTH 7	0.406622833 B	0.06741977	6.03	<.0001
MONTH 8	0.155038583 B	0.05017025	3.09	0.0020
MONTH 11	-0.222168683 B	0.03139462	-7.08	<.0001
MONTH 12	0.000000000 B	. . .		
HOLD 2	-0.087252179 B	0.02984882	-2.92	0.0035
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.