Northwest Atlantic Fisheries Organization

Serial No. N6873 **NAFO SCR Doc. 18/059**

NAFO/ICES *PANDALUS* ASSESSMENT GROUP – OCTOBER 2018

The Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait / off East Greenland 1978 – 2018.

by

Frank Rigét

Pinngortitaleriffik, Greenland Institute of Natural Resources
P.O. Box 570, DK-3900 Nuuk, Greenland

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. Until 2011, the stock has been assessed as a single population by evaluation of fishery dependent data only. Data from an annual survey series has been available since 2008; however no survey were performed in 2016 and 2017. 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 totally 561 tons in 2017. In recent years (2016-2018) the catch rates index has increased considerably. However, the recent catch rate index are not a reliable index for the biomass because of the very low fishing effort in these years. Survey biomass index has decreased steadily since 2009 from 8 500 tons to 1 600 tons in 2016.

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. Most shrimp biomass concentrations occur from 150-600 m. There is no evidence of distinct sub-populations and the stock is assessed as a single population. Until 2011, 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 (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 then catches fluctuated around 12 000 tons until 2003 (Table 1, Fig. 2A). Since 2004, catches have been decreasing and was 561 tons in 2017 and 545 tons in until July 2018. 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 but since 2013 no fishing has been taken place south of 65°N. 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 are large factory trawlers in the range of 1000-4000 GRT.

Since 2008 surveys has been performed except for the last two years. Therefore, the survey biomass index will shortly be described here. Since 2009 the biomass index has decreased from about 8 500 tons to 1 600 tons in 2016.

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 2018 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 catch and effort by statistical units of 7.5' latitude and 15' longitude (Fig. 4a,b).

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 involves a two-step process. In the first step multiplicative General Linear Modelling (GLM) 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. 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,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 81 of 118 vessels met the criteria for inclusion in the analysis (at least three years of fishing in the area). The 81 vessels qualifying for the index were collapsed into 17 groups

consisting of 1-11 vessels. The month effect was reduced to 8 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 R using the rjags library programming framework in R (version 3.4.3, R Core Team, 2017). 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 2013, no fishery

has been conducted south of 65°N (Table 2, Fig. 1).

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 and 561 tons in 2017. The catch until July 2018 was 545 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 2012.

Fishing effort

The high increase in catches during the first ten-year period was mainly driven by increased fishing effort and peaked in 1989 with nearly 120 000 hours (Fig. 1B, Table 2). Since then the total effort gradually decreased and 327 hours in 2016 and 1633 hours in 2017. Until July 2018 the total effort has been 1128 hours.

The historic development of fishing effort spent in the northern area follows the one described for the total area closely – except for 2001, where 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 hours but increased again to 20 000 hours in 2001. Since then effort in the southern area has been declining (Fig. 1B, Table 2).

Catch rate

Catch rates (total area) decreased from 298 kg/hr to 109 kg/hr in the period 1981-1989 follow by increasing trend until 2009. From 2010 to 2015 catch rates have continuously been declining to the lowest value of 117 kg/hr in the latest 2 decades (Fig. 1C, Table 2). In 2016, 2017 and 2018 the catch rates increased considerably and until July 2018 the catch rates was 483 kg/hour.

Catch rates in the northern area follow the same trend as the overall figures except for the period 1993 to 2009 when catch rate in the southern area were considerably higher than in the northern area.

In the southern area, catch rates increased considerably in the period 1993 to 1999 followed by a general decrease to 2008. The high catch rates observed in the years 2010 to 2013 are based on relatively few hauls.

Standardised catch rate indices

The CPUEs for the southern area in 2011 and 2013 to 2018 were omitted from the GLMs because of no hauls or very low number of hauls (below 10) conducted.

Results of the two multiple regression analysis to standardise catch rates showed that all main effects and interaction between YEAR and AREA were highly significant ($p<0.01$). The R-squared of the models for Greenland and Iceland were 68% and 78%, respectively (see appendix 1 for the Greenland model).

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 and the mean index values 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. After 2009, the index decreased to a low level in 2014 not seen since the beginning of 1990s. In recent years, the index has increased considerably. However, the recent high catch rates cannot be considered as reflecting the biomass because of small fishing efforts in these years.

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. Since then the index went down and was in 2014 lower than the late 1990's. In recent years, the index has increased considerably. However, as for the total area, the recent high catch rates cannot be considered as reflecting the biomass because of small fishing efforts in these years.

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 area was calculated in 2011 and 2013 to 2018.

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 2016 to 2018. 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. No standardised effort for the southern area was calculated for 2011 and 2013 to 2018.

Conclusions

Total catches fluctuated around 12 000 tons from 1994 to 2003 (Table 1, Fig. 1A). Since then catches have been decreasing to a low of 49 tons in 2016 and 561 tons in 2017. The catch until July 2018 was 545 tons.

The combined CPUE index for the total area (Fig. 2, Table 3) indicated that the stock more than halved during the period 1987-1993. In the succeeding years, the stock has been rebuilding reaching and increased until the end of the 1990s, and stabilized at a level one third above that of 1987. From the late 90'ties the biomass index has been fluctuating without a trend until 2009 where the index more than doubled compared to 1987.Neveretheless, the combined index once more decreased to the lowest level observed in 2014. In the last three years, the index has increased considerably. However, the recent index values cannot be considered as a reliable index for the biomass because of the very low fishing effort in these years.

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

Survey biomass index has decreased since 2009 and was in 2016 about 1 600 tons. No survey were performed in 2016 and 2017

References

ANON., 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1988. 1028 pp.

HVINGEL, C., H. LASSEN and D.G. PARSONS (2000). A biomass index for northern shrimp (*Pandalus borealis*) in Davis Strait based on multiplicative modelling of commercial catch-per-unit-effort data (1976 - 1997). *J. Northw. Atl. Fish. Sci. vol.26:25–36.*

HVINGEL, C. 2003. Correction of reported past catches of Northern Shrimp within the Greenland EEZ to conform to a revision of reporting practices. NAFO SCR Doc., No. 03/74 Ser. No. N4913. 3 pp.

R CORE TEAM (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

SIEGSTAD, HELLE 2016. Results of the Greenland Bottom Trawl Survey for Northern shrimp (P*andalus borealis*) off East Greenland (ICES Subarea XIV b)), 2008-2016. *NAFO SCR Doc*., No.16/045 Serial No. N6594

SIEGSTAD, HELLE and HVINGEL, C. An Assessment of the Shrimp Stock in Denmark Strait/off East Greenland - 2006. *NAFO SCR Doc*., No.06/078 Serial No. N5328

Table 1. Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland from 1978 to July 2018. 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
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
Faroe Islands	-	0	5296	892	922	554	836	843	910	754	847	738	1029	1265	1355	689	462	931	995
France	-	0	63	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0
Greenland	-	0	250	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	1771	1326	2390	359
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566
Norway	-	1001	3079	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	1831	2180	2402	1544
Total	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	6982	5731	7176	3490
South of 65°N																			
Denmark (EU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	613	731	1167
Faroe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	280	974	295	402
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1141	3603	2667	5295
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	424	1011	720	1590
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1904	6201	4412	8453
Total area																			
EU (DK,EST,LTU)	-	0	878	727	926	255	554	442	626	703	554	454	476	450	199	198	863	1033	1193
Faroe Islands	-	0	5296	892	922	554	836	843	910	754	847	738	1029	1265	1355	968	1436	1225	1397
France	-	0	63	442	518	364	626	803	976	1305	616	472	62	148	0	0	0	0	0
Greenland	-	0	250	1256	1395	1835	2815	3248	7232	8396	9304	7408	7580	5283	2496	2912	4929	5057	5655
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1431	1326	281	465	1750	2553	1514	1151	566
Norway	-	1001	3079	2522	2372	2161	2662	2566	2535	2586	2561	2601	3052	3146	3102	2255	3190	3122	3133
Total	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944
Total all areas	363	1486	10325	5964	6133	5212	8235	9696	13428	15073	15313	12999	12480	10757	8901	8886	11932	11588	11944
Advised TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	100003	100003	100003	8000	5000	5000	5000	5000
Effective TAC[1]	-	-	-	8000	4500	5725	5245	6090	75255	75255	87255	90255	14100	14500	13000	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 2018. Values for the fishery in the Greenland EEZ by EU, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel 2003.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014[2]
North of 65°N																		
EU (DK,EST,LTU)	85	401	793	459	72	816	861	482	304	618	421	389	892	1345	927	1411	1533	434
Faroe Islands	635	1268	867	956	214	1029	1062	894	615	342	319	612	1325	781	0	0	0	0
France	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenland	105	646	614	115	650	638	695	578	454	223	802	14	844	426	183	481	170	175
Iceland	2856	1421	769	132	10	1231	703	411	29	0	0	0	0	0	0	0	0	0
Norway	797	1628	1783	2759	1291	1630	2861	2700	2613	2704	1771	1514	883	770	36	2	0	0
Total	4478	5364	4827	4420	2237	5344	6183	5065	4015	3887	3313	2529	3945	3323	1145	1893	1703	609
South of 65°N																		
Denmark (EU)	1657	1300	1095	1900	2473	2309	1827	1022	644	683	431	251	28	101	0	0	0	0
Faroe Island	656	138	453	340	2402	1013	303	255	176	227	169	14	28	0	0	0	0	0
Greenland	4701	3950	4966	5235	4943	4333	4194	3488	2737	316	638	0	447	178	53	215	3	0
Norway	2261	670	378	157	1855	1098	197	186	180	76	48	0	107	0	0	0	0	0
Total	9276	6057	6893	7632	11674	5985	6522	4951	3737	1302	1286	266	610	279	53	215	3	0
Total area																		
EU (DK,EST,LTU)	1742	1701	1888	2358	2545	2548	2688	1504	948	1301	852	640	920	1446	927	1411	1533	434
Faroe Islands	1292	1406	1321	1296	2616	1322	1365	1149	791	569	488	627	1354	782	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenland	4806	4595	5581	5349	5593	4484	4890	4066	3191	539	1440	14	1292	605	236	696	173	175
Iceland	2856	1421	769	132	10	1231	703	411	29	0	0	0	0	0	0	0	0	0
Norway	3059	2298	2160	2917	3147	1743	3059	2886	2793	2780	1819	1514	990	770	36	2	0	0
Total	13754	11422	11719	12053	13911	11329	12705	10016	7752	5189	4599	2794	4555	3602	1199	2109	1706	609
Total all areas	13754	11422	11719	12053	13911	11242	12637	9985	7752	5189	4599	2794	4555	3602	1199	2109	1706	609
Advised TAC	5000	5000	9600	9600	9600	9600	9600	12400	12400	12400	12400	12400	12400	12400	12400	12400	12400	2000
Effective TAC[1]	9563	9563	10600	12600	10600	10600	10600	15043	12400	12400	12400	12400	12835	11835	12400	12400	12400	8300

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

[2]Catch until July

Table 1 (continued). Catch (tons) of shrimp by the fishery in Denmark Strait/off East Greenland from 1978 to July 2018. Values for the fishery in the Greenland EEZ by EU, Faeroe Islands, France, Greenland and Norway are corrected according to Hvingel 2003.

	2015	2016	2017	2018[2]
North of 65°N				
EU (DK,EST,LTU)	402	49	178	545
Faroe Islands	0	0	0	0
France	-	-	-	-
Greenland	174	0	383	0
Iceland	0	0	0	0
Norway	0	0	0	0
Total	576	49	561	545
South of 65°N				
Denmark (EU)	0	0	0	0
Faroe Island	0	0	0	0
Greenland	0	0	0	0
Norway	0	0	0	0
Total	0	0	0	0
Total area				
EU (DK,EST,LTU, GBR)	402	49	178	545
Faroe Islands	0	0	0	0
France	0	0	0	0
Greenland	174	0	383	0
Iceland	0	0	0	0
Norway	0	0	0	0
Total	576	49	561	545
Total all areas	576	49	561	545
Advised TAC	2000	2000	2000	2000
Effective TAC[1]	6100	5300	5300	4300

[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	561	1633	344	0	-	-	561	1633	344
2018*	545	1128	483	0	-	-	545	1128	483

*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					0.95	0.09	1.07	0.10
1989	0.64	0.06	1.34	0.12					0.65	0.06	1.33	0.13
1990	0.64	0.06	1.30	0.12					0.65	0.07	1.27	0.13
1991	0.55	0.05	1.31	0.12					0.55	0.06	1.29	0.13
1992	0.44	0.04	1.33	0.13					0.44	0.05	1.33	0.14
1993	0.36	0.04	1.27	0.13	1.00	-	1.00	-	0.42	0.04	1.39	0.14
1994	0.84	0.09	0.45	0.05	0.66	0.05	1.44	0.14	1.16	0.12	0.68	0.07
1995	0.70	0.07	0.68	0.07	0.57	0.05	1.23	0.11	0.91	0.09	0.84	0.09
1996	0.63	0.07	0.37	0.04	0.58	0.05	1.68	0.11	1.16	0.12	0.68	0.07
1997	0.83	0.10	0.36	0.05	0.89	0.08	1.95	0.13	1.42	0.15	0.64	0.07
1998	1.04	0.12	0.34	0.04	0.61	0.09	1.11	0.16	1.49	0.16	0.51	0.06
1999	0.90	0.11	0.35	0.04	0.52	0.08	0.98	0.10	1.70	0.20	0.46	0.05
2000	1.11	0.12	0.26	0.03	0.90	0.08	1.13	0.11	1.75	0.19	0.46	0.05
2001	0.98	0.13	0.15	0.02	0.77	0.08	2.28	0.10	1.73	0.19	0.53	0.06
2002	1.02	0.13	0.35	0.04	0.61	0.11	0.95	0.17	1.98	0.22	0.38	0.04
2003	0.97	0.11	0.42	0.05	0.63	0.11	1.23	0.08	1.54	0.16	0.55	0.06
2004	1.35	0.14	0.25	0.03	0.50	0.08	0.96	0.11	1.70	0.19	0.39	0.04
2005	1.36	0.16	0.20	0.02	0.47	0.08	0.57	0.10	1.99	0.23	0.26	0.03
2006	1.42	0.17	0.18	0.02	0.58	0.10	0.21	0.06	1.86	0.23	0.18	0.02
2007	1.25	0.15	0.18	0.02	0.31	0.16	0.19	0.03	1.63	0.20	0.19	0.02
2008	1.55	0.20	0.11	0.01	1.22	0.38	0.06	0.03	1.90	0.25	0.10	0.01
2009	2.30	0.29	0.11	0.01	0.72	0.09	0.07	0.01	2.69	0.35	0.11	0.01
2010	1.19	0.14	0.19	0.02	0.81	0.10	0.04	0.02	1.42	0.17	0.17	0.02
2011	1.29	0.21	0.06	0.01	-	-	-	-	1.44	0.24	0.06	0.01
2012	1.01	0.13	0.12	0.02	-	-	-	-	1.21	0.17	0.12	0.02
2013	0.61	0.08	0.19	0.03	-	-	-	-	0.73	0.10	0.16	0.02
2014	0.42	0.10	0.10	0.02	-	-	-	-	0.54	0.14	0.08	0.02
2015	0.48	0.08	0.08	0.01	-	-	-	-	0.60	0.11	0.06	0.01
2016	0.68	0.35	0.005	0.002	-	-	-	-	0.91	0.50	0.00	0.002
2017	1.16	0.25	0.032	0.007	-	-	-	-	1.25	0.30	0.03	0.01
2018	1.83	0.44	0.020	0.005	-	-	-	-	2.21	0.58	0.02	0.004

* Until July

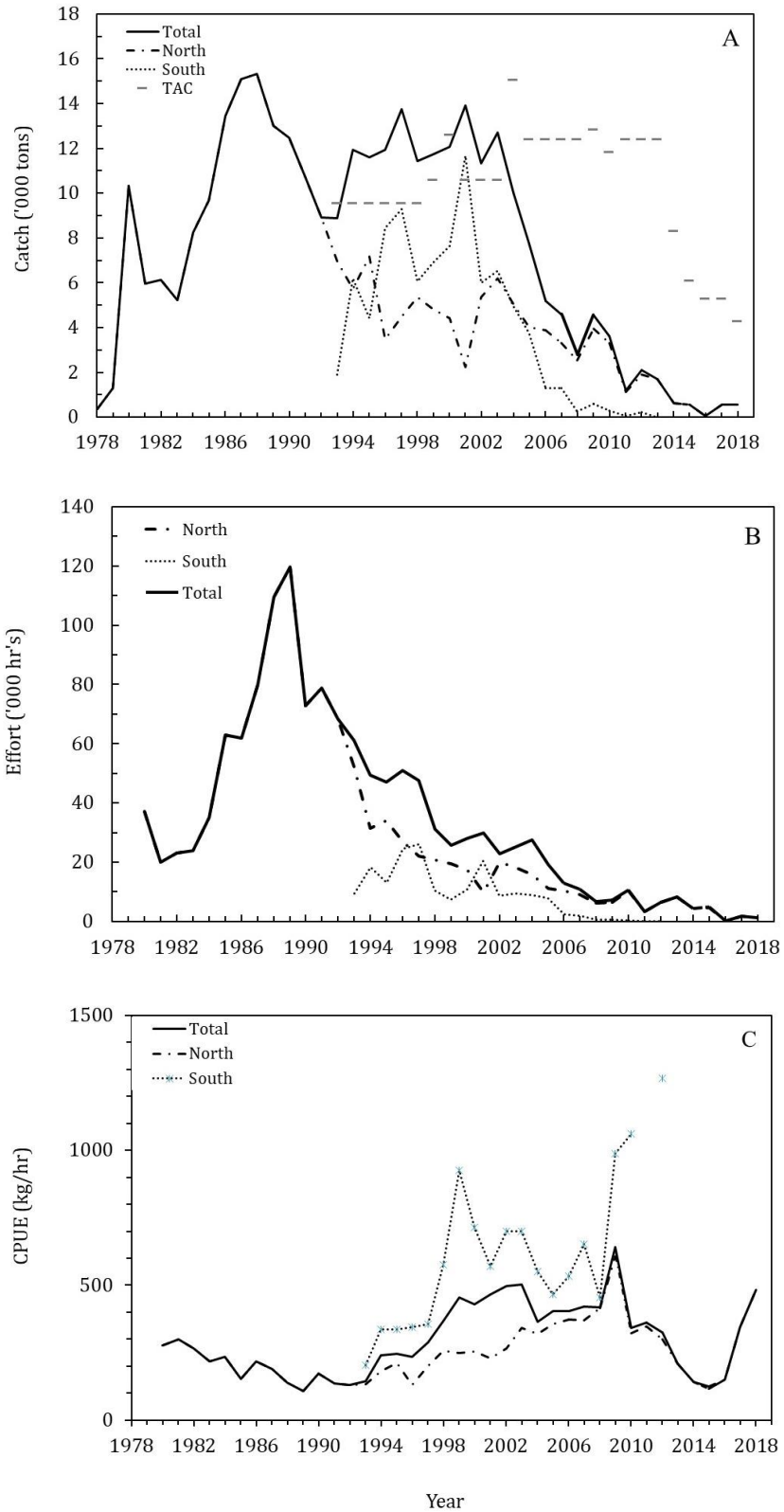

Fig. 1. Catch (A), fishing effort (B) and catch-per-unit-effort (C) by shrimp trawlers fishing in Denmark Strait/off East Greenland. Series are given for the areas north and south of 65°N and overall. (Data for 2018 is part-years data, until July).

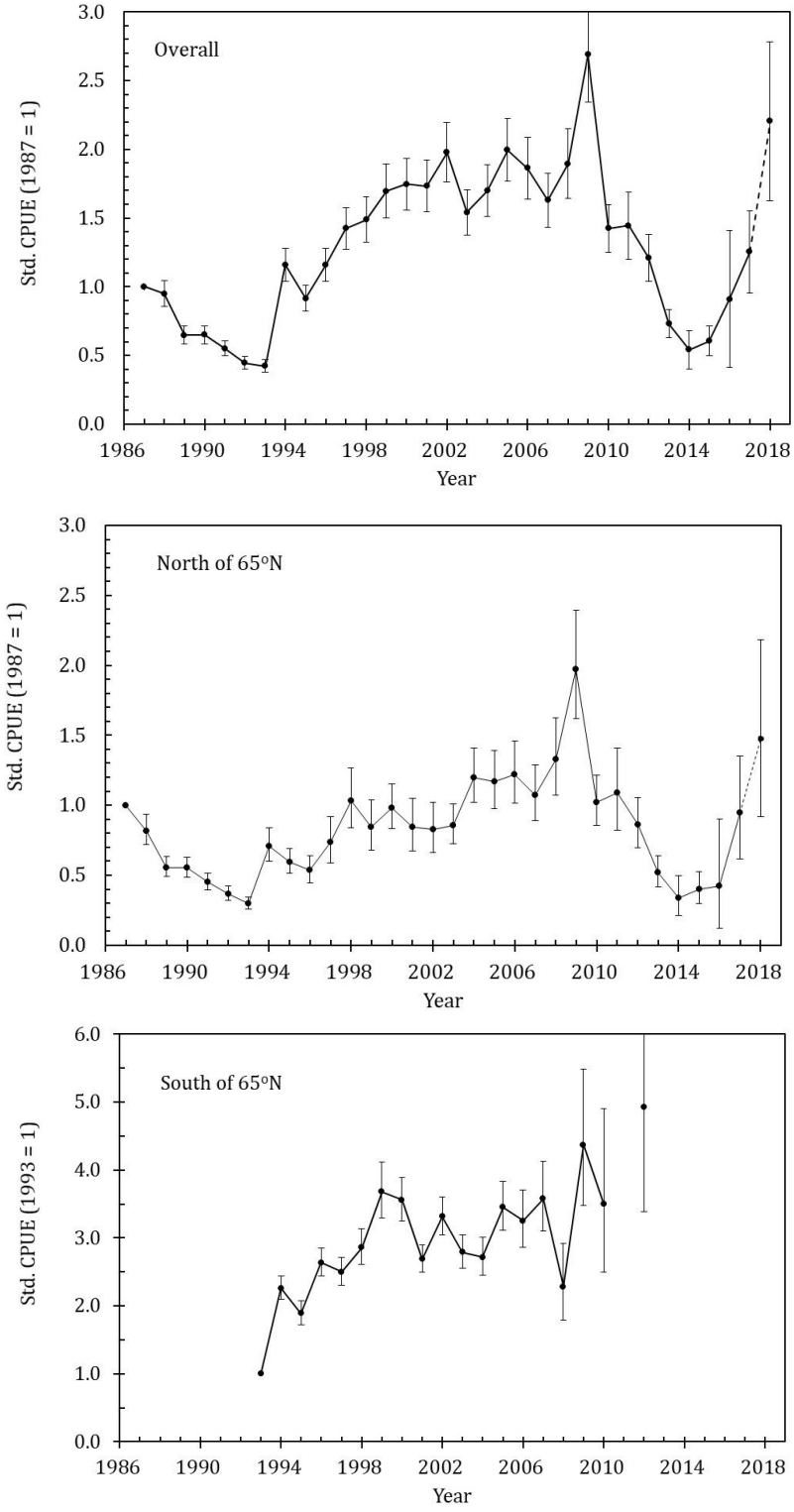

Fig. 2. Standardized Catch-Per-Unit-Effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas south of 65°N, overall fishery north of 65°N (both in Greenland and Iceland EEZ), and overall standardized CPUE for the stock (Estimates for 2018 are based on data until July). No index for the southern area has been calculated since 2012 due to a low number of hauls (less than 10 each year).

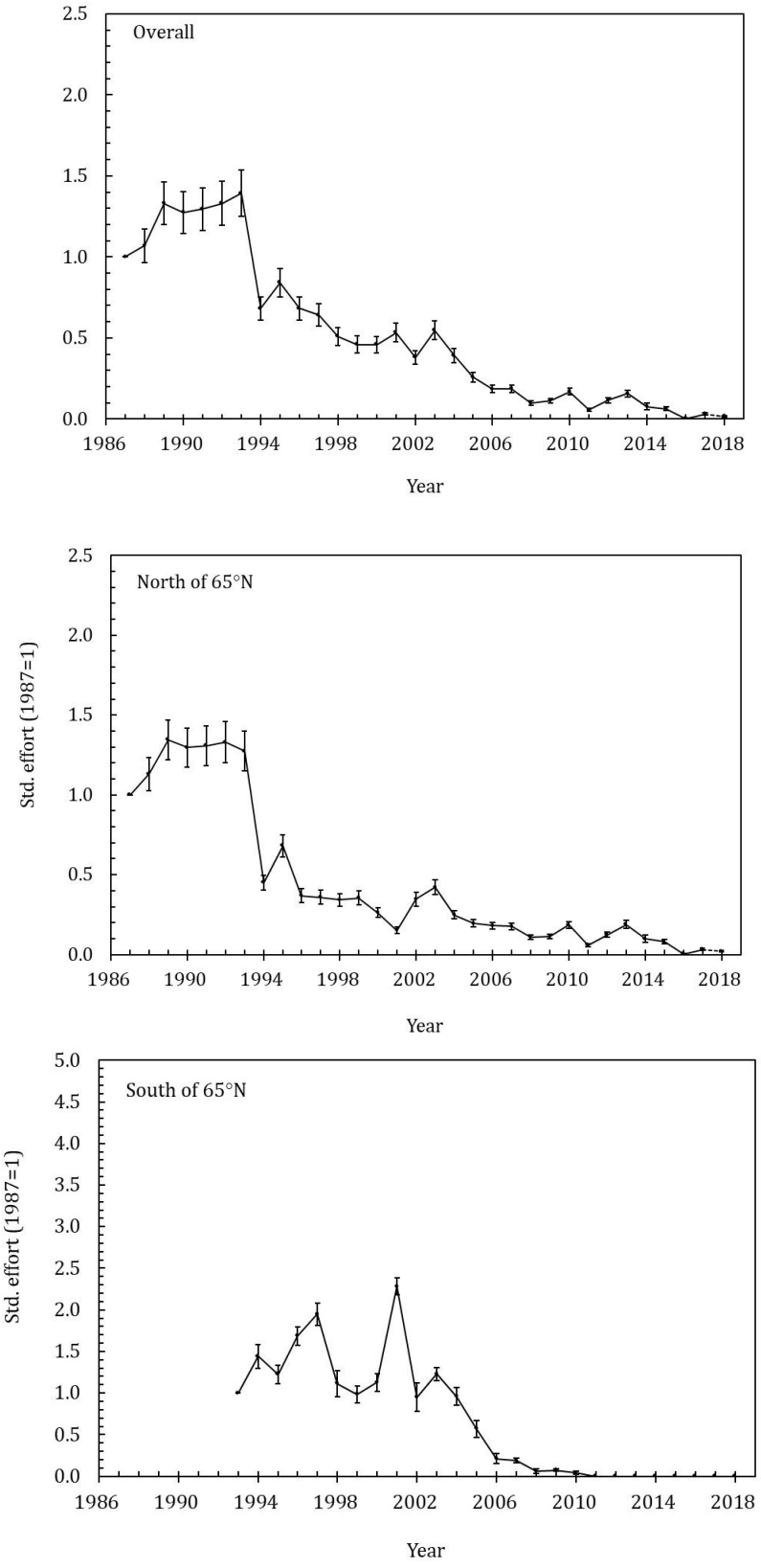

Fig. 3. Standardised effort indices of the shrimp fishery in Denmark Strait and off East Greenland in the areas north of 65°N, south of 65°N and overall (Estimates for 2018 are based on data until July).

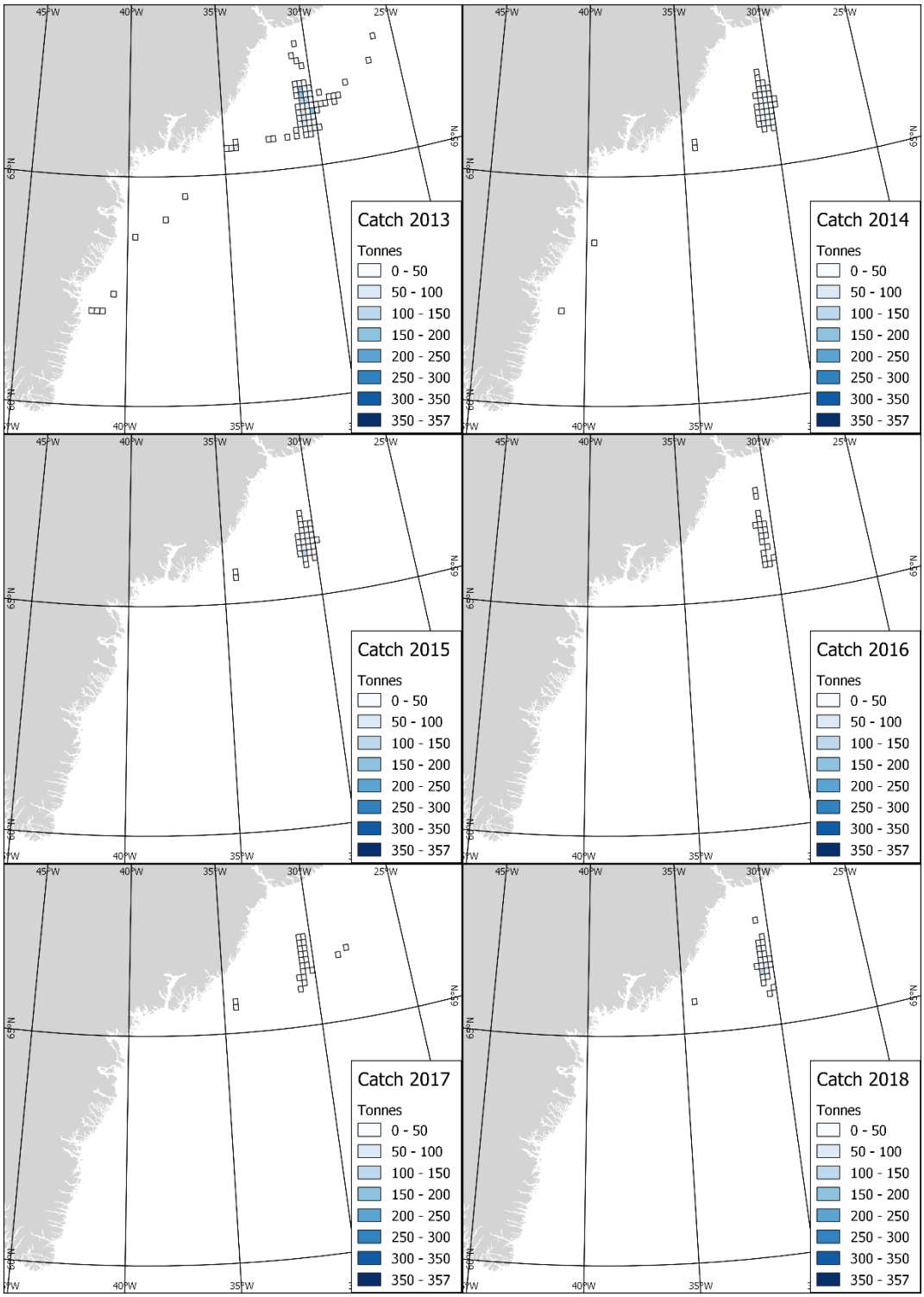

Fig.4a. Thematic mapping of different levels of catch in the shrimp fishery in Denmark Strait/off East Greenland 2013-2018 (2018 until July).

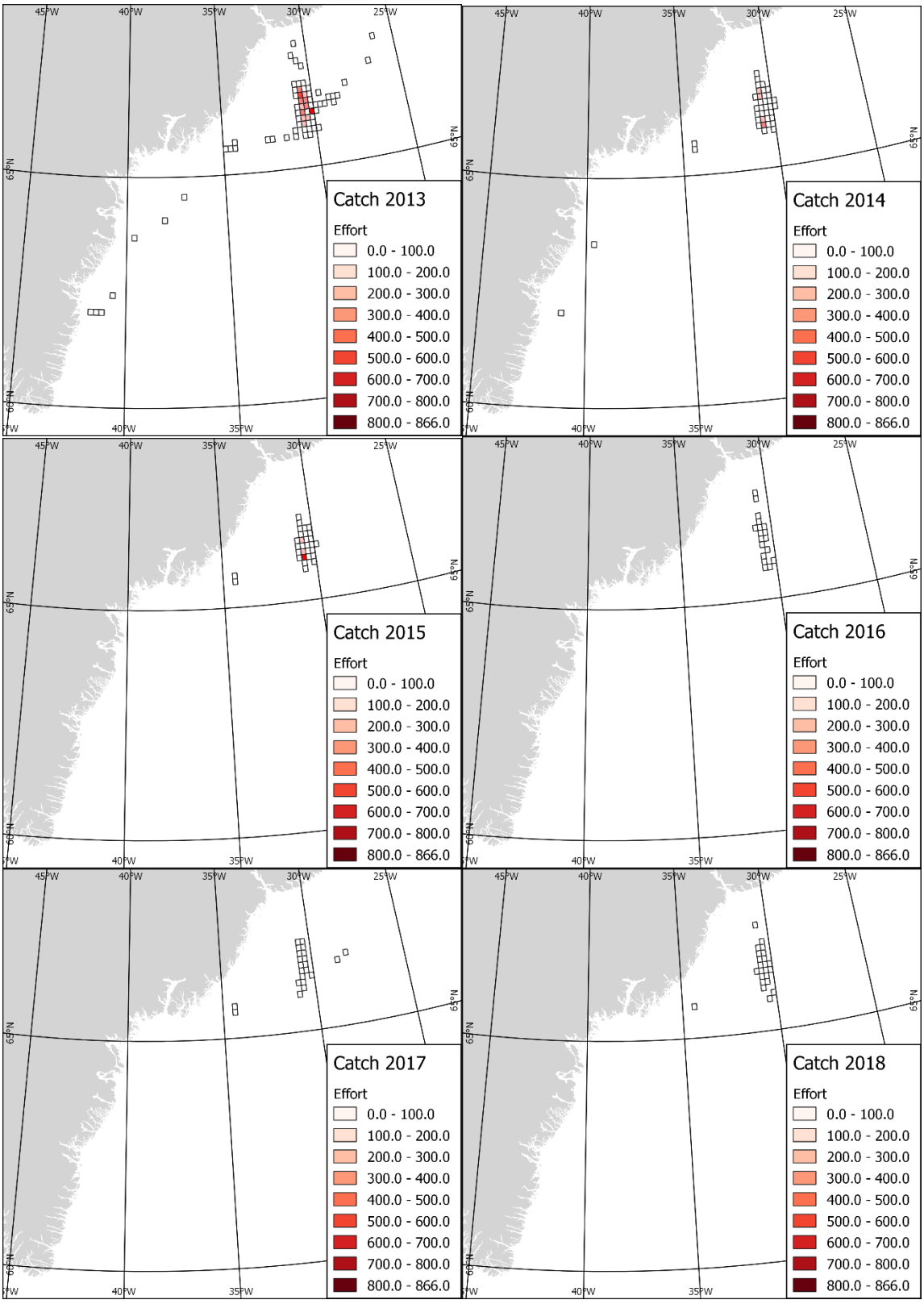

Fig. 4b. Thematic mapping of different levels of effort in the shrimp fishery in Denmark Strait/off East Greenland 2013-2018 (2018 until July).

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	32	87 88 89 90 91 92 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 999
MONTH	9	1 2 4 5 6 7 8 11 12
AREA	2	21 22
HOLD	2	2 9

Dependent Variable: LNCPUE

Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	74	52312.64325	706.92761	93.46	<.0001
Error	3288	24869.95113	7.56385		
Corrected Total	3362	77182.59438			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.677778	248.0088	2.750246	1.108931

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	15	23412.69308	1560.84621	206.36	<.0001
YEAR*AREA	50	24488.49049	489.76981	64.75	<.0001
MONTH	8	4388.11370	548.51421	72.52	<.0001
AREA	0	0.00000	.	.	.
HOLD	1	23.34598	23.34598	3.09	0.0790

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	15	8897.51097	593.16740	78.42	<.0001
YEAR*AREA	49	16456.16979	335.84020	44.40	<.0001
MONTH	8	4357.81494	544.72687	72.02	<.0001
AREA	1	1733.95495	1733.95495	229.24	<.0001
HOLD	1	23.34598	23.34598	3.09	0.0790

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	1.071710338	B	0.11029385	9.72	<.0001
BAAD E005	-1.168017287	B	0.10146002	-11.51	<.0001
BAAD E008	-1.072492841	B	0.09734522	-11.02	<.0001

Parameter	Estimate		Standard Error	t Value	Pr > |t|
BAAD E013	-0.972841578	B	0.09848375	-9.88	<.0001
BAAD E020	-0.885678023	B	0.09578583	-9.25	<.0001
BAAD E025	-0.789652766	B	0.09441620	-8.36	<.0001
BAAD E031	-0.722944115	B	0.09333782	-7.75	<.0001
BAAD E033	-0.661022401	B	0.09457393	-6.99	<.0001
BAAD E042	-0.569070140	B	0.09192190	-6.19	<.0001
BAAD E046	-0.526750329	B	0.09330168	-5.65	<.0001
BAAD E052	-0.456422117	B	0.09642457	-4.73	<.0001
BAAD E059	-0.388532346	B	0.09353478	-4.15	<.0001
BAAD E066	-0.305544250	B	0.09053073	-3.38	0.0007
BAAD E072	-0.232876635	B	0.09178121	-2.54	0.0112
BAAD E074	-0.193052257	B	0.09353910	-2.06	0.0391
BAAD E079	-0.111199827	B	0.09350796	-1.19	0.2344
BAAD E082	0.000000000	B	.	.	.
YEAR*AREA 87 21	0.696633952	B	0.07060386	9.87	<.0001
YEAR*AREA 88 21	0.495360050	B	0.06659680	7.44	<.0001
YEAR*AREA 89 21	0.109973865	B	0.06575520	1.67	0.0945
YEAR*AREA 90 21	0.101230041	B	0.06567671	1.54	0.1233
YEAR*AREA 91 21	-0.099962244	B	0.06496268	-1.54	0.1240
YEAR*AREA 92 21	-0.306356353	B	0.06807363	-4.50	<.0001
YEAR*AREA 94 21	0.351135373	B	0.08329130	4.22	<.0001
YEAR*AREA 94 22	0.815115552	B	0.07637001	10.67	<.0001
YEAR*AREA 95 21	0.175258450	B	0.07506854	2.33	0.0196
YEAR*AREA 95 22	0.637288810	B	0.09217647	6.91	<.0001
YEAR*AREA 96 21	0.071941151	B	0.09081932	0.79	0.4283
YEAR*AREA 96 22	0.969307184	B	0.07746556	12.51	<.0001
YEAR*AREA 97 21	0.391276093	B	0.11178340	3.50	0.0005
YEAR*AREA 97 22	0.917051334	B	0.08099171	11.32	<.0001
YEAR*AREA 98 21	0.729225935	B	0.10273904	7.10	<.0001
YEAR*AREA 98 22	1.050119931	B	0.09113827	11.52	<.0001
YEAR*AREA 99 21	0.526308736	B	0.10676724	4.93	<.0001
YEAR*AREA 99 22	1.303062932	B	0.11126209	11.71	<.0001
YEAR*AREA 100 21	0.676447447	B	0.08156641	8.29	<.0001
YEAR*AREA 100 22	1.269506007	B	0.08970243	14.15	<.0001
YEAR*AREA 101 21	0.528946475	B	0.11053480	4.79	<.0001
YEAR*AREA 101 22	0.988760394	B	0.07562984	13.07	<.0001

Parameter	Estimate		Standard Error	t Value	Pr > |t|
YEAR*AREA 102 21	0.503651795	B	0.10770292	4.68	<.0001
YEAR*AREA 102 22	1.197988442	B	0.08331743	14.38	<.0001
YEAR*AREA 103 21	0.538535429	B	0.08380510	6.43	<.0001
YEAR*AREA 103 22	1.025334049	B	0.08659509	11.84	<.0001
YEAR*AREA 104 21	0.877358967	B	0.07981103	10.99	<.0001
YEAR*AREA 104 22	0.998461891	B	0.10317478	9.68	<.0001
YEAR*AREA 105 21	0.850953549	B	0.08828104	9.64	<.0001
YEAR*AREA 105 22	1.239448401	B	0.10420055	11.89	<.0001
YEAR*AREA 106 21	0.893629217	B	0.09148795	9.77	<.0001
YEAR*AREA 106 22	1.179013983	B	0.12939607	9.11	<.0001
YEAR*AREA 107 21	0.767394793	B	0.09204355	8.34	<.0001
YEAR*AREA 107 22	1.275204102	B	0.14204475	8.98	<.0001
YEAR*AREA 108 21	0.978954368	B	0.10345309	9.46	<.0001
YEAR*AREA 108 22	0.826130264	B	0.24371161	3.39	0.0007
YEAR*AREA 109 21	1.376204422	B	0.09799939	14.04	<.0001
YEAR*AREA 109 22	1.474665043	B	0.22698483	6.50	<.0001
YEAR*AREA 110 21	0.716542382	B	0.08833327	8.11	<.0001
YEAR*AREA 110 22	1.253675407	B	0.33684848	3.72	0.0002
YEAR*AREA 111 21	0.779463074	B	0.13431004	5.80	<.0001
YEAR*AREA 112 21	0.545487903	B	0.10455279	5.22	<.0001
YEAR*AREA 112 22	1.594181258	B	0.37362642	4.27	<.0001
YEAR*AREA 113 21	0.037737002	B	0.10767373	0.35	0.7260
YEAR*AREA 114 21	-0.393905658	B	0.20995861	-1.88	0.0607
YEAR*AREA 115 21	-0.220408150	B	0.14108269	-1.56	0.1183
YEAR*AREA 116 21	-0.165060801	B	0.44594871	-0.37	0.7113
YEAR*AREA 117 21	0.639786001	B	0.19247867	3.32	0.0009
YEAR*AREA 118 21	1.084951808	B	0.21222365	5.11	<.0001
YEAR*AREA 999 21	-0.515325375	B	0.07090022	-7.27	<.0001
YEAR*AREA 999 22	0.000000000	B	.	.	.
MONTH 1	0.321492810	B	0.02954477	10.88	<.0001
MONTH 2	0.291227762	B	0.02943446	9.89	<.0001
MONTH 4	0.160643072	B	0.02844184	5.65	<.0001
MONTH 5	0.097235080	B	0.04067636	2.39	0.0169
MONTH 6	-0.041146679	B	0.07725191	-0.53	0.5943
MONTH 7	0.343994846	B	0.07090584	4.85	<.0001
MONTH 8	0.061907874	B	0.05170071	1.20	0.2312

Parameter	Estimate		Standard Error	t Value	Pr > |t|
MONTH 11	-0.259033997	B	0.03118664	-8.31	<.0001
MONTH 12	0.000000000	B	.	.	.
AREA 21	0.000000000	B	.	.	.
AREA 22	0.000000000	B	.	.	.
HOLD 2	0.050239329	B	0.02859627	1.76	0.0790
HOLD 9	0.000000000	B	.	.	.

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	17	E001 E006 E012 E015 E024 E034 E043 E049 E054 E058 E063 E065 E070 E074 E079 E082 E083
YEAR	39	80 81 82 83 84 85 86 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 999
MONTH	8	2 3 4 6 7 8 11 12
HOLD	2	2 9

Number of Observations Read 3961

Dependent Variable: LNCPUE

Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	62	59707.52641	963.02462	107.65	<.0001
Error	3898	34869.76963	8.94555		
Corrected Total	3960	94577.29605			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.631309	251.5405	2.990912	1.189038

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BAAD	16	24468.66312	1529.29144	170.96	<.0001
YEAR	38	32247.15096	848.60924	94.86	<.0001
MONTH	7	2907.21063	415.31580	46.43	<.0001
HOLD	1	84.50170	84.50170	9.45	0.0021

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BAAD	16	15617.06740	976.06671	109.11	<.0001
YEAR	38	30321.31438	797.92933	89.20	<.0001
MONTH	7	2942.78148	420.39735	47.00	<.0001
HOLD	1	84.50170	84.50170	9.45	0.0021

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	2.174428710	B	0.10078181	21.58	<.0001
BAAD E001	-1.996832575	B	0.16589093	-12.04	<.0001
BAAD E006	-1.587294657	B	0.10262477	-15.47	<.0001
BAAD E012	-1.451120302	B	0.09686320	-14.98	<.0001

Parameter	Estimate		Standard Error	t Value	Pr > |t|
BAAD E015	-1.348509754	B	0.10197763	-13.22	<.0001
BAAD E024	-1.254314944	B	0.09490513	-13.22	<.0001
BAAD E034	-1.140172806	B	0.09356137	-12.19	<.0001
BAAD E043	-1.016672340	B	0.09440332	-10.77	<.0001
BAAD E049	-0.945580177	B	0.09262195	-10.21	<.0001
BAAD E054	-0.894394928	B	0.09647930	-9.27	<.0001
BAAD E058	-0.786311838	B	0.10131449	-7.76	<.0001
BAAD E063	-0.685940571	B	0.09295291	-7.38	<.0001
BAAD E065	-0.611735913	B	0.10640829	-5.75	<.0001
BAAD E070	-0.548104597	B	0.09352988	-5.86	<.0001
BAAD E074	-0.482701871	B	0.09402751	-5.13	<.0001
BAAD E079	-0.377372668	B	0.09517080	-3.97	<.0001
BAAD E082	-0.260455055	B	0.10730713	-2.43	0.0153
BAAD E083	0.000000000	B	.	.	.
YEAR 80	0.321849231	B	0.24267255	1.33	0.1848
YEAR 81	0.343732523	B	0.22124552	1.55	0.1204
YEAR 82	-0.098811449	B	0.56794446	-0.17	0.8619
YEAR 83	0.183002788	B	0.28125547	0.65	0.5153
YEAR 84	0.714031473	B	0.21616799	3.30	0.0010
YEAR 85	0.221710603	B	0.10616857	2.09	0.0368
YEAR 86	0.287221300	B	0.06673530	4.30	<.0001
YEAR 88	-0.191277890	B	0.04793429	-3.99	<.0001
YEAR 89	-0.604538370	B	0.04723564	-12.80	<.0001
YEAR 90	-0.589828380	B	0.04742718	-12.44	<.0001
YEAR 91	-0.777586102	B	0.04724022	-16.46	<.0001
YEAR 92	-1.001026339	B	0.05206386	-19.23	<.0001
YEAR 93	-1.042590113	B	0.05214845	-19.99	<.0001
YEAR 94	-0.004902754	B	0.05377574	-0.09	0.9274
YEAR 95	-0.245218610	B	0.05346511	-4.59	<.0001
YEAR 96	0.011281819	B	0.05486746	0.21	0.8371
YEAR 97	0.243351913	B	0.06012420	4.05	<.0001
YEAR 98	0.323773368	B	0.06614754	4.89	<.0001
YEAR 99	0.451936851	B	0.07388713	6.12	<.0001
YEAR 100	0.421865421	B	0.05830873	7.24	<.0001
YEAR 101	0.401843829	B	0.05782493	6.95	<.0001
YEAR 102	0.543353353	B	0.06300734	8.62	<.0001

Parameter	Estimate		Standard Error	t Value	Pr > |t|
YEAR 103	0.305311474	B	0.05922027	5.16	<.0001
YEAR 104	0.400780618	B	0.06277884	6.38	<.0001
YEAR 105	0.535138902	B	0.06850563	7.81	<.0001
YEAR 106	0.468123614	B	0.07489422	6.25	<.0001
YEAR 107	0.334566133	B	0.07767484	4.31	<.0001
YEAR 108	0.479506672	B	0.09371575	5.12	<.0001
YEAR 109	0.828098812	B	0.08918906	9.28	<.0001
YEAR 110	0.197765294	B	0.07867257	2.51	0.0120
YEAR 111	0.190197650	B	0.13640157	1.39	0.1633
YEAR 112	0.025548033	B	0.09969741	0.26	0.7978
YEAR 113	-0.480063235	B	0.10500529	-4.57	<.0001
YEAR 114	-0.844744613	B	0.22193195	-3.81	0.0001
YEAR 115	-0.685978652	B	0.14516559	-4.73	<.0001
YEAR 116	-0.643393443	B	0.48215416	-1.33	0.1821
YEAR 117	0.009510413	B	0.20355198	0.05	0.9627
YEAR 118	0.554202641	B	0.22517947	2.46	0.0139
YEAR 999	0.000000000	B	.	.	.
MONTH 2	0.179349654	B	0.02693837	6.66	<.0001
MONTH 3	0.090707696	B	0.03094681	2.93	0.0034
MONTH 4	0.135262314	B	0.03615836	3.74	0.0002
MONTH 6	0.017693841	B	0.03966488	0.45	0.6556
MONTH 7	0.394235033	B	0.06756917	5.83	<.0001
MONTH 8	0.144197174	B	0.05020747	2.87	0.0041
MONTH 11	-0.236889126	B	0.03108754	-7.62	<.0001
MONTH 12	0.000000000	B	.	.	.
HOLD 2	-0.092339518	B	0.03004405	-3.07	0.0021
HOLD 9	0.000000000	B	.	.	.