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The Fishery for Northern Shrimp (*Pandalus borealis*) Off East Greenland, Greenlandic Zone, 1987-1999

by

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Abstract

Northern shrimp (*Pandalus borealis*) occurs off East Greenland from Cap Farewell to about 70°N on both sides of the territorial midline between Greenland and Iceland. The stock is assessed as a single population and managed by Total Allowable Catch in the Greenlandic zone. There is no management of the stock component in the Icelandic zone.

A multinational fleet exploits the stock with catches in the order of 7500-11500 tons during the 1990's. The fishery was originally conducted in areas between 65° and 67°30' N. Since 1993 fishery was also conducted in various smaller areas extending south to the Cap Farewell. Effort is equally distributed among the northern and southern areas. The overall spatial distribution of the 1999 fishery expected be similar to that of recent years.

From the fishery in the Greenlandic zone logbooks are available from Greenlandic, Faeroese and Danish vessels.
The overall effort spent by these fleets has declined from more than 50000 hours to about 14000 hours since 1989. Catches declined from a level of about 7000 tons in the late 1980's to 3000 tons in 1993 when the new fishing grounds south of 65°N enhanced overall catch rates and made catches increase to a new level of around 5000-6000 tons. In 1999 catches by these nations are projected to increase further to around 6000-8000 tons.

A unified standardised CPUE index for the total area indicated that the stock was reduced by a factor 4 in the period 1987-1993 after which it has been rebuilding at a corresponding rate. The projected 1999 value is at the same level as that of 1998 which was among the highest of the time series. Standardised effort indicated a decreasing trend in fishing mortality since 1990.

The size structure of catches indicates good recruitment to the female group in 1999-2000 in the southern areas. North of 65°N recruitment of more moderate size is to be expected. However, an abundant female group will probably maintain catch rates in year 2000.

Introduction

Northern shrimp (*Pandalus borealis*) occurs off East Greenland in ICES Divisions XIV and XVI. The stock is distributed from Cap Farewell to at about 70°N in depths down to around 800 meters (Fig. 1). 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.

The shrimp fishery off East Greenland began in the late 1970's as a multinational fishery and catches increased rapidly to more than 10000 tons during the following 10-year period. In the 1990's catches have fluctuated between 7500-11500 tons. The fishery was originally conducted north of 65°N in the Dohrnbank-Stredebank area and on the slopes of Storefjord Deep. However, in 1993 fishery was also initiated in various smaller areas extending south to the Cap

Farewell (Fig. 1). Fishery takes place on both sides of the territorial midline between Greenland and Iceland. Catches in the Greenland zone accounts for around 70-90% of the total. In the Greenland zone the stock is managed by a Total Allowable Catch (TAC). There are no restrictions on the fishery in the Icelandic zone.

Fleets from Greenland, Denmark, the Faroe Islands and Norway participated in the fishery in the Greenlandic zone in 1998 and 1999. All vessels are large factory trawlers in the range of 1000-3000 GRT. Individual shares of the total TAC are assigned to each nation by the Greenland government. Logbooks are available since 1987 from Greenland, Faeroe Islands and Denmark, which account for 75-80% of the catches in the Greenlandic zone.

This paper presents time series of total catch, catch composition, effort, CPUE-indices and geographical distribution of the shrimp fishery conducted by the Greenlandic, Faeroese and Danish fleets off East Greenland in the Greenlandic zone. This is the first step in a process towards integrating available data from all nations participating in this fishery in a single paper – a process not expected to be finalised till year 2000-2001.

Materials and methods

Logbook data from the Danish, Faroese and Greenlandic fleets were analysed to show the spatial distribution of the fishery and the overall distribution of catch, effort and catch rates by month and year.

Seven standardised CPUE indices were calculated by general linear modelling. As in recent assessments logbook data from the Greenlandic trawlers only formed the input for four separate indices: one for the area north of 65°N and one for the areas south of 65°N. In each case the calculations were done for the catches of shrimp larger than 8.5g and for the total catch. The method used is described in Hvingel and Folmer, 1998. Few data were available for 1999 and the models were therefor fitted to 1987-1998 data only.

Likewise three new indices were calculated, which in addition to data from the Greenlandic fleet also included data from Faroese and Danish logbooks: one for each of the northern and southern areas and one for the total area (Greenlandic zone) including an area effect with two levels. All indices were constructed by using the approach described in Hvingel *et al.* (in press) for calculating a CPUE-index of an individual fleet. Fifty-two of 67 vessels met the criteria for inclusion in the analysis i.e. 37 Greenlandic, 9 Faeroese and 6 Danish vessels. Based on an exploratory run of the main effects model the vessel effect was collapsed into 8 groups consisting of 4-8 vessels with similar fishing power. The month effect was reduced to 3 levels by grouping months with similar indices of relative shrimp availability.

Size compositions of shrimp catches were generated from samples from the Greenlandic fishery. Samples taken by observers before processing were sorted by sexual characteristics (McCrary, 1971) and measured to the nearest 0.1 mm carapace length. The data were then pooled in 0.5 mm length groups and adjusted by ratio of weight to the number caught in the set. Numbers from all sets for the month were totalled and adjusted by weight to the monthly catch reported in vessel logs. The numbers from all months were totalled and adjusted by weight to the total catch of the year in the respective areas.

Results and Discussion

Geographical distribution of the fishery

The fishery for shrimp off East Greenland was originally conducted north of 65°N at the Dohrnbank, Stredebank and the slopes of Storefjord Deep. Since 1993 the fishing pattern has changed as new fishing grounds were found south of 65°N. Fishing effort has largely been equally distributed among the two areas (Fig 2B). Figure 1A-I shows the geographical distribution of the Greenlandic catches from 1991 to 1999.

Catch, effort and unstandardised CPUE from vessel logs

The fishery has gradually changed from an all year activity with a minimum in the summer months, to effort being spent only in the winter months (Nov-April). This time of year generally produces the highest catch rates.

Compared to the late 1980's catch and effort in the area north of 65°N has been reduced by about 85% (Table 1 and Figure 2A+B). According to Greenlandic skippers this was due to a decline in catch rates of large shrimp, which was the

prime target of the Greenlandic fishery in Denmark Strait. Fishing opportunities elsewhere, i.e. at Flemish Cap, and the development of the new fishery south of 65°N may also have contributed to the reduced attractiveness of the traditional fishing grounds.

South of 65°N the largest catches are generally taken Nov.-Feb. Although catch rates are about twice as high as in the northern area (Figure 2C) a large part of the effort is still spent in the north - mostly due to less favourable bottom conditions for trawling in the southern areas.

Total effort in the Greenland zone has shown a declining trend from about 50000 hr's in the late 1980's - early 1990's to a level of about 15,000 hr's in 1998's (Table 1 and Figure 2B). The data for 1999 suggests a fishing effort within the range of 14000-24000 hr's. The total catches followed a similar downward trend from about 7000 tons to 3000 tons until 1993 (Fig 2A) when the new fishing grounds south of 65°N enhanced overall catch rates and made catches increase to a new level of around 5000-6000 tons in the years thereafter. In 1999 catches are projected to increase further to around 6000-8000 tons.

Standardised CPUE from Greenlandic vessel logs

Results of the seven multiple regression analysis to standardise catch rates showed that all main effects were highly significant ($p<0.0001$). The r-squared of the four models were in the range of 40-60%. The model diagnostical outputs (residual plots, Cook's D influence statistics, test of normality etc.) 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 two indices based on the total catches by Greenlandic vessels only are shown in Figure 3 (the series for shrimp>8.5g are not given as they show exactly the same trend). The index for the northern area has declined from 1987 to 1993 succeeded by an overall increasing trend until 1998. The CPUE index values of the southern area has increased throughout the time series. The index values for 1997-1998 were based on relative few observations and are therefore be estimated with greater uncertainty than the index values of the previous years. The 1998-1999 development in CPUE may be obtained from the raw CPUE data in table 1, which show an increase for both areas.

Including also the data from the Faeroese and Danish fleets (Fig. 2D+E) did not change the results appreciably. The extra data however enabled a reliable estimation of the 1999 values as well: in the northern area the CPUE index declines from 1998-1999 whereas that for the southern areas increases.

A unified index for the total area could be estimated by pooling the data from the two areas and including an area effect in the model assumed to take account of the differences in biomass density north and south of 65°N respectively. This index (Fig. 2F) indicates that the stock was reduced by a factor 4 in the period 1987-1993 after which it has been rebuilding at a corresponding rate. The projected 1999 value is at the same level as that of 1998 which was among the highest of the time series. A standardised effort based on this CPUE index was calculated by applying it to the total catches by the fleet included (Fig. 2G). This series indicate a decreasing trend in fishing mortality since 1990. However, standardised effort is expected to increase from 1998 to 1999.

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 CPUE time series interpreted as a biomass index is therefore 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.*, in press).

Length distributions

Besides practical problems collecting samples, adequate sampling in time and space for constructing length distribution of the catches are made difficult by the ongoing changes in fishing pattern. In this investigation samples taken north and south of 65°N were treated separately. Modal analyses were not applied for the same reasons as discussed in Hvingel (this meeting). The numbers of samples included are presented in Table 2.

The length frequency distributions of Greenlandic catches in the northern and southern areas are shown in Figure 4A+4B. In the northern area data is available for 1991-1995 and 1998-1999. A high proportion of males in 1995 (Table 3) indicated that some good recruitment was on its way to enter the fishery as females during the late 1990's. In fact female catch rates did increase in 1998 and 1999 where catches were dominated by shrimp at almost 30mm cpl. (Figure 4A). The relative abundant group of females should still be able to support the catches of year 2000. However, the size composition does suggest recruitment of more moderate size in the coming years.

The catch composition in the southern area was dominated by males in 1997 and 1998 (Figure 4B), which indicate good recruitment to female group for 1999-2000. There is currently no data available for 1999.

References

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Table 1. Catch (tons), effort (hr's) and CPUE (kg/hr) by Danish, Faeroese and Greenlandic shrimp trawlers fishing off East Greenland in the Greenlandic zone north and south of 65°N 1987-June 1999.

Catch (tons)

Year	Denmark			Faeroe Islands			Greenland			Total		
	North	South	Total	North	South	Total	North	South	Total	North	South	Total
1987	0	0	0	0	0	0	6627	0	6627	6627	0	6627
1988	0	0	0	0	0	0	7450	0	7450	7450	0	7450
1989	366	0	366	595	0	595	5981	0	5981	6942	0	6942
1990	390	0	390	843	0	843	6210	0	6210	7443	0	7443
1991	358	0	358	1007	0	1007	4205	0	4205	5570	0	5570
1992	160	0	160	1092	0	1092	2012	0	2012	3264	0	3264
1993	110	48	158	556	224	780	1425	918	2343	2091	1190	3281
1994	198	486	684	368	776	1144	1056	2869	3925	1622	4131	5753
1995	241	395	636	626	132	758	1913	2135	4048	2780	2662	5442
1996	21	938	959	820	323	1143	289	4256	4545	1129	5518	6647
1997	68	1328	1396	435	448	882	146	3777	3923	648	5553	6201
1998	295	713	1008	639	1	640	502	2847	3349	1436	3561	4997
1999	218	0	218	413	0	413	308	222	530	938	222	1160

Effort (hr's)

Year	Denmark			Faeroe Islands			Greenland			Total		
	North	South	Total	North	South	Total	North	South	Total	North	South	Total
1987	0	0	0	0	0	0	25168	0	25168	25168	0	25168
1988	0	0	0	0	0	0	37931	0	37931	37931	0	37931
1989	2786	0	2786	4707	0	4707	43382	0	43382	50875	0	50875
1990	5424	0	5424	7556	0	7556	39254	0	39254	52234	0	52234
1991	5418	0	5418	11269	0	11269	36256	0	36256	52943	0	52943
1992	3626	0	3626	13541	0	13541	19712	0	19712	36879	0	36879
1993	2417	576	2993	8446	2416	10862	15174	4245	19419	26037	7237	33274
1994	1620	2445	4065	2410	3473	5883	6200	7780	13980	10230	13698	23928
1995	1509	1040	2549	5879	1235	7114	9430	5923	15353	16818	8198	25016
1996	222	2827	3049	8904	2082	10986	2572	12324	14896	11698	17233	28931
1997	615	3591	4206	3679	2635	6314	1130	8065	9195	5424	14291	19715
1998	1022	2290	3312	2821	6	2827	2285	5670	7955	6128	7966	14094
1999	812	0	812	2170	0	2170	1357	324	1681	4339	324	4663

CPUE (kg/hr)

Year	Denmark			Faeroe Islands			Greenland			Total		
	North	South	Total	North	South	Total	North	South	Total	North	South	Total
1987	-	-	-	-	-	-	263	-	263	263	-	263
1988	-	-	-	-	-	-	196	-	196	196	-	196
1989	131	-	131	126	-	126	138	-	138	136	-	136
1990	72	-	72	112	-	112	158	-	158	142	-	142
1991	66	-	66	89	-	89	116	-	116	105	-	105
1992	44	-	44	81	-	81	102	-	102	89	-	89
1993	46	83	53	66	93	72	94	216	121	80	164	99
1994	122	199	168	153	223	194	170	369	281	159	302	240
1995	160	380	249	106	107	107	203	360	264	165	325	218
1996	93	332	315	92	155	104	112	345	305	97	320	230
1997	110	370	332	118	170	140	129	468	427	119	389	315
1998	289	311	304	226	183	226	219	502	421	234	447	355
1999	268	-	268	190	-	190	227	686	315	216	686	249

Table 2. Catch samples from Greenlandic trawlers 1991-1999 summed by month and by area north and south of 65°N.

North

Year	Month	Number of samples	Sample weight	Numbers measured	Sample represent catch (kg)
91	1	30	184.6	12041	21898
91	2	28	235.4	16196	15250
91	3	42	211.5	16147	30367
91	4	74	318.8	24067	52571
91	5	32	142.0	9861	18707
92	2	20	63.4	1502	9437
93	2	55	203.3	5014	21953
94	2	19	79.9	6682	14025
95	1	13	42.1	3505	11098
95	3	15	67.3	6124	31757
96	10	10	28.4	2643	4861
98	1	10	25.7	1875	11300
98	2	19	75.9	5485	19775
98	10	10	35.2	2412	5153
98	11	18	53.4	4082	5554
98	12	16	37.3	2665	14610
99	5	6	11.9	823	6517
99	6	2	3.8	286	2777
	Total	419	1820	121410	297610

South

Year	Month	Number of samples	Sample weight	Numbers measured	Sample represent catch (kg)
93	3	10	58.6	6323	7758
93	4	37	355.5	27169	76376
94	1	30	134.3	9957	61702
94	2	8	41.0	2712	10137
94	3	14	52.7	3916	8288
94	4	11	62.0	5115	14623
96	4	10	38.3	4973	16717
96	5	7	33.9	2571	2222
96	8	12	39.9	4405	11257
96	11	24	72.3	6444	31013
97	7	3	10.3	1214	13252
97	11	6	14.0	1951	5705
97	12	9	31.6	2982	10388
98	2	12	40.6	3951	14551
98	3	34	101.2	11618	47672
98	10	15	44.2	5313	21344
98	11	19	40.9	5317	25422
98	12	8	15.8	2224	10128
	Total	269	1187.2	108155	388555

Table 3. Mean shrimp size, numbers caught and estimated abundance calculated from logbook data and catch samples from the Greenlandic fishery in Denmark Strait north and south of 65°N 1991-1999. The sign "-" denotes missing data. Data for 1999 are preliminary.

Mean size

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cpl (mm)	27.0	26.5	26.7	26.0	26.2	-	-	27.9	27.6
Weight (g)	12.2	12.6	13.2	12.1	12.7	-	-	13.9	13.1
Count (no/kg)	82	79	76	83	79	-	-	72	76

Proportion of total catch

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Males	-	-	-	29%	51%	-	-	36%	29%
Primi	-	-	-	48%	7%	-	-	8%	15%
Multi	-	-	-	23%	41%	-	-	55%	56%
Females total	-	-	-	71%	49%	-	-	64%	71%

Number caught (millions)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Males	-	-	-	25	77	-	-	13	0
Primi	-	-	-	42	11	-	-	3	0
Multi	-	-	-	20	62	-	-	20	0
Females Total	-	-	-	62	73	-	-	23	0
Total	344	159	108	87	151	-	-	36	0

Abundance index

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Males	-	-	-	0.2	0.3	-	-	0.3	-
Primi	-	-	-	0.3	0.0	-	-	0.1	-
Multi	-	-	-	0.1	0.2	-	-	0.4	-
Females total	-	-	-	0.4	0.3	-	-	0.5	-

Mean size

Year	1993	1994	1995	1996	1997	1998	1999
Cpl (mm)	26.0	26.5	-	24.8	23.6	22.8	-
Weight (g)	11.5	12.7	-	9.1	9.6	6.5	-
Count (no/kg)	87	78	-	109	104	154	-

Proportion of total catch

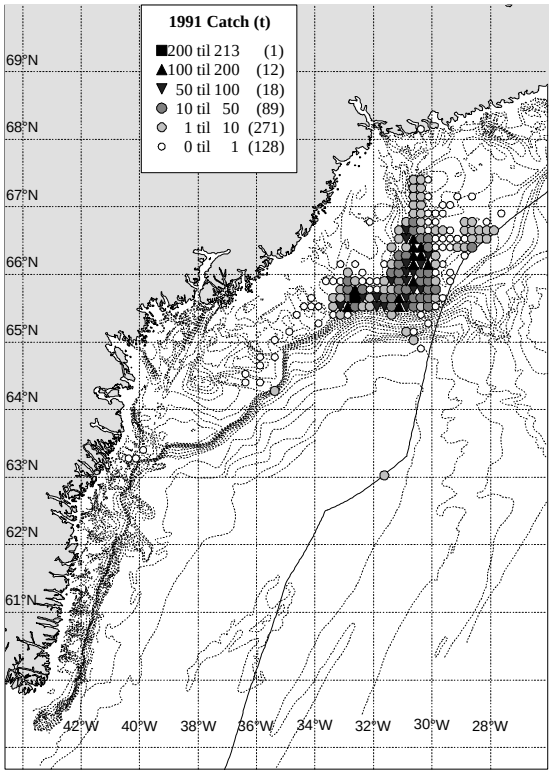
Year	1993	1994	1995	1996	1997	1998	1999
Males	-	32%	-	55%	74%	77%	-
Primi	-	15%	-	11%	2%	4%	-
Multi	-	54%	-	34%	24%	18%	-
Females total	-	68%	-	45%	26%	23%	-

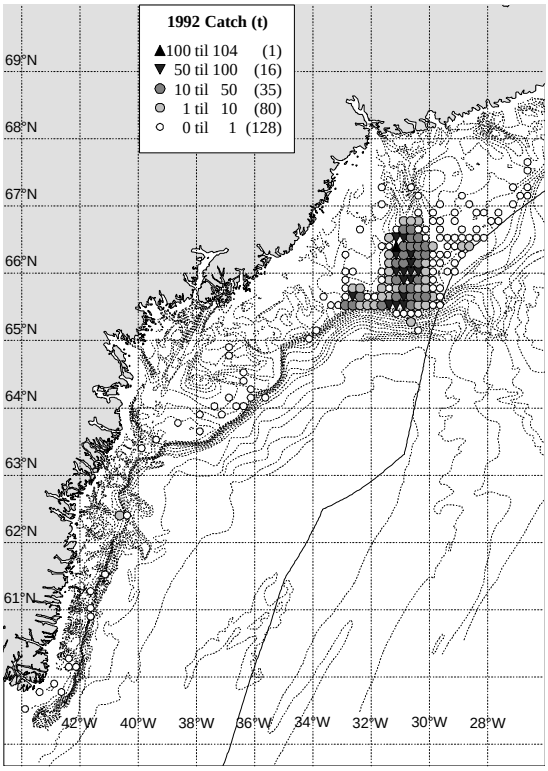
Number caught (millions)

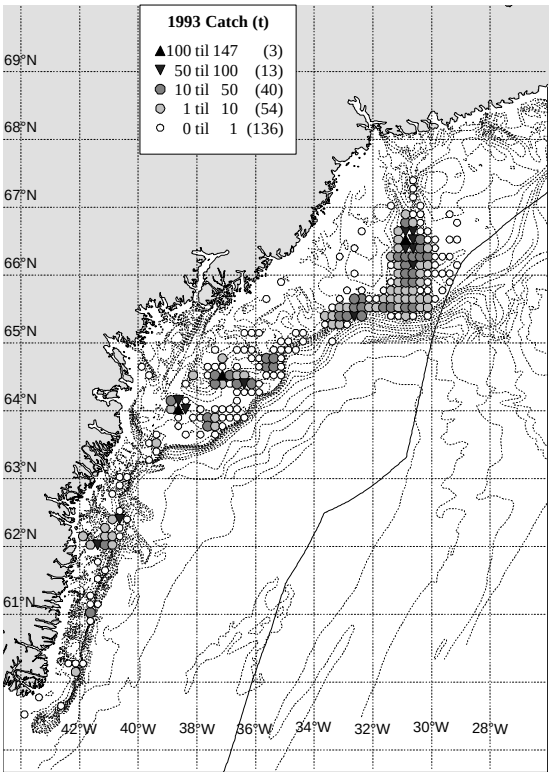
Year	1993	1994	1995	1996	1997	1998	1999
Males	-	72	-	258	293	339	-
Primi	-	33	-	52	6	18	-
Multi	-	120	-	156	95	81	-
Females Total	-	153	-	208	101	99	-
Total	80	225	-	466	395	439	-

Abundance index

Year	1993	1994	1995	1996	1997	1998	1999
Males	-	1.8	-	5.3	6.8	11.9	-
Primi	-	0.8	-	1.1	0.1	0.6	-
Multi	-	3.0	-	3.2	2.2	2.8	-
Females total	-	3.8	-	4.3	2.4	3.5	-







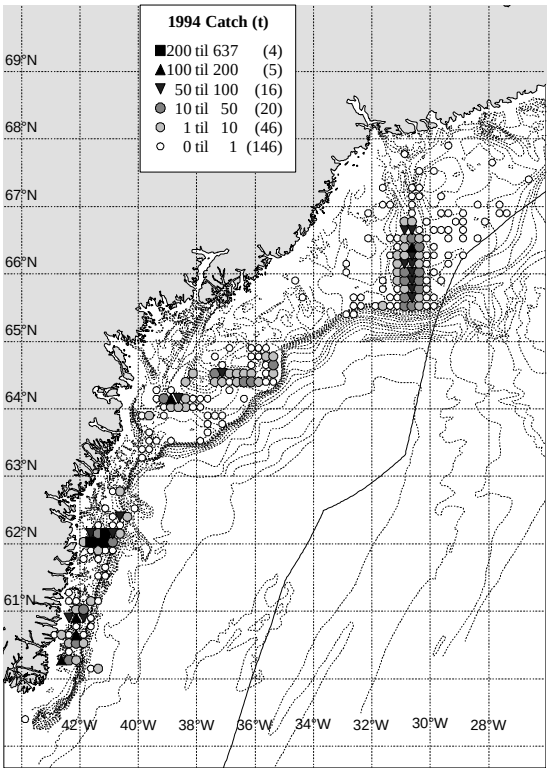
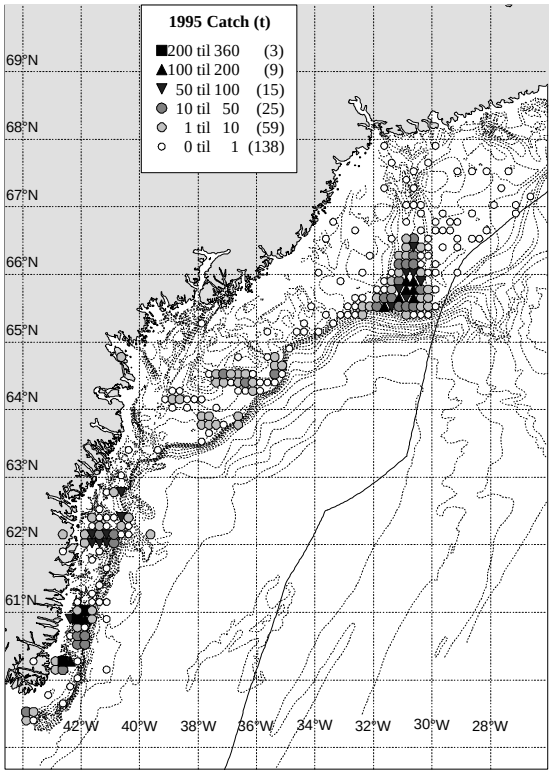
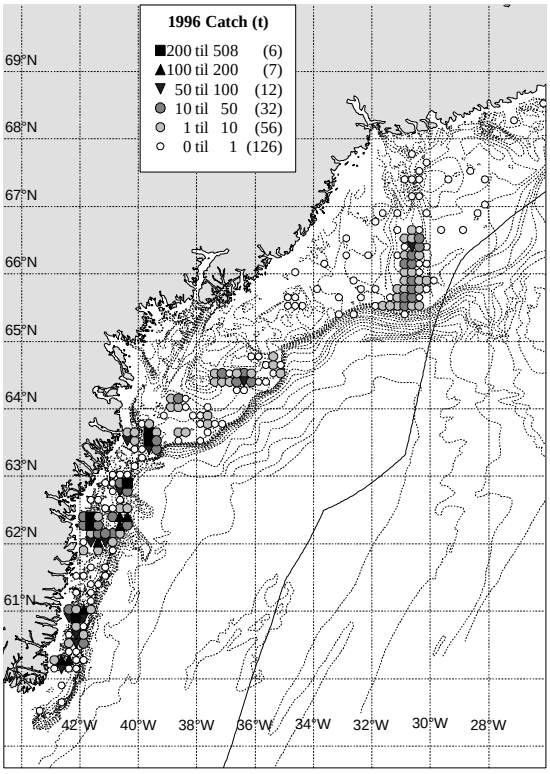
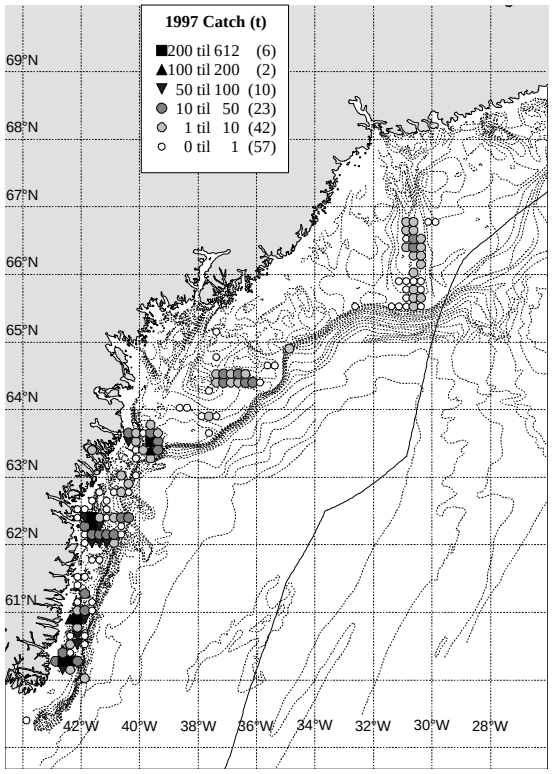
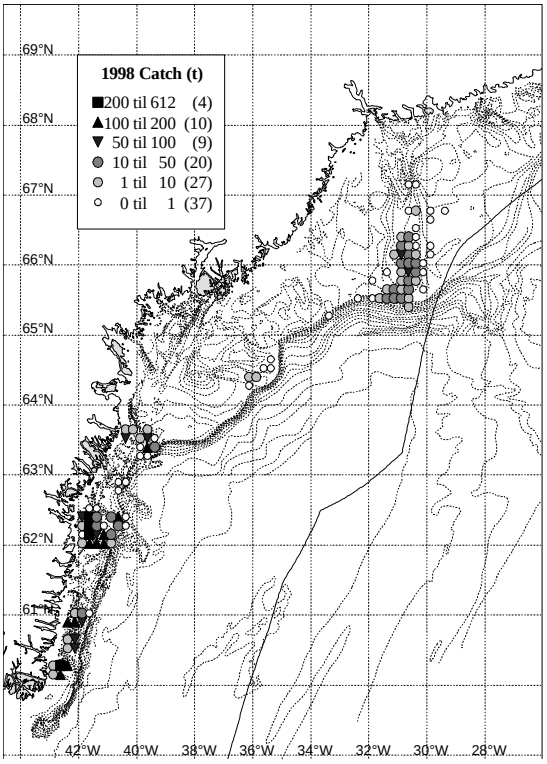


Figure 1. Spatial distribution of the Greenlandic shrimp catches off East Greenland 1991-1999, continues...









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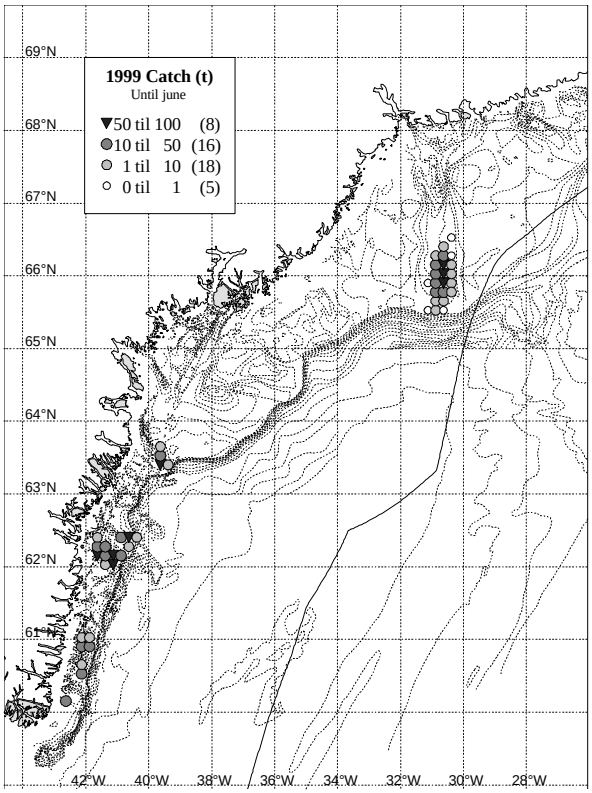

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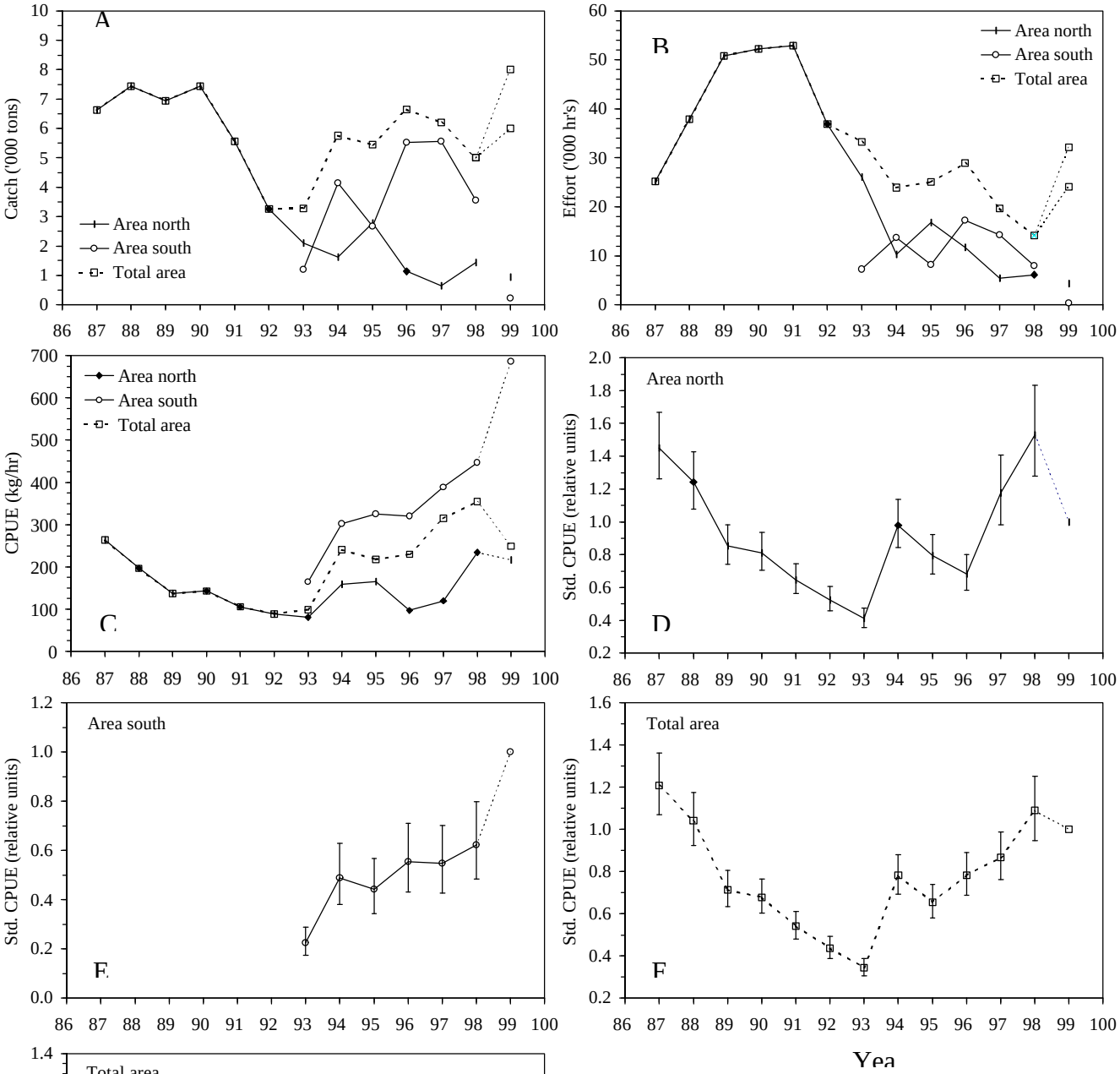

Figure 2. Catch, effort and CPUE by Greenlandic, Faeroese and Danish vessels fishing off East Greenland in the Greenlandic zone 1987-1999. The areas North and South refer to north and south of 65°N. Total area are these to areas combined.
The values for 1999 are either preliminary data collected until June (data point not attached to the rest of the time series) or projected (data point attached to the time series by a dotted line). The projected 1999 values may be given as a range. Error bars indicate

+/- 1 SE.

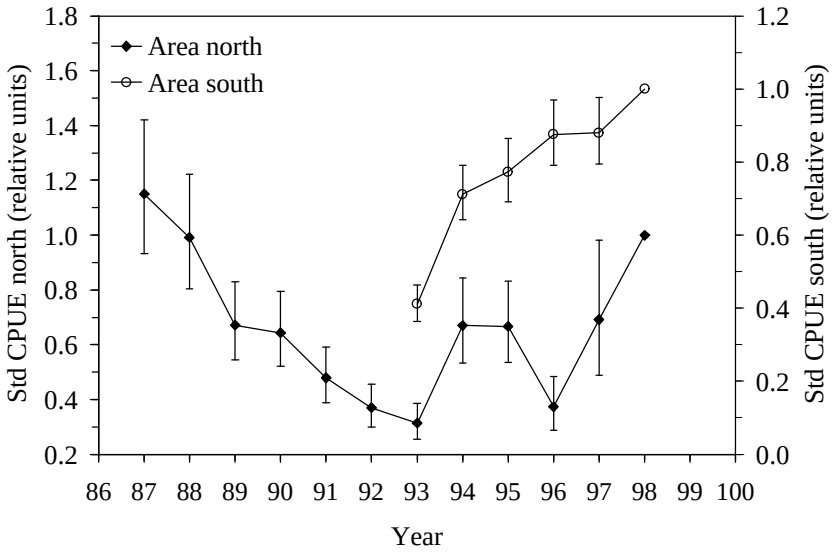

Figure 3. Standardised catch rates (+/- 1 SE) by Greenlandic vessels in the areas north and south of 65°N.

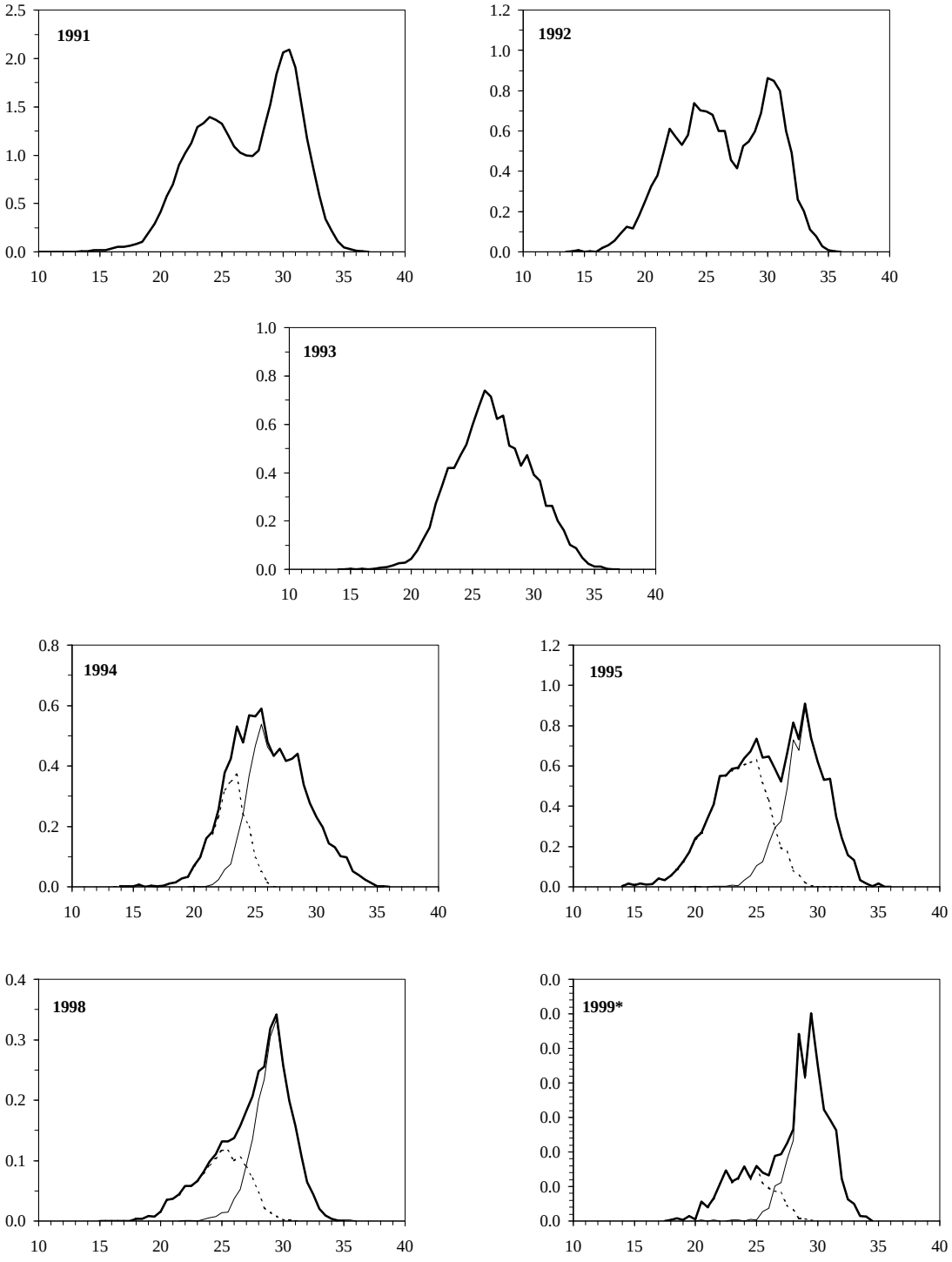

Figure 4A. Length frequency distributions of commercial shrimp catches off East Greenland north of 65°N, 1991 - 1999 (no data available for 1996-1997). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line. *preliminary data, no absolute values on y-axis.

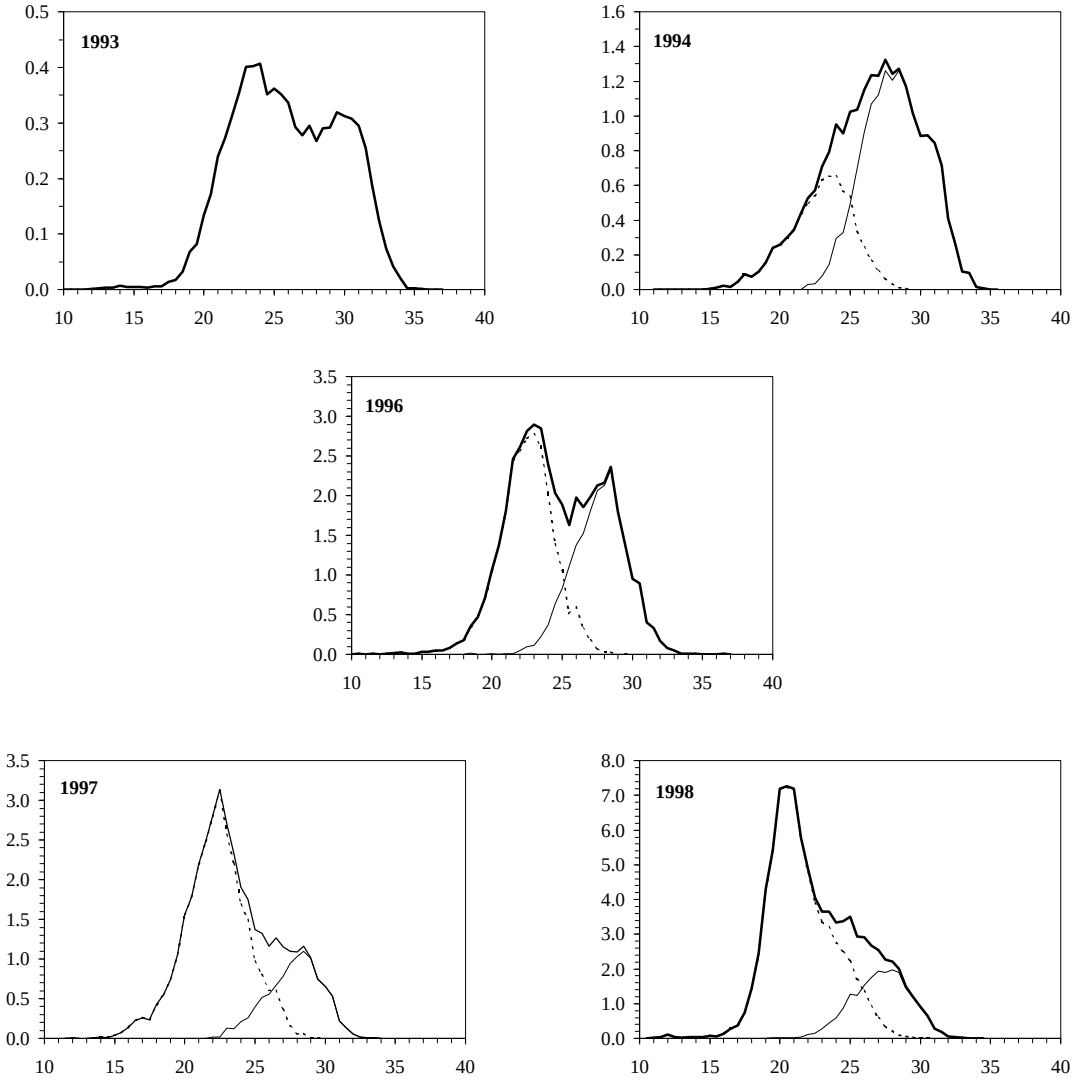

Figure 4B. Length frequency distributions of commercial shrimp catches off East Greenland South of 65°N, 1993-1999 (no data available for 1995 and 1999). The distribution of male shrimp is shown by a dotted line, females by a thin line and overall distribution by a bold line.