Northwest Atlantic Fisheries Organization

Serial No. N4021 **NAFO SCR Doc. 98/112**

SCIENTIFIC COUNCIL MEETING - NOVEMBER 1998

The Greenlandic Fishery for Northern Shrimp (*Pandalus borealis*) in Denmark Strait 1997 - September 1998

by

C. Hvingel and O. Folmer

Greenland Institute of Natural Resources
Box 570, DK-3900 Nuuk, Greenland

Introduction

At its meeting in November 1997 STACFIS concluded that the information available provided no basis for changing the advised TAC, which has remained at 5000 tons since 1993. Like in 1993-1997 the effective TAC for 1998 in the Greenlandic zone was set to 9,563 tons of which 3,888 tons was allocated to Greenland. No effective TAC is set for the Icelandic zone.

Vessels from Greenland, Denmark, the Faroe Islands and Norway participated in the fishery in the Greenlandic zone in 1997 and 1998. The total catches by these nations as reported to Greenlandic authorities amounted to 8,743 tons in 1997 and 5,222 tons in the period Jan-Oct 1997. Greenlandic vessels accounted in 1997 for 44% of the total catches amounting to 3,851 tons. By the end of October 1998 Greenlandic vessels had taken 41% of the catches equalling 2,132 tons.

The present paper updates time series of total catch, catch composition, effort, CPUE-indices and geographical distribution of the Greenlandic shrimp fishery in Denmark Strait, Greenlandic zone.

Materials and methods

Based on compulsory weekly reporting to Greenlandic authorities, total catch and number of vessels in the Greenlandic zone was compiled by nation and month. Logbook data from the Danish, Faroese and Greenlandic fleets were analysed to show the overall distribution of catches by year, and of catch, effort and catch rates by month. The spatial distribution of the Greenlandic fishery was also analysed.

Logbook data from the Greenlandic trawlers were used in calculating standardised catch rate indices for the traditional fishing area north of 65°N and for the new areas south of 65°N. This was done by using an approach similar to the one described in Hvingel, Lassen and Parsons, 1998.

We derived standardised indices separately for each area using multiplicative models, which included the following variables: (1) individual vessel fishing power, (2) seasonal availability and (3) annual mean CPUE. The multiplicative model was represented in logarithmic form:

$$\ln Cpue_{jkl} = \ln(u) + \ln(S_j) + \ln(V_k) + \ln(Y_l) + \varepsilon_{jkl}$$

Where $CPUE_{ijklm}$ is the mean CPUE for vessel k, fishing in the jth month during the lth year (k = 1,..,n; j = 1,…,s; l = 1,…,y); ln(u) is overall mean ln(CPUE); S_j is the effect of the jth month; V_k is the effect of the kth vessel; Y_l is the effect of the lth year; ε_{ikl} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ where n is the number of observations in the cell. The standardised CPUE indices are the antilog of the year coefficient

The input data were catch and effort were aggregated by vessel, month and year. Each cell was weighted by the number of hauls included. Indices were calculated for total catch and for catches of shrimp larger than 8.5 g to avoid the influence of unreported discard of smaller shrimp (Carlsson & Lassen, 1991). Only vessels with at least three years of continual fishing activity in the area were included in the calculations.

Significant interactions between the year effect and the other main effects exist in the data but their contribution to the variation is small in relation to that explained by the main effects alone. The final analysis was therefore run with main effects only.

Size compositions of shrimp catches in the areas north and south of 65°N 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.

Annual length frequency distributions of catches were analysed by modal analysis (Macdonald & Pitcher, 1979) in an attempt to isolate year classes. The number of age components and initial estimates of their mean lengths were unknown and the iterations were allowed to run freely for best fit, except for a fixed coefficient of variation at 0.045.

Results and Discussion

Geographical distribution of the Greenlandic fishery

The fishery for shrimp in Denmark Strait was originally conducted at the Dohrn Banke north of 65°N. Since 1993 the fishing pattern has changed as new fishing grounds were found south of 65°N. Figures 1A-H show the geographical distribution of the Greenlandic catches from 1991 to 1998.

Following the introduction in 1993 the new fishing areas south of 65°N received about 50% of the total effort spent by Greenland in Denmark Strait 1994-1995. Since then the fishery has almost exclusively taken place in the southern areas (Fig 2B).

Reported catches 1997 – 1998

Table 1 shows catches by month and nation and the numbers of reporting vessels in the Greenlandic zone in 1997 and 1998. Total reported catch in 1997 was 8,743 tons. Preliminary catch figures indicate that the total catches of 1998 will be at the 1994-1997 level.

A total of 39 vessels participated in the fishery in 1997 and until October 1998 24 vessels have been registered. The seasonal distribution of the fishery was similar to previous years with minimum activity in the summer period.

Catch, effort and unstandardised CPUE from vessel logs

Monthly, semi-annual and annual catch, effort and mean catch rates based on logbooks from the Greenlandic, Danish and Faroese fishery in the Denmark strait were compiled and are given in details in (Skúladóttir, 1998). Only the data of the Greenlandic fleet is presented in this paper.

The Greenlandic fishery in the traditional area north of 65°N has gradually changed from an all year activity with a minimum in the summer months, to effort only being spent only in December and the first three or four months of the year. 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 approximately one order of magnitude (Table 2 and Figure 2A+B). The main explanation for this development is not to be found in a decline of overall catch rates (Figure 2E) but in a decline in catch rates of large shrimp, which is the prime target of the Greenlandic fishery in Denmark Strait (Skippers, person. Comm.). Participation in the fishery at Flemish Cap and the development of the new fishery in the southern area of Denmark Strait are also major causes of the reduced attractiveness of the traditional area.

The fishery in areas south of 65°N began in 1993. No decisive seasonal pattern is yet obvious and effort has been distributed over all months. The largest catch is generally taken Nov.-Feb. Although catch rates were about twice as high as north of 65°N (Figure 2E) only about 20-50% of the Greenlandic effort was spent in the southern area during the first three years - probably due to less favourable bottom conditions for trawling in this area. Following this period of learning more than 75% of total effort has been allocated to the southern area since 1996.

Total Greenlandic fishing effort in the Denmark Strait has shown a declining trend from about 43,000 hr's in 1989 to a level of about 15,000 hr's in the mid 1990's (Table 2 and Figure 2F). The data for 1997 and 1998 suggests a fishing effort well below that level. The total catches followed the same trend until 1993 when the new fishing grounds south of 65°N enhanced overall catch rates and made catches reach a new level of around 4,000 tons (Fig 2E+F). In 1998 catches are projected to be at this level.

Standardised CPUE from Greenlandic vessel logs

Results of the multiple regression analysis to standardise catch rates of large shrimp (>8.5 g) and total catch both north and south of 65°N 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 annual catch rate indices for large shrimp and total catch are presented in Figure 2C and 2D, northern and southern areas respectively. The northern area received very little effort in 1997-1998 i.e. there were very few data available for those particular years. The model were therefor fitted on 1987-1996 data only and the 1997 and 1998 index values were calculated by applying the estimated effects of that model to the 1997 and 1998 data. The models of the southern area were fitted to the 1993-1998 data.

In the northern area the two index time series are almost parallel showing a declining trend from 1987 to 1993, succeeded by an increase to a higher level in the mid to late 90's. The index values for 1996-1998 were based on relative few observations and may therefore be estimated with greater uncertainty than the index values of the previous years. We were not able to estimate the variance of those particular years. The CPUE index values of the southern area for total catches showed an increasing trend, while the large shrimp index were more or less stable (Figure 2C).

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. Unsolved problems of population structure further made stratification of the analyses difficult. In this investigation samples taken north and south of 65°N were treated separately. The numbers of samples included are presented in Table 3.

The length frequency distributions of the northern and southern areas are shown in Figure 3a-b Modal analysis was applied to the annual length frequency distributions of the Greenlandic catches (Table 4). Runs with 6 age components produced the best fits and estimated reasonable consistent mean lengths from year to year. Skúladóttir (1994) also found 6 age components in a similar analysis. The mean lengths estimated in this study for the northern area show some agreement with her findings. In the southern area the mean length at age turned out a little smaller. Due to lack of knowledge of shrimp growth in the Denmark Strait assigning of absolute age to the found age components is still a matter of belief. In this paper we assigned age to the year classes as presented by Skúladóttir (1994).

The estimated proportions of each age group in the catch were applied to the total numbers caught to produce a catch-at-age matrix. This matrix was subsequently divided by standardised effort to produce age-specific indices of abundance (Table 4). In general catch rates for all year classes indicate increasing abundance up to about age 7, suggesting only partial recruitment to the fishery, at least up to age 7.

In the northern area data is available for 1991-1995 and 1998. Some good recruitment of young shrimp (age 3+4) seemed on its way in 1995 to enter the fishery as females in the late 1990's (Table 4). In fact female catch rates did increase in 1998 (Figure 4) where catches were dominated by shrimp at almost 30mm cpl. (Figure 3a). The catches of 1999 and possibly also of year 2000 should be supported by the relative abundant age 6+7 as seen in the 1998 data. However, the size composition does suggest recruitment below average in the years thereafter.

In the southern area catch rates of the largest shrimp were still good in 1998 (Table 4). Female abundance has showed an up-going trend since 1993 (Figure 4) along with an increasing male abundance. The catch composition in the southern area was dominated by males in 1998 (Figure 3b). Catch rates of males at around 20mm cpl were the highest of the time series and may indicate good recruitment to the fishery for 1999-2000.

Conclusion

Total catches in Denmark Strait, Greenlandic zone by all nations will probably be at the same level in 1998 as the 1997 catches of about 9,000 tons.

The overall effort spent by Greenland in Denmark Strait has declined from more than 40,000 hours to about 10,000 hours since 1989. The total catches followed the same downward trend until 1993 when the new fishing grounds south of 65°N enhanced overall catch rates and made catches increase to a new level of around 4,000 tons. In 1998 catches are projected to be at that level.

The geographical distribution of the Greenlandic fishery in the Denmark Strait in 1997 was maintained in 1998. However, a substantial reduction of effort spent in the traditional area north of 65° has taken place in recent years. Effort spent in the southern area has increased since the beginning of this fishery in 1993. At present more than 75% of the total Greenlandic effort spent in Denmark strait are allocated to this area.

The overall unstandardised catch rates have increased by almost a factor 3 since 1993 mostly due to the high catch rates in the new fishing grounds south of 65°N, but also influenced by an increase in biomass north of 65°N as indicated by the standardised CPUE. Standardised catch rates of the southern area has also shown an increasing trend since the beginning of this time series in 1993.

The size structure of both the northern and southern area as judged from the 1998 data, may indicate good recruitment to the female group in 1999 and possibly also year 2000. Prospects of recruitment for the succeeding years seem good for the southern area but maybe less optimistic for the northern area.

References

Carlsson, D. M. & H. Lassen (1991). A catch-rate index for large shrimp in the Greenland shrimp fishery in NAFO Division 1B. *NAFO SCR Doc. 91/57, Serial No. N1941.*

Hvingel, C., Lassen, H. and Parsons, D.G. (1998). A biomass index for northern shrimp (*Pandalus borealis*) in Davis Strait based on multiplicative modelling of commercial catch-per-unit-effort data (1976 - 1997). *NAFO SCR Doc. xx/xxx Serial No. xxxx.*

Macdonald, P. D. M. & T. J. Pitcher (1979). Age-groups from size-frequency data: A versatile and efficient method of analysing distribution mixtures. *J. Fish. Res. Board Can., 36: 987-1011.*

McCrary, J. A. (1971). Sternal spines as a characteristic for differentiating between females of some Pandalidae. *J. Fish. Res. Board Can., 28: 98-100.*

Skúldóttir, U. (1994). The Icelandic shrimp fishery (Pandalus borealis) in the Denmark Strait in 1992-1994, and a preliminary Estimation of age. *NAFO SCR Doc. 94/97, Serial No. N2486.*

Skúldóttir, U. (1997). The Catch Statistics of the Shrimp Fishery (Pandalus borealis) in the Denmark Strait in the years 1980-1996. *NAFO SCR Doc. 96/107, Serial No. N2804.*

Table 1. Catch (tons) and number of vessels fishing in Denmark Strait, Greenland zone by months and nation as reported to Greenlandic authorities 1997 and 1998. Data for 1998 are preliminary.

Catches (tons)

Year	Nation	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1997	Denmark	0	4	0	236	173	262	232	165	61	124	95	54	1406
	Faroe Isl.	261	268	87	28	0	0	0	0	5	38	112	236	1035
	Greenland	1035	220	6	22	0	0	112	0	0	98	757	1601	3851
	Norway	342	423	296	485	140	0	82	40	129	213	222	79	2451
	Total	1638	915	389	771	313	262	426	205	195	473	1186	1970	8743
1998	Denmark	128	165	278	119	21	17	0	213	116	64	-	-	1121
	Faroe Isl.	268	476	209	53	0	0	0	0	0	0	-	-	1006
	Greenland	119	486	1251	1	0	0	0	135	27	113	-	-	2132
	Norway	179	332	88	0	0	0	0	56	212	96	-	-	963
	Total	694	1459	1826	173	21	17	0	404	355	273	-	-	5222

No. of vessels

Year	Nation	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1997	Denmark	0	1	0	1	1	1	1	1	1	1	1	1	1
	Faroe Isl.	6	3	3	1	0	0	0	0	1	3	3	5	6
	Greenland	12	4	1	1	0	0	3	0	0	4	13	15	15
	Norway	7	9	9	9	6	0	2	2	5	8	7	3	17
	Total	25	17	13	12	7	1	6	3	7	16	24	24	39
1998	Denmark	1	1	1	1	1	1	0	1	1	1	-	-	1
	Faroe Isl.	4	6	3	2	0	0	0	0	0	0	-	-	6
	Greenland	3	6	10	1	0	0	0	2	1	2	-	-	10
	Norway	3	4	1	0	0	0	0	1	7	4	-	-	7
	Total	11	17	15	4	1	1	0	4	9	7	-	-	24

Table 2. Catch (tons), effort (hr's and index) and catch rates (kg/hr and index) by Greenlandic shrimp trawlers fishing in Denmark Strait 1987-1998. Data is given by areas north and south of 65°N and by total area.

	Catch (tons)			Effort (hr's)			Std.effort		CPUE (kg/hr)			Std. CPUE	
Year	North	South	Total	North	South	Total	North	South	North	South	Total	North	South
1987	6627	0	6627	25168	0	25168	2.90		263		263	2.28	
1988	7450	0	7450	37931	0	37931	3.79		196		196	1.96	
1989	5981	0	5981	43382	0	43382	4.49		138		138	1.33	
1990	6210	0	6210	39254	0	39254	4.87		158		158	1.28	
1991	4205	0	4205	36256	0	36256	4.43		116		116	0.95	
1992	2012	0	2012	19712	0	19712	2.74		102		102	0.73	
1993	1425	918	2343	15174	4245	19419	2.30	2.32	94	216	121	0.62	0.40
1994	1056	2869	3925	6200	7780	13980	0.80	4.17	170	369	281	1.33	0.69
1995	1913	2135	4048	9430	5923	15353	1.45	2.86	203	360	264	1.32	0.75
1996	289	4256	4545	2572	12324	14896	0.29	5.03	112	345	305	1.00	0.85
1997	82	3736	3817	560	8027	8587	0.06	4.39	146	465	445	1.37	0.85
1998	258	1359	1617	1120	3054	4174	0.15	1.36	231	445	387	1.77	1.00

Table 3. Catch samples taken in Denmark Strait 1991-1998 on Greenlandic trawlers summed by month and by area.

North

Year	Month	Number of samples	Sample weight	Numbers measured	Sample represent catch (kg)
91	1	30	184.6	21898	14898
91	2	28	235.4	15250	20127
91	3	42	211.5	30367	17872
91	4	75	323.8	52713	24286
91	5	32	142	18707	9861
92	2	20	63.36	9437	4834
93	2	56	207.33	21964	16258
94	2	19	79.92	14025	6682
95	1	13	42.1	11098	3505
95	2	1	3.21	1091	187
95	3	15	67.34	31757	6124
96	10	10	28.39	4861	2643
98	1	10	25.7	11300	1875
98	2	18	72.64	18684	5298
	Total	369	1687.29	263152	134450

South

Year	Month	Number of samples	Sample weight	Numbers measured	Sample represent catch (kg)
93	3	10	58.6	7758	6560
93	4	37	350.82	75969	27933
94	1	30	134.32	61702	9957
94	2	8	40.98	10137	2712
94	3	14	52.72	8288	3916
94	4	11	62.01	14623	5115
96	4	10	38.29	16717	4973
96	5	7	33.92	2222	2571
96	8	12	39.93	11257	4405
96	11	24	72.32	31013	6444
97	7	3	10.34	13252	1214
97	11	6	14.02	5705	1951
97	12	10	33.72	10760	3093
98	2	12	40.58	14551	3951
98	3	34	102.21	47672	11618
	Total	228	1084.78	331626	96413

Table 4. Output from modal analyses of annual length frequency distribution from Greenland shrimp catches in Denmark Strait and derived age specific catch rates. Note that the assignment of age is a matter of convenience rather than actual knowledge of shrimp growth at East Greenland.

Area North

Mean Cpl. length (mm)

Year class	1991	1992	1993	1994	1995	1998
3	18,9	18,7	18,7	19,1	19,2	19,0
4	21,2	21,3	21,4	20,7	21,2	21,1
5	23,5	23,8	23,3	22,9	23,0	23,3
6	26,0	25,9	25,9	25,0	25,2	25,4
7	29,4	29,2	28,8	27,9	28,9	28,1
8+	31,2	30,7	31,5	31,1	30,9	29,9

Proportion of total catch

Year class	1991	1992	1993	1994	1995	1998
3	0,02	0,04	0,01	0,01	0,05	0,01
4	0,12	0,16	0,06	0,05	0,12	0,05
5	0,22	0,20	0,18	0,22	0,20	0,08
6	0,18	0,18	0,38	0,32	0,27	0,22
7	0,27	0,19	0,25	0,30	0,27	0,37
8+	0,18	0,23	0,12	0,10	0,08	0,27

Number caught (millions)

Year class	1991	1992	1993	1994	1995	1998
3	7	6	1	1	8	0
4	41	25	6	4	18	1
5	76	32	19	19	30	2
6	62	29	41	28	41	4
7	93	30	27	26	41	7
8+	62	37	13	9	12	5
Total	344	159	108	87	150	19

Abundance index

Year class	1991	1992	1993	1994	1995	1998
3	203	305	62	143	678	169
4	1215	1221	369	715	1626	846
5	2228	1526	1108	3147	2711	1354
6	1823	1373	2339	4578	3659	3724
7	2734	1450	1539	4292	3659	6263
8+	1823	1755	739	1431	1084	4570
Total	10126	7629	6156	14305	13553	16928

Area south

Mean Cpl. length (mm)

Year class	1993	1994	1995	1996	1997	1998
3	18.0	16.8	-	16.3	16.0	16.9
4	20.4	19.5	-	19.1	18.6	19.3
5	22.7	21.9	-	21.4	21.1	21.0
6	25.0	24.3	-	23.5	23.3	23.4
7	27.7	27.2	-	26.9	26.5	25.9
8+	30.5	30.1	-	29.1	28.6	28.4

Proportion of total catch

Year class	1993	1994	1995	1996	1997	1998
3	0.01	0.01	-	0.01	0.02	0.01
4	0.11	0.05	-	0.05	0.07	0.18
5	0.23	0.11	-	0.24	0.27	0.16
6	0.22	0.21	-	0.28	0.35	0.27
7	0.18	0.34	-	0.25	0.15	0.22
8+	0.25	0.28	-	0.17	0.14	0.14

Number caught (millions)

Year class	1993	1994	1995	1996	1997	1998
3	1	2	-	3	6	2
4	9	11	-	24	26	30
5	19	24	-	109	106	26
6	18	44	-	126	136	44
7	14	72	-	115	61	36
8+	20	60	-	78	57	23
Total	80	211	-	455	392	164

Abundance index

Year class	1993	1994	1995	1996	1997	1998
3	178	201	-	241	634	537
4	1634	1115	-	2010	2658	9667
5	3549	2535	-	9131	10957	8593
6	3369	4623	-	10602	14078	14500
7	2713	7590	-	9661	6264	11815
8+	3835	6320	-	6538	5864	7519
Total	15190	22384	-	38184	40454	53705

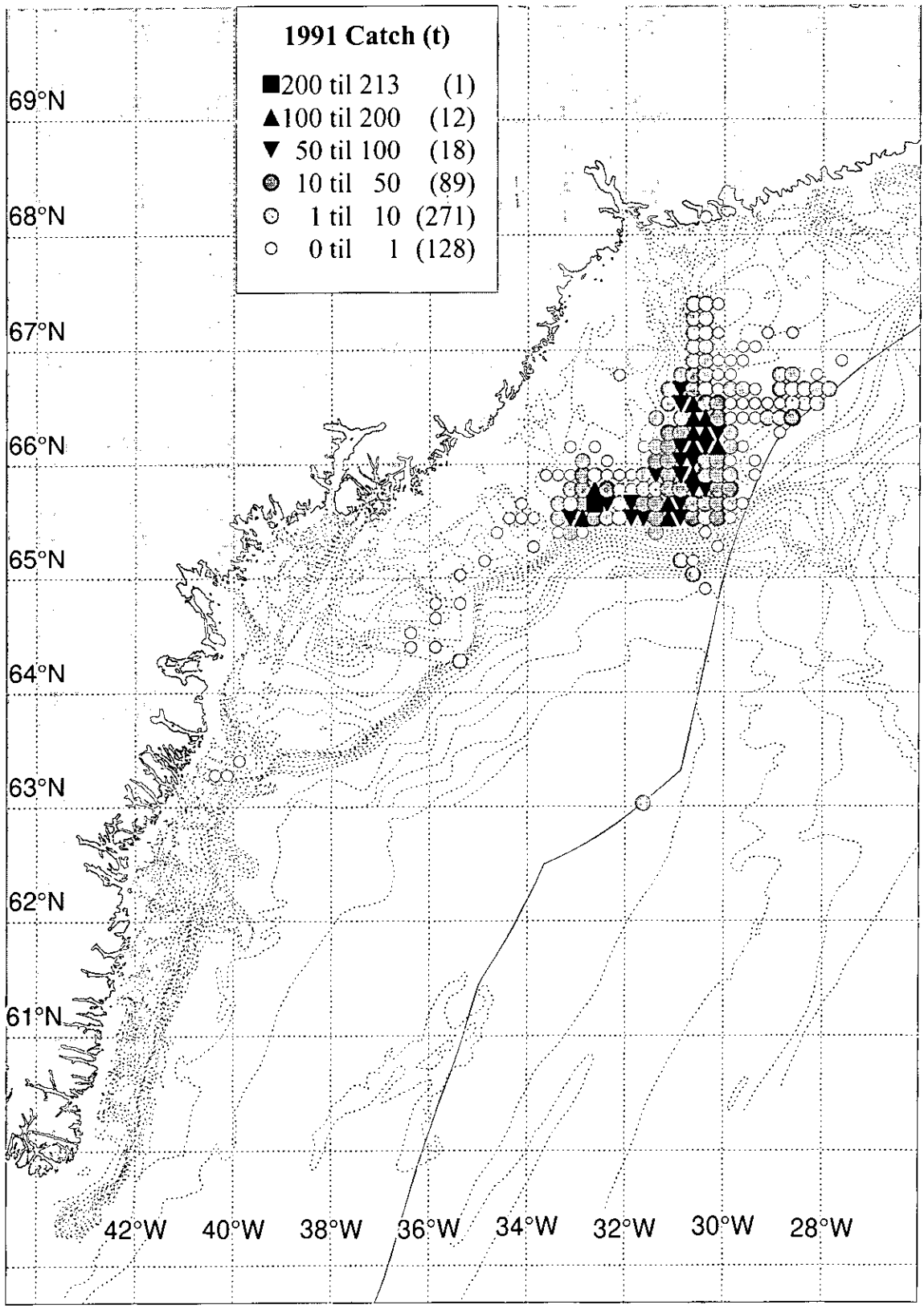


Figure 1A. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1991.

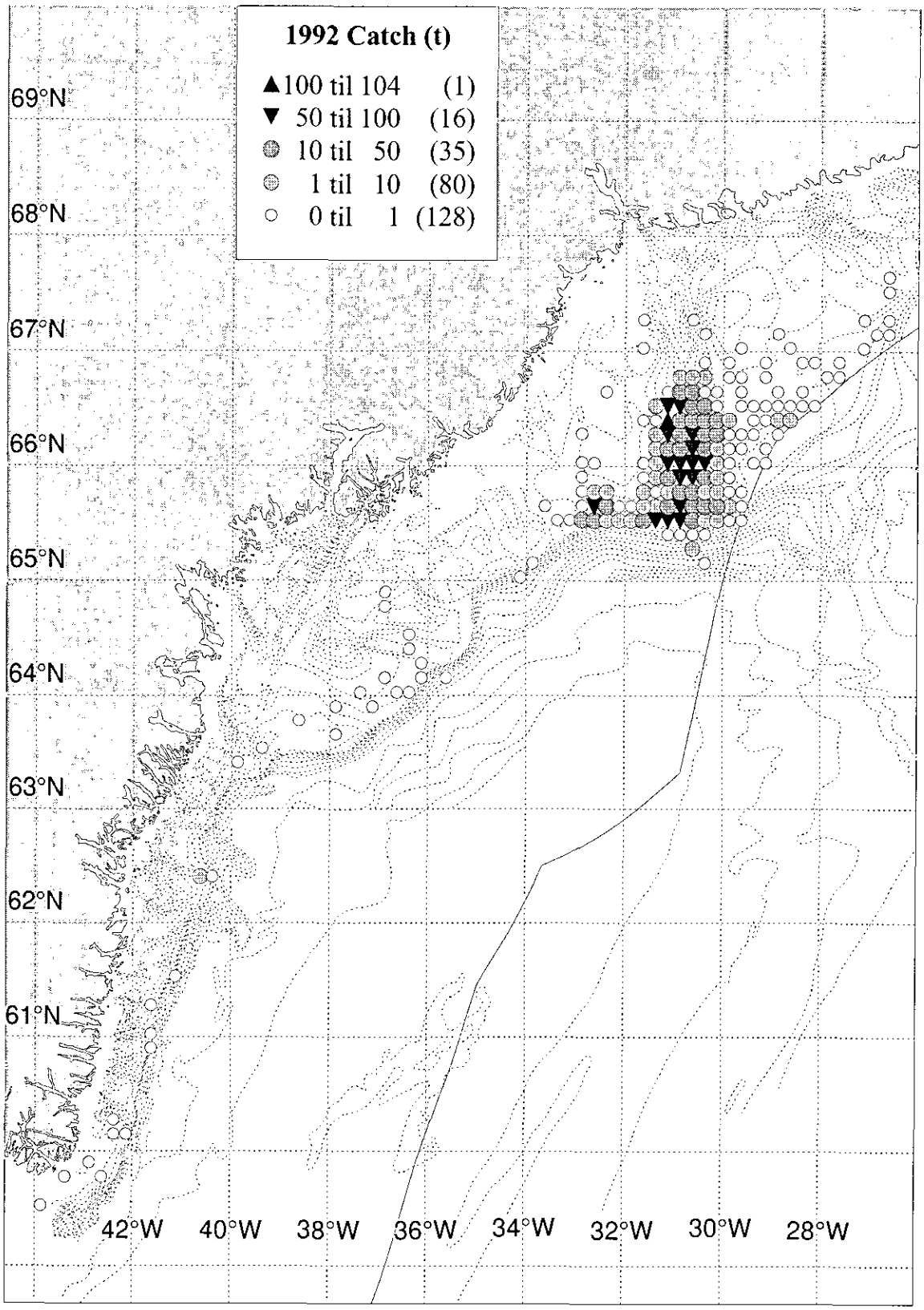


Figure 1B. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1992.

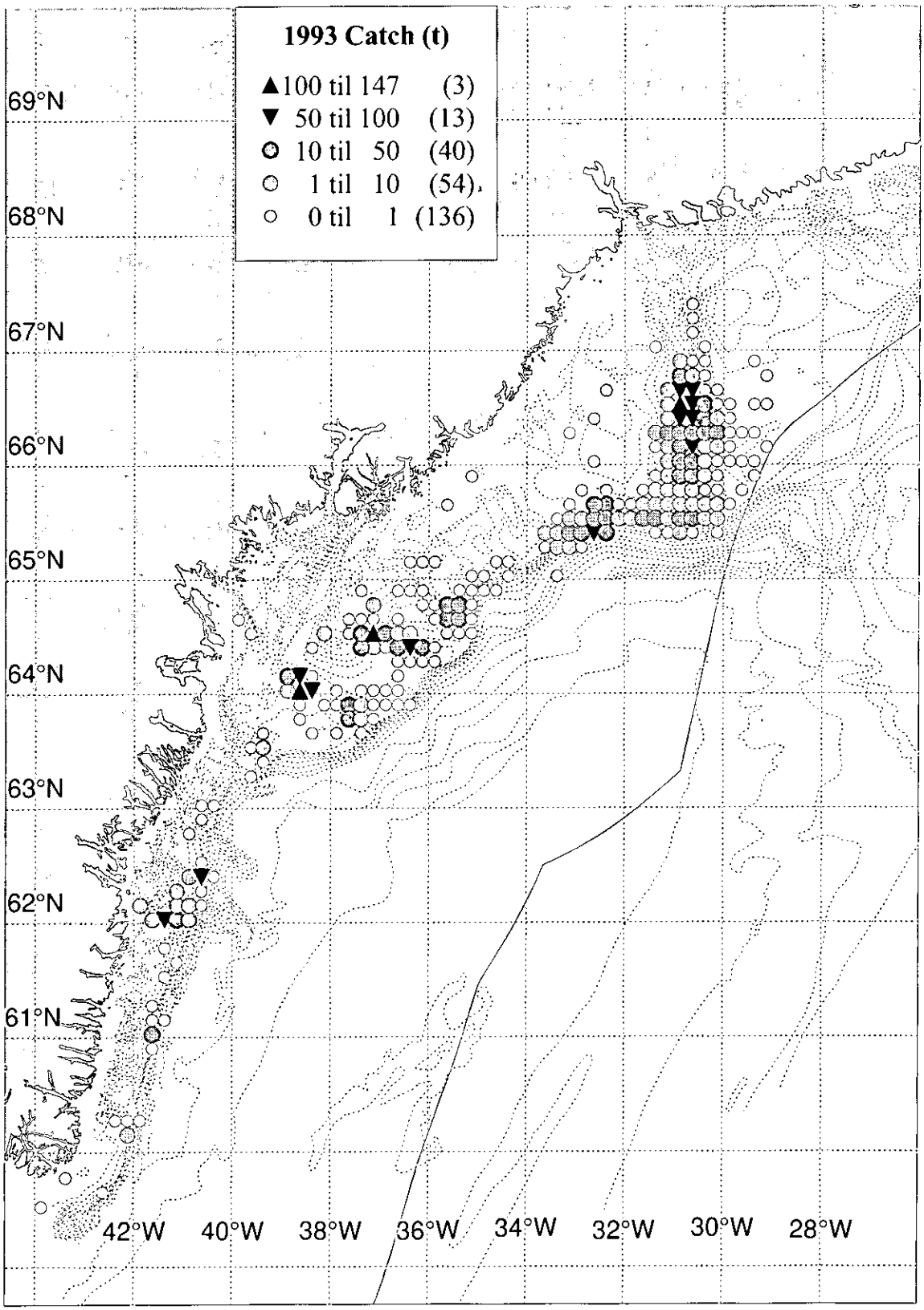


Figure 1C. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1993.

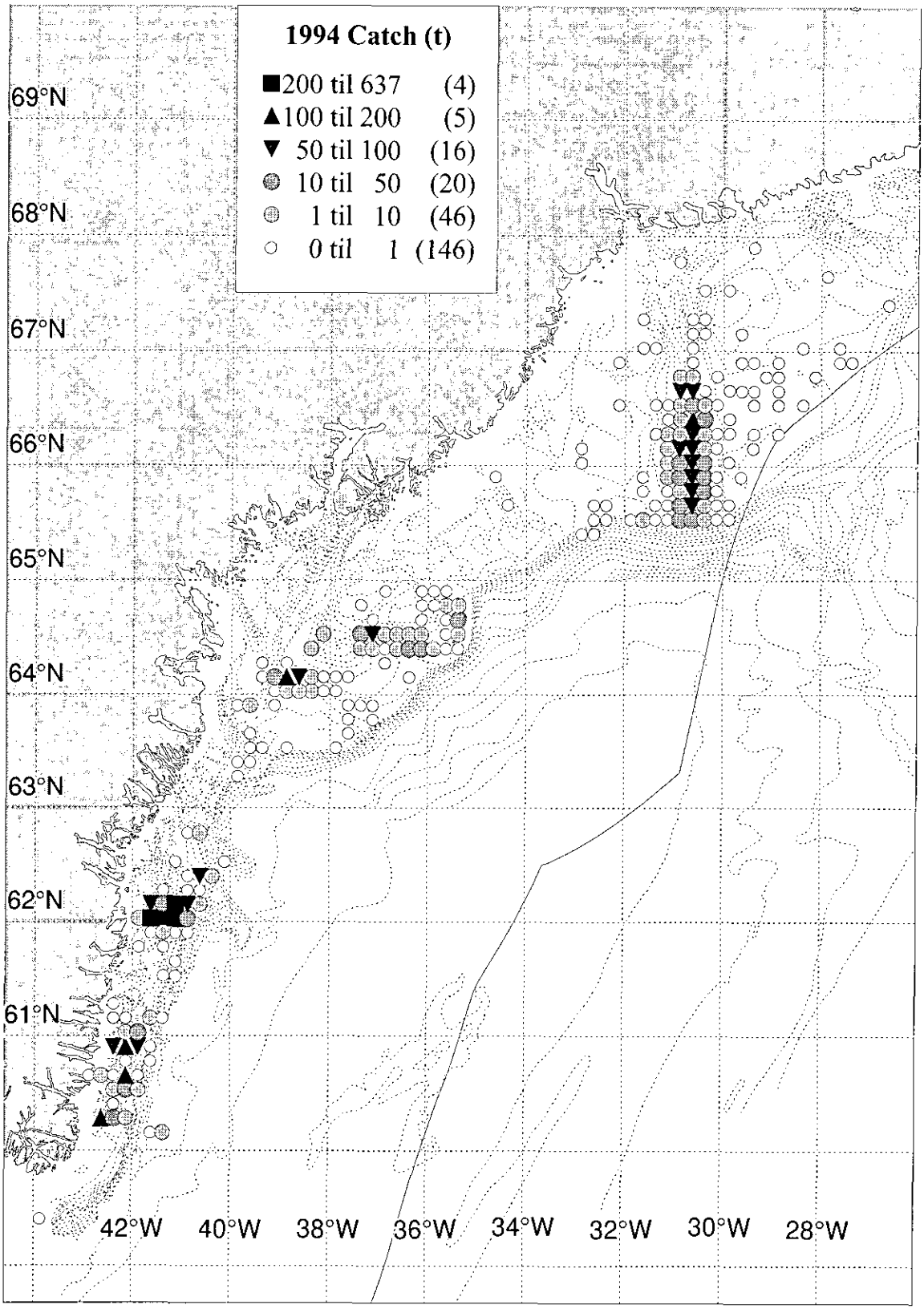


Figure 1D. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1994.

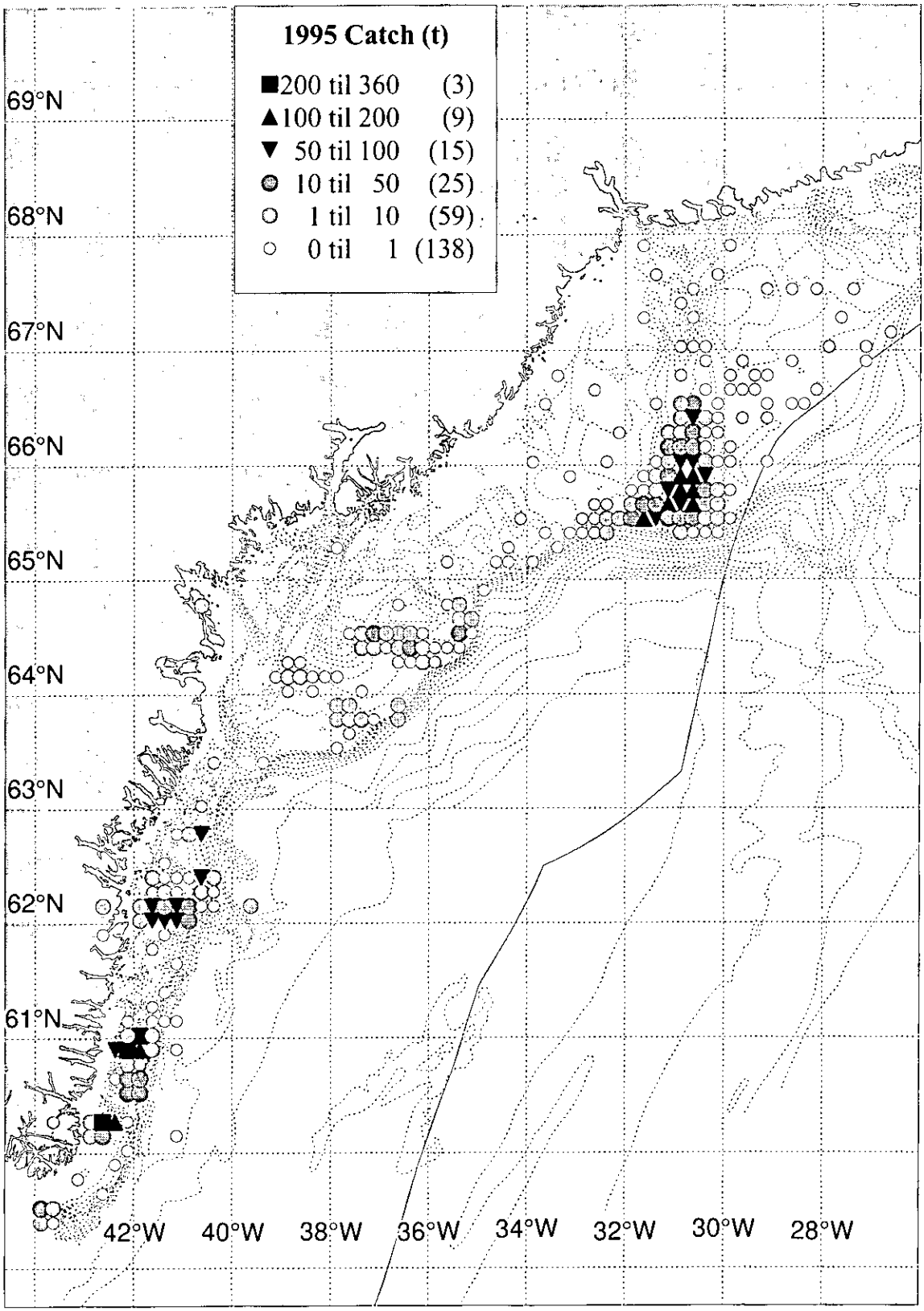


Figure 1E. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1995.

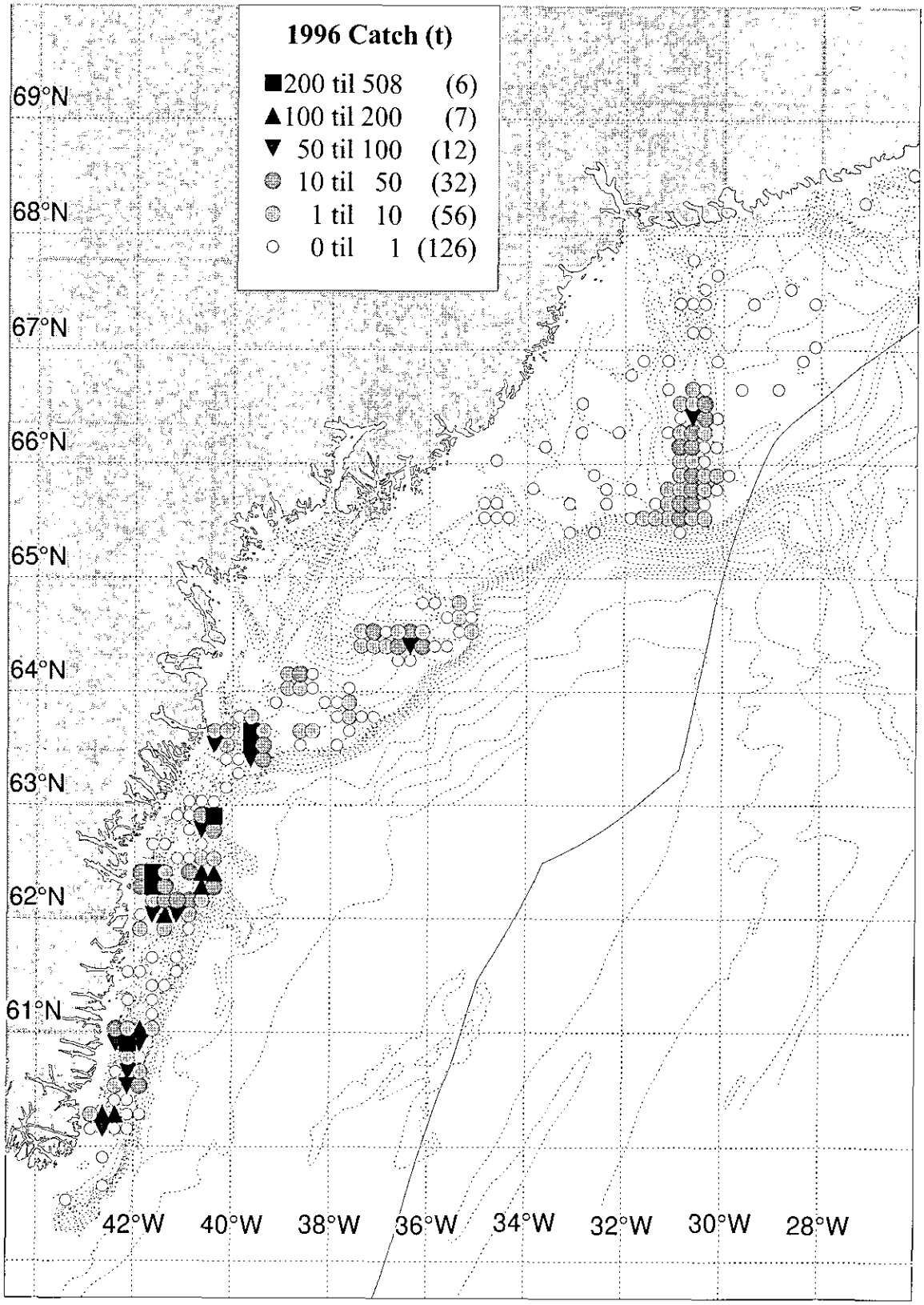


Figure 1F. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1996.

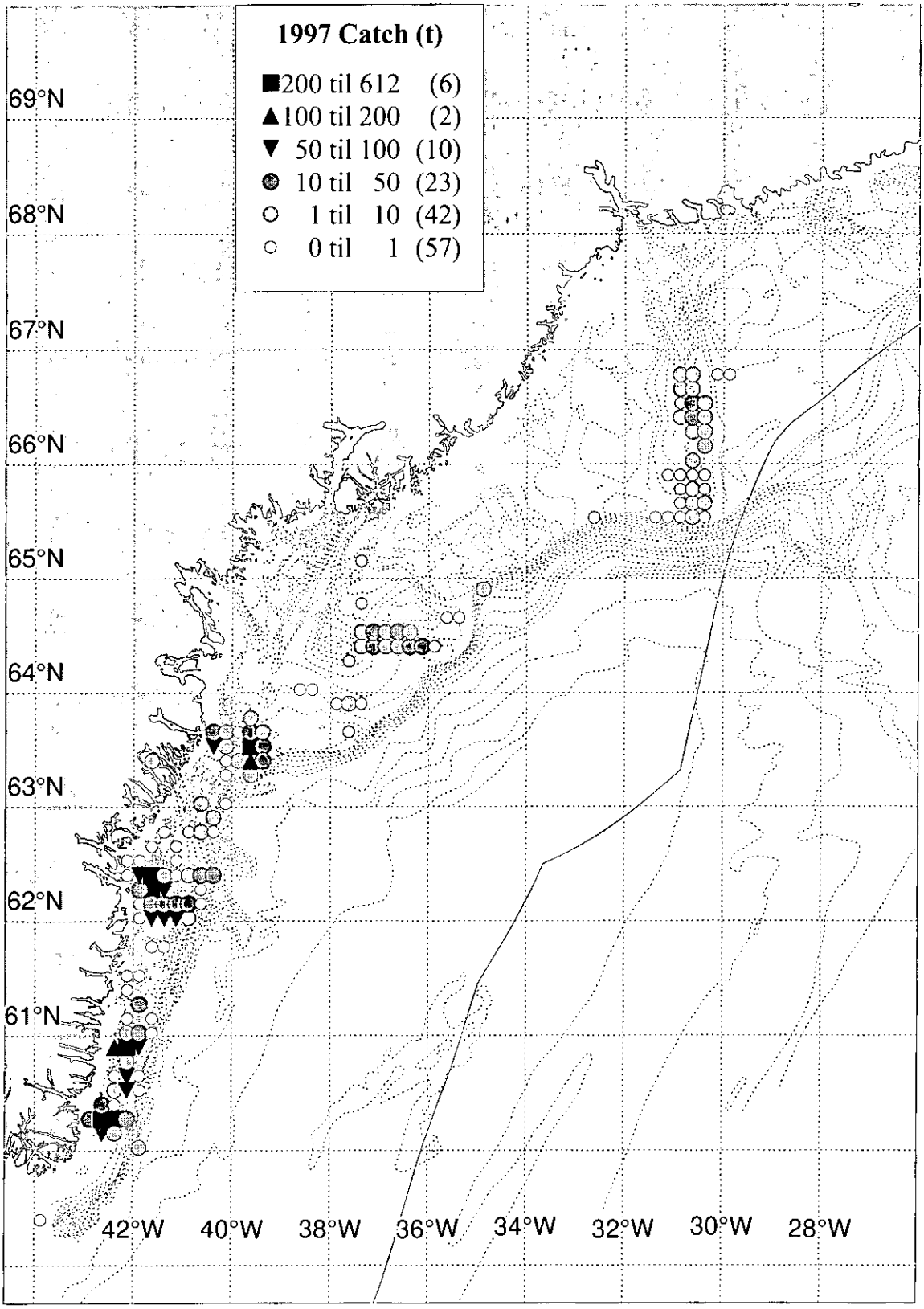


Figure 1G. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1997.

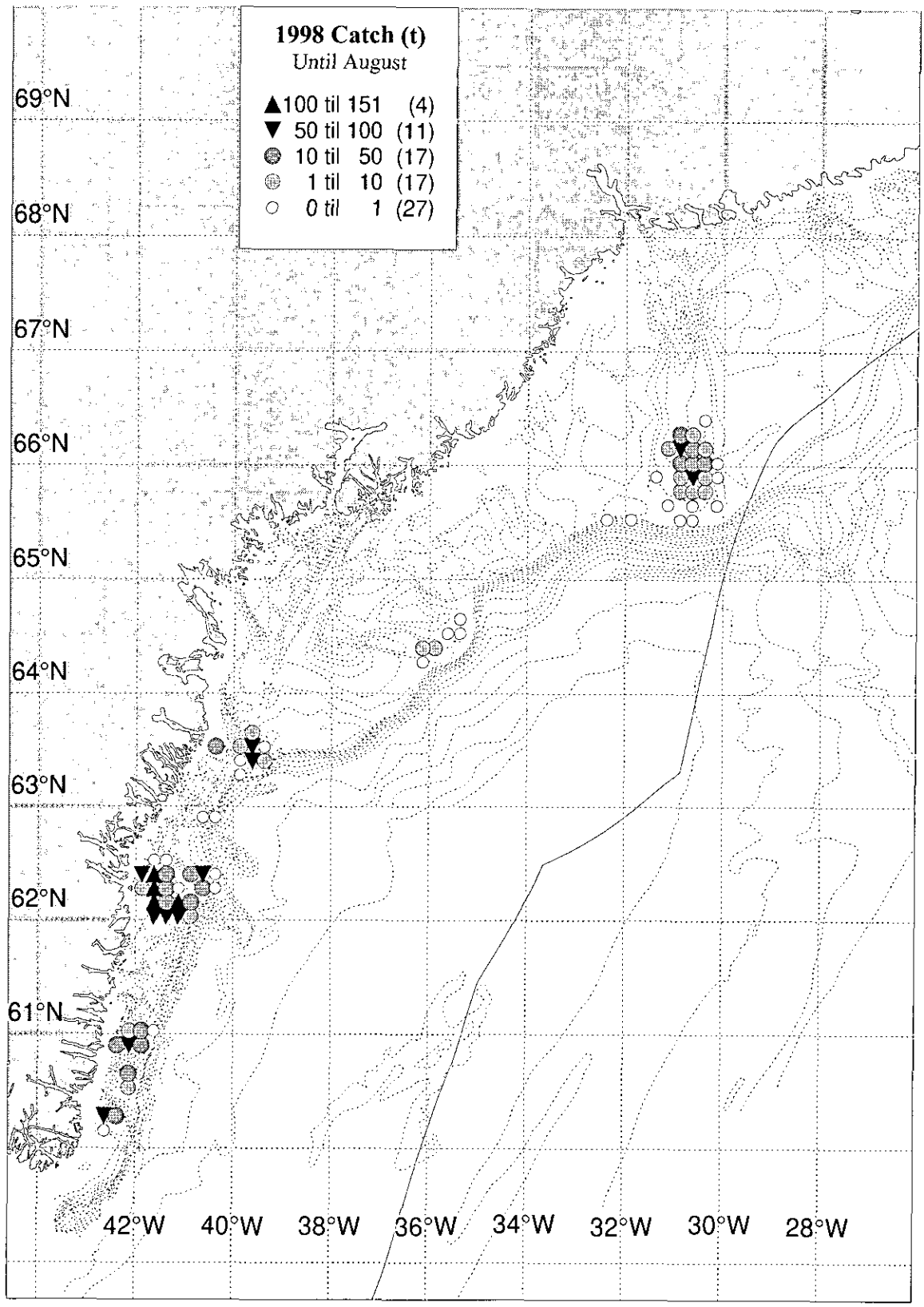


Figure 1H. Spatial distribution of the Greenlandic shrimp catches in Denmark Strait 1998.

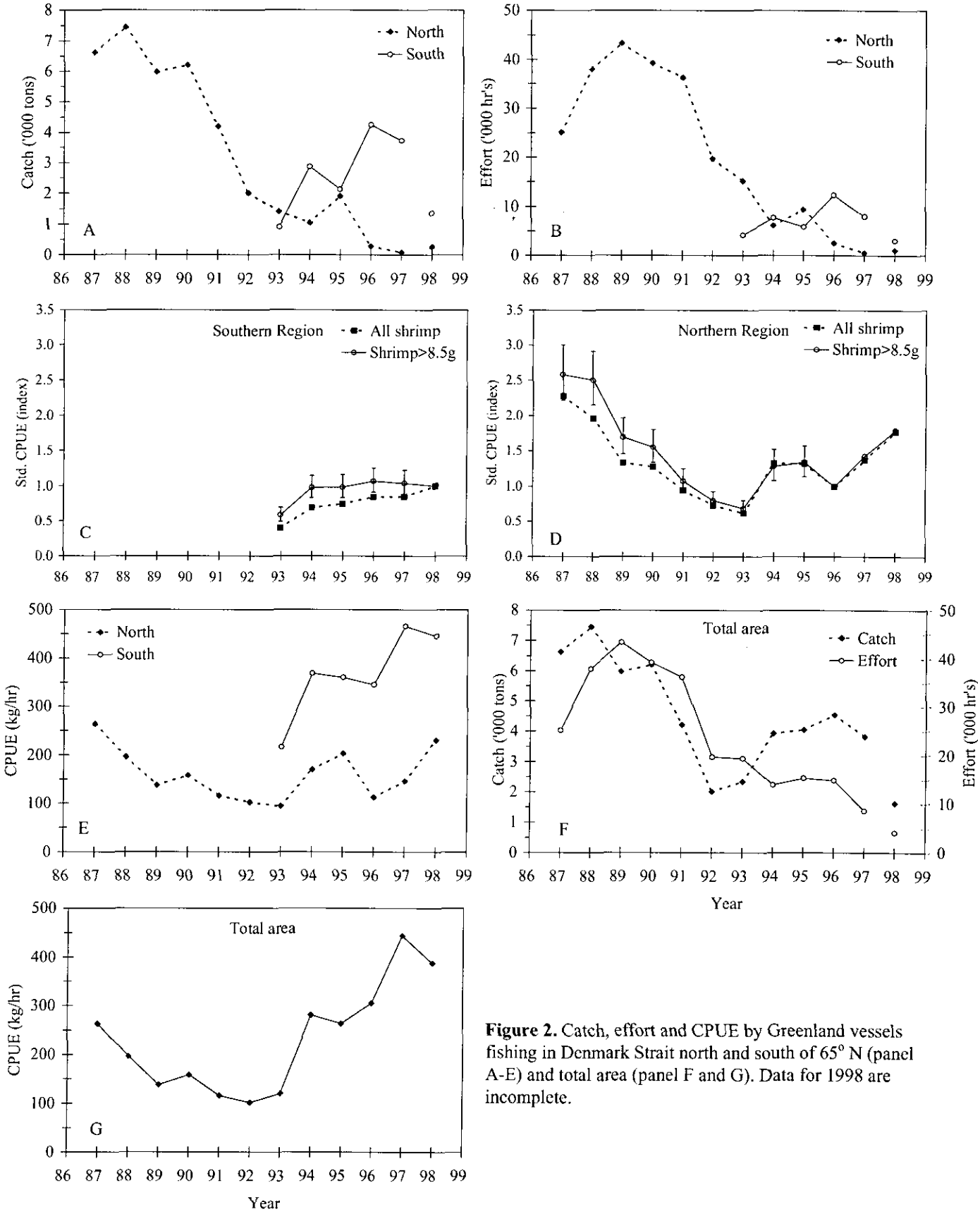


Figure 2. Catch, effort and CPUE by Greenland vessels fishing in Denmark Strait north and south of 65° N (panel A-E) and total area (panel F and G). Data for 1998 are incomplete.

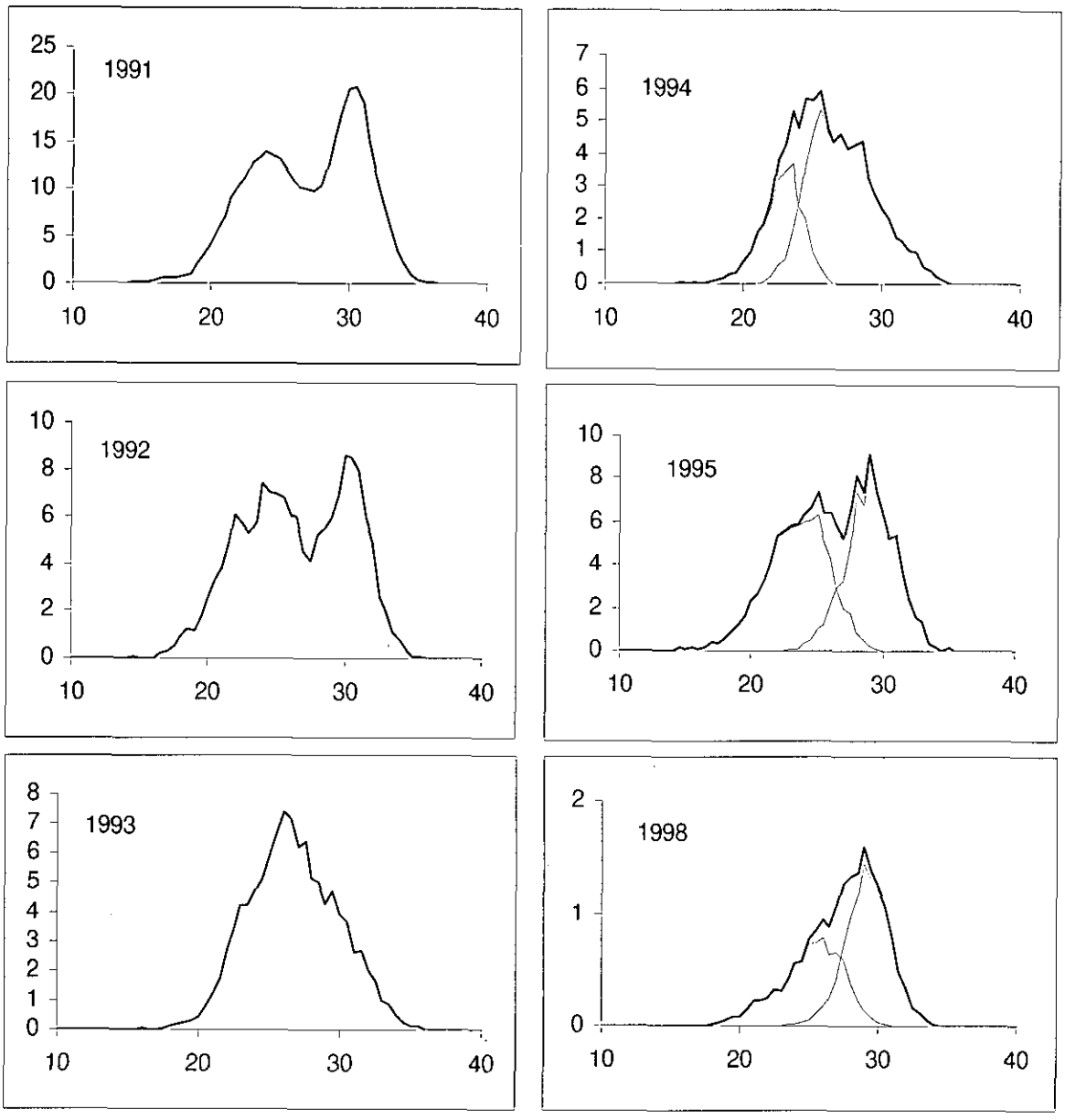


Figure 3a. Length frequency distribution of shrimp catches North of 65°N in Denmark Strait by Greenlandic vessels. Male and female components are indicated under the total distributions where data are available.

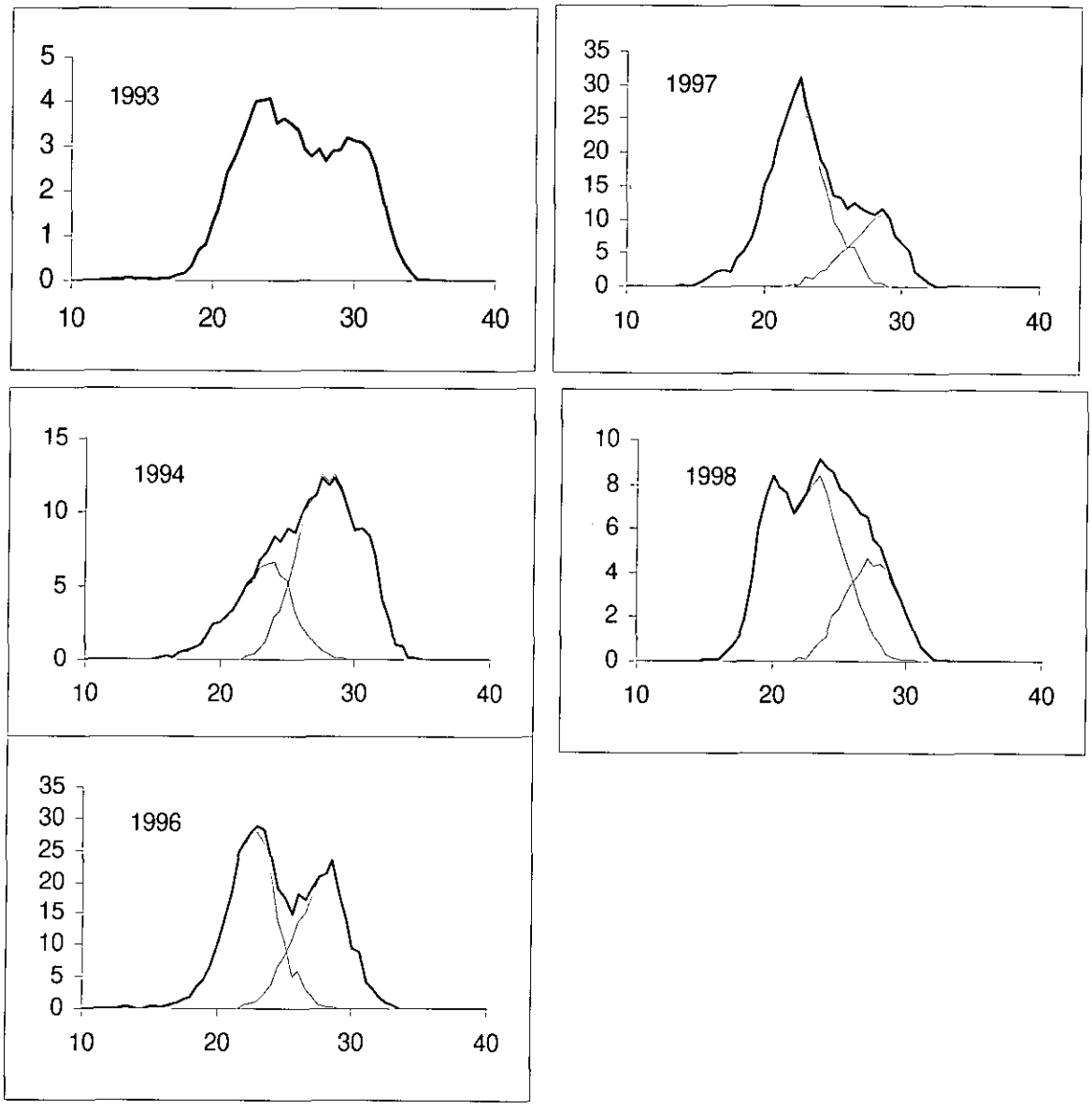
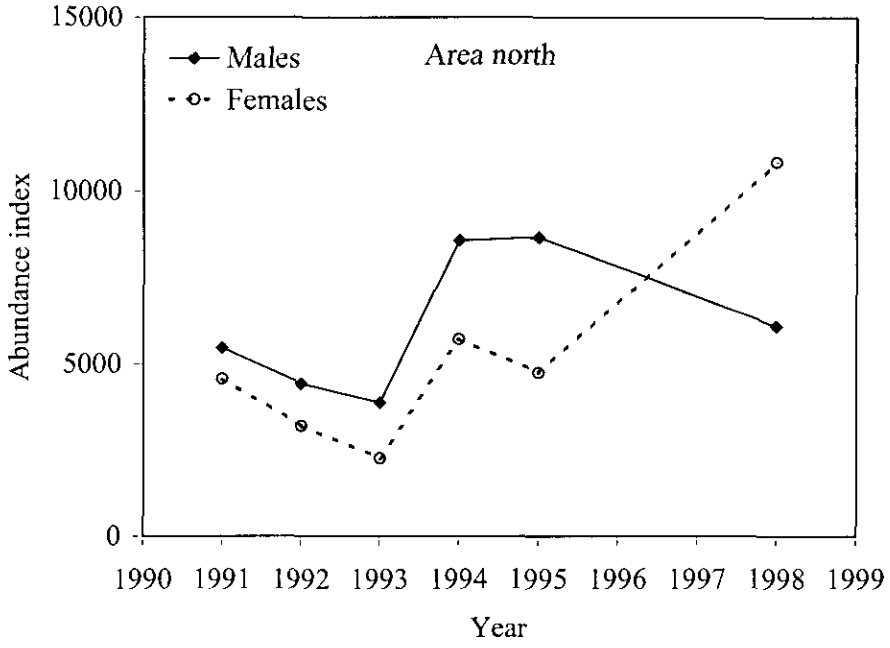


Figure 3b. Length frequency distribution of shrimp catches South of 65°N in Denmark Strait by Greenlandic vessels. Male and female components are indicated under the total distributions where data are available.



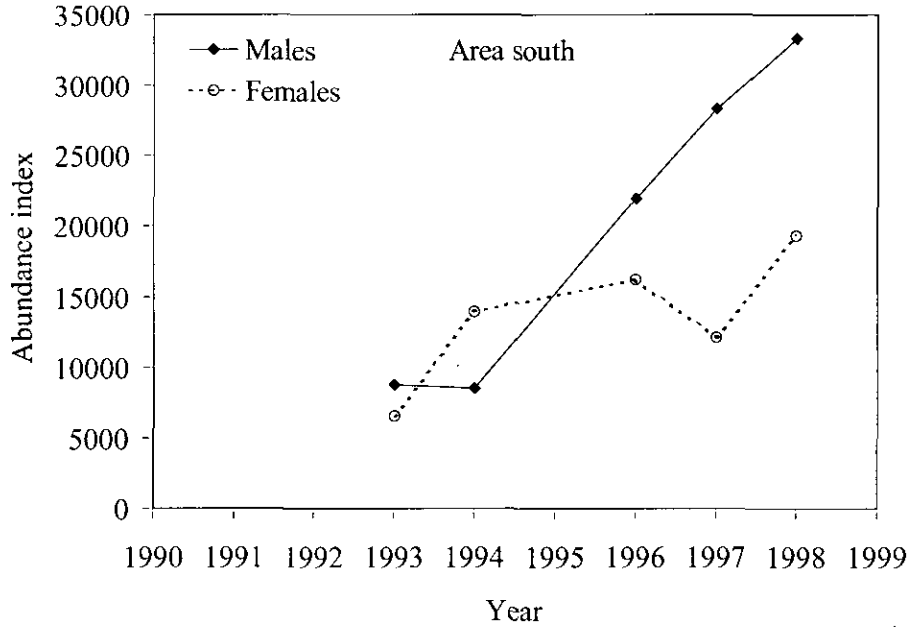


Figure 4. Catch rate of males and female shrimp in numbers pr. standardised hour (from Table 6). No data were available for the northern area in 1996-1997 and the southern area in 1995.