Northwest Atlantic　　　Fisheries Organization

SCIENTIFIC COUNCIL MEETING - JUNE 1992

Assessment of Shrimp in Denmark Strait

by

L. Savard[1], D. Parsons[2], U. Skuladottir[3], D. Carlsson[4], P. Kanneworff[4],
and H. Siegstad[5]

[1]Institut Maurice-Lamontagne, DFO, C.P. 1000, Mont-Joli, Quebec
[2]Northwest Atlantic Fisheries Centre, P. O. Box 5667, St. John's, Newfoundland
[3]Marine Research Institute, Skulagata 4, P. O. Box 1390, 121-Reykjavik, Iceland
[4]Greenland Fisheries Research Institute, Tagensvej 135, DK-2200 Copenhagen
[5]Greenland Fisheries Research Institute, Box 570, 3900 Nuuk, Greenland

1.　INTRODUCTION

The fishery in Denmark Strait began in 1978 with a catch of about 360 tons and subsequently increased to around 12,500 tons in 1988. In 1989 and 1990 the nominal catch of the Danish, Faroese, French, Greenlandic, Icelandic and Norwegian vessels decreased to less than 11,000 tons. In 1991, the total nominal catch of the aforementioned nations was about 8,200 tons. Reported catches and TACs throughout the history of the fishery are given in Table 1.

The shrimp fishery in the Denmark Strait occurs primarily in the area of Strede and Dohrn Banks as well as on the slopes of Storfjord Deep (Fig. 1). The available fishing ground at a given time depends heavily on the ice conditions. The main fishing area extends from approximately 65°20'N to 67°30'N and between 27°W and 33°W. During the last 6 years about 60 vessels participated in the fishery on the western side of the midline, and about 30 vessels on the eastern side of the midline.

2.　INPUT DATA

2.1. COMMERCIAL FISHERY DATA

2.1.1　Trends in catch and effort

Catch and effort data were available from logbooks from Greenland, Norway, Iceland and France since 1980 (Skuladottir 1991 and 1992 a). Some Greenlandic data from the early months of 1992 were also available. Catches and corresponding effort were compiled by month and by fleet. CPUEs were calculated by month and the mean weighted CPUE of two periods of the year (January to June and July to December) was then applied to the total catch of the period to estimate the total effort.

Total catches increased rapidly from 1978 to 1980, decreased in 1981 and remained stable to 1983. Catches increased steadily from 1983 to 1988 and then decreased to 1991 (Fig. 2). For the most recent years, more than 80% of the shrimp in Denmark Strait was caught by Greenland, Norway and Iceland. Total effort values show the same pattern as catch. Between 1980 and 1989, effort increased from about 35,000 hours to more than 100,000 hours, declining thereafter to about 92,000 and 95,000 hours in 1990 and 1991, respectively. The fishery from July-December became more important at the end of the eighties, accounting for approximately 50% of the total annual effort. In 1991 the spring fishery was again the most important.

2.1.2　Standardization of the catch rates

All available catch and effort data from 1980 to 1991 were analysed using SAS multiple regression procedures to account for the seasonality (months: January to December) of the fishery and performance of the different fleets, namely Greenland, Norway, Iceland and France.

The analysis of variance explains 63% of the total variability with the three variables highly significant (Table 2). The plot of the residuals distributed with no obvious outliers (Fig. 3). No interactions between the variables were tested. T-values indicate that the 1989 and 1990 catch rates were not significantly different ($P > 0.05$) from the 1991 catch rate (Table 2). The catch rates from January to May were not significantly different from the December rate.

2.1.3　Trends in catch rates

Abundance indices were calculated from both the unstandardized and standardized series using 1991 as the reference point:

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Unst.	2.67	2.69	2.33	1.93	2.32	1.74	2.20	1.86	1.41	1.08	1.22	1.00
Stand	2.76	2.08	1.98	2.30	1.97	1.92	1.94	1.88	1.24	1.00	1.14	1.00

Both indices show an overall declining trend from 1980 to 1991 (Fig. 4). Within the general trend, however, a period of fluctuating (unstandardized) or stable (standardized) catch rates can be seen from 1981 to 1986-87, followed by an obvious decline from 1986-87 to 1989. Catch rates were similar in 1989, 1990 and 1991. The 1989-91 level was about 50% of the level seen during the period of relative stability from the early to mid 1980's. The 1978 and 1979 catch rates correspond to very low effort and, therefore, are not comparable to the later years.

2.2 COMMERCIAL BIOLOGICAL DATA

2.2.1 Norwegian fishery data

The Norwegian observer samples of shrimp from 1981 to 1991, usually obtained in the period February-March, are shown in Figure 5 and Table 3. In all years there is a prominent peak of females around 30 mm carapace length (CL). In 1981, 1984 and particularly 1990 and 1991 (Smedstad and Torheim 1992, Skuladottir et al 1991), there were considerable numbers of smaller animals (males) present in the samples. The occurence of males (shrimp < 27 mm) was estimated at 20, 29, 34, and 38 %, respectively, compared to less than 10% in the remaining years.

2.2.2 Icelandic fishery data

The Icelandic observer samples (Fig. 6) taken in the fall of 1987 and 88 agree well with the Norwegian samples from the same years in that the catches were comprised mainly of female shrimp with a distinct mode at 30 mm CL (Skuladottir et al 1991). The 1990 fall samples show the increased importance of the male component (about 50% compared to 32 and 26% in 1987 and 1988) which is even more pronounced than in the Norwegian data. The 1991 and 1992 samples taken in spring (Skuladottir 1992) show that male shrimp dominated at this time in both years.

The occurrence of a component of female shrimp with a mode at 25 mm in the 1990 samples suggested that sex change occurred earlier than normal. This could indicate a response to fishing pressure, as indicated by declining catch rates of the past years, or there could have been an immigration of shrimp from Icelandic waters where males change sex at a smaller size. The 1991 and 1992 samples show the occurrence of some female shrimp at these smaller sizes but there was no noticeable component as seen in the 1990 data.

2.2.3. Greenlandic fishery data

The Greenlandic observer data of 1990 and 1991 (Carlsson and Kanneworff 1992 b) also compare well with the Norwegian data in that the mode of female shrimp continues to dominate and that the catches in these years comprise a substantial proportion of small (male) shrimp (Fig. 7).

2.2.4 Discards in the shrimp fishery

Norwegian observer data indicate a decrease of the discard rate from 1990 to 1991 (Smedstad and Torheim, 1992). The discard rate estimated from the Norwegian observer data series is as followed:

%	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Mean	14.9	1.7	0.8	3.4	2.3	0.9	3.0	2.2	2.0	3.0	0.8
Min.	11.5	1.0	0.0	0.7	0.1	0.0	1.2	1.0	0.0	0.0	0.0
Max.	15.7	7.0	2.1	5.9	7.8	1.6	7.2	2.8	5.3	7.6	5.1

However, these values correspond to only one vessel fishing in a limited area for a short period of time and may not be representative of the activities of all fleets in the whole season.

Size distributions of the shrimp catch of factory trawlers were estimated by sampling in 1990 and 1991. Shrimp discards were estimated by comparing size distributions of the catches with those of all size categories kept. The factory trawler discard of shrimp in Denmark Strait was estimated at a minimum of 1034 tons in 1990 and 840 in 1991 (Carlsson and Kanneworff, 1992 a).

Discard procedures may have changed over the years due to market requirements for larger shrimp and the development of effective grading machines. The high number of vessels in the fishery and vessel quota limitations may have resulted in higher, not reported, amounts of discarded shrimp.

3. SUMMARY OF ALL INDICES

Trends in catches
Increase from 1978 to 1980.
Decrease in 1981 and stabilization in 82 and 83 at around 4,700 tons.
Steady increase from 1983 to 1988 to 12,500 tons.
Decrease from 1988 to 1991.

Trends in effort
General increase from 1979 to 1989.
Decrease from 1989 to 1990.
Effort at the same level in 1990 and 1991.

Temporal shift in the fishery
Spring fishery from 1981 to 1986.
From 1987 to 1990, spring and fall effort approximately the same.
In 1991, return to a spring fishery.

Trends in catch rates
Overall declining trend from 1980 to 1989-91.
A period of stability between 1981 and 1986-87.
A decrease from 1986-87 to 1989.
Stability from 1989 to 1991.

Demographic structure of catches
Catches from 1981 to 1991 dominated by females with modal length about 30 mm.
Proportions of males (< 27 mm) at higher levels in 1981, 1984 and especially in
1990 and 1991.
The indications of earlier sex change in 1990 were not so evident in 1991 and
1992.

Discarding
The data show that animals between 20 and 28 mm (mostly males) were discarded.
The estimated rate of discarding increased by 50 % from 1990 to 1991 (January to
June).
Levels of discarding were estimated at approximately 1,000 tons in 1990 and 800
tons in 1991 for the observed vessels.

4.   SUMMARY OF ADVICE FROM PREVIOUS YEARS

The interpretation of the effects of fishing on the stock in the Denmark Strait
has changed since the first assessment was conducted in 1980.   In 1981 (NAFO,
1981), it was thought that the decreases observed in the spring catch rates were
due to heavy exploitation.   Also, it was considered that the stock was at the
northern limit of the species distribution range, and as such, could be more
sensitive to exploitation. Therefore, a cautious approach for the exploitation
was recommended, and the TAC was set at 4,200 tons (the estimated MSY). By 1985
(NAFO, 1985), it was interpreted that the stock was stable and the TAC of 5,000
tons (average catch 81-84) was advised.

No TAC advice was provided for 1986, 87 or 88 because the catch rates could not
be interpreted as an index of stock abundance.   In 1988 (NAFO, 1988), it was
observed that increased catches over the previous several years had had no
apparent effect on the resource and catch levels at around 10,000 tons were
recommended as an exploratory level for several years.

Catch rates declined in 1987 and 1988, however catch composition and biomass
estimates from 1985 to 1989 suggested that the stock was stable and in 1990
(NAFO, 1990), it was recommended that the TAC remain at 10,000 tons. The 1989
survey showed that the stock was dispersed and, the sexes well mixed.   In 1991
(NAFO, 1991), the catch rate series was standardized to account for changes in
seasonality and fleet composition and it was interpreted that the stock in 1989-
90 was substantially lower than in the period of stabilized catch rates. Also
more males appeared in the catches and there were indications of earlier sex
change. These concerns resulted in an arbitrary reduction of the TAC from 10,000
to 8,000 tons.

5.   STATUS OF THE RESOURCE

As interpreted in 1991, the abundance of the resource on the fishing grounds is
thought to be at a lower level than it was during the period of relative
stability. This could be due to a reduction in stock abundance, a change in the
distribution of the resource or some combination of the two. The decrease of CPUE
associated with an increasing proportion of male shrimp in the catches could
indicate a decrease of the abundance of the females. The apparent decrease in the
size at sex reversal in 1990 was interpreted as a possible response to a decrease
in population abundance. However, this observation was anomalous and therefore,
at this time, cannot be considered indicative of a trend towards earlier sex
change within the population.

The surveys showed a change in the distribution of the stock in 1989 in that it
appeared more widespread and that the sexes were well mixed throughout the survey
area. The 1990 and 1991 fishery data indicate that this is still the case.
Moreover, there is no decrease in the mean size of the female shrimp which might
be expected after heavy and prolonged exploitation.

6.   PROGNOSIS

The current low level of the shrimp resource in Denmark Strait could be due to
a reduction in stock abundance (through fishing) or a change in the distribution
of the resource. At present, we are not able to distinguish or determine which
of the scenarios or, more likely, combination of scenarios is correct. However,
faced with this uncertainty, catches should be limited over the next several
years to levels below those attained from 1986 to 1990 (10,000 to 12,500 tons)
in an attempt to increase the catch rates and prevent a possible overexploitation
of the apparently low spawning biomass.

REFERENCES

Carlsson, D. M., and P. Kanneworff. MS 1992a. Estimate of shrimp discard from
    shrimp factory trawlers in Davis Strait and Denmark Strait in 1991. NAFO
    SCR Doc. 92/56. Serial No. N2109.

        MS1992b. The commercial shrimp fishery in Denmark Strait in 1991 and
    1992. NAFO SCR Doc. 92/64. Serial No. N2118.

NAFO. 1981. Reports of Scientific Council. NAFO Sci. Coun. Rep., 1981, p. 118..

    1985. Reports of Scientific Council. NAFO Sci. Coun. Rep., 1985, p. 9.

    1988. Reports of Scientific Council. NAFO Sci. Coun. Rep., 1988, p. 81.

    1990. Reports of Scientific Council. NAFO Sci. Coun. Rep., 1990, p. 102.

    1991. Reports of Scientific Council. NAFO Sci. Coun. Rep., 1991, p. 99.

Skuladottir, U. MS 1991. The Catch Statistics of the Shrimp Fishery (Pandalus
    borealis)in the Denmark Strait in the Years 1980-1990. NAFO SCR Doc.
    91/58. Serial No. N1942.

        MS 1992a. The catch statistics of the shrimp fishery (Pandalus
    borealis) in the Denmark Strait in 1991 and early-1992. NAFO SCR Doc.
    92/49. Serial No. N2101.

        MS 1992b. The Icelandic shrimp fishery (Pandalus borealis) in the
    Denmark Strait in 1991 and early-1992. NAFO SCR Doc. 92/62. Serial No.
    N2116.

Skuladottir, U., L. Savard, K. Lehmann, D. G. Parsons, and D. M. Carlsson.
    Preliminary Assessment of Shrimp in Denmark Strait. NAOF SCR Doc. 91/96.
    Serial No. N1985.

Smedstad, O. M., and S. Torheim. Norwegian investigations on shrimp (Pandalus
    borealis) in East Greenland Waters in 1991. NAFO SCR Doc. 92/17. Serial
    No. N2062.

Country	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991 ***	1992
Denmark	-	-	702	581	740	204	443	353	500	555	444	366	390	358	
Faroe Islands	-	-	4233	713	737	443	668	674	727	595	679	595	843	1007	
France	-	-	50	353	414	291	500	642	780	1030	494	381	51	118	
Greenland	-	-	200	1004	1115	1467	2250	2596	5781	6627	7456	5981	6210	4202	
Iceland	363	485	759	125	0	43	742	1794	1150	1330	1424	1326	281	465	
Norway	-	800	2461	2016	1896	1727	2128	2051	2026	2041	2052	2098	2500	2504	
Total catch	363	1285	8405	4792	4902	4175	6731	8110	10964	12178	12549	10747	10275	8654	
Total catch eastern side	363	485	759	125	0	43	742	1794	1150	1330	1424	1326	281	465	
Total catch western side	0	800	7646	4667	4902	4132	5989	6316	9814	10848	11125	9421	9994	8189	
Adviced TAC	-	-	-	-	4200	4200	4200	5000	-	-	-	10000*	10000*	10000*	8000
Effective TAC western side	-	-	-	8000	4500	5725	5245	6090	7525**	7725**	8725**	9025**	14100	14500	13000

* Adviced for a few years as a precautionary measure.

** Not including Greenland fishery north of 66° 30' N.

*** Provisional data.

Table 1.   Nominal catches (tons) of shrimp in the Denmark Strait.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	12	1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991
MONTH	12	1 2 3 4 5 6 7 8 9 10 11 12
FLEET	4	1 2 3 4

Number of observations in data set = 275

General Linear Models Procedure

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	75.86112806	3.03444512	17.16	0.0001
Error	249	44.03480584	0.17684661		
Corrected Total	274	119.89593391			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.632725	-19.78130	0.420531	-2.1259032

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	11	29.32616068	2.66601461	15.08	0.0001
MONTH	11	23.29314926	2.11755902	11.97	0.0001
FLEET	3	10.85135155	3.61711718	20.45	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-2.111255290 B	-13.42	0.0001	0.15729061
YEAR	1980	1.014600355 B	8.17	0.0001	0.12423725
	1981	0.731255405 B	5.23	0.0001	0.13974778
	1982	0.684903500 B	4.17	0.0001	0.16422759
	1983	0.831359228 B	5.82	0.0001	0.14282673
	1984	0.677977502 B	5.21	0.0001	0.13014891
	1985	0.651727069 B	5.55	0.0001	0.11742181
	1986	0.660723896 B	6.05	0.0001	0.10912849
	1987	0.630095348 B	5.53	0.0001	0.11389792
	1988	0.218385412 B	2.01	0.0452	0.10851192
	1989	-0.002265640 B	-0.02	0.9833	0.10841224
	1990	0.130852138 B	1.18	0.2384	0.11072353
	1991	0.000000000 B	.	.	.
MONTH	1	0.201389718 B	1.28	0.2024	0.15755337
	2	0.090225942 B	0.60	0.5459	0.14919029
	3	0.075715877 B	0.53	0.5957	0.14251991
	4	0.070146170 B	0.50	0.6154	0.13944654
	5	-0.016145856 B	-0.12	0.9069	0.13796924
	6	-0.566952027 B	-3.90	0.0001	0.14525267
	7	-0.648144219 B	-4.05	0.0001	0.16000758
	8	-0.691736133 B	-4.76	0.0001	0.14519150
	9	-0.496141214 B	-3.46	0.0006	0.14327680
	10	-0.556143337 B	-3.95	0.0001	0.14079175
	11	-0.520568681 B	-3.60	0.0004	0.14478847
	12	0.000000000 B	.	.	.
FLEET	1	0.033524565 B	0.38	0.7074	0.08920958
	2	-0.397494640 B	-4.55	0.0001	0.08745028
	3	-0.388187781 B	-4.03	0.0001	0.09634810
	4	0.000000000 B	.	.	.

Table 2. Results of the multiple regression analysis.

Fleet 1: Greenland   Fleet 2: Norway
Fleet 3: Iceland   Fleet 4: France

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991		Sum/11
14												0	0
15	1												0
16									1	0	0		0
17	1								3	0	0		0
18	4						1		2	5	2		1
19	9	2		3		2	1	4	8	9	11		4
20	14			9	1		1	4	10	23	20		7
21	21	1	1	13	3	4	3	4	14	32	27		11
22	37	3		23	4		5	4	13	56	59		19
23	29	5	4	42	12		7	11	18	68	74		25
24	26	4	3	52	12		18	13	18	59	71		25
25	28	6	5	57	18	12	22	21	24	61	63		29
26	28	14	14	88	28	27	38	40	39	53	54		38
27	59	68	68	85	72	59	46	63	66	59	45		63
28	140	198	210	98	171	180	154	126	111	77	77		140
29	192	267	285	139	223	262	250	208	184	105	124		204
30	173	208	212	137	236	256	265	245	236	174	173		211
31	115	120	109	143	126	121	124	132	151	119	104		124
32	71	72	59	65	62	51	47	107	73	66	56		66
33	29	24	23	36	25	20	16	15	26	26	27		24
34	18	7	8	9	5		2	4	3	6	11		7
35	4	1		2	1	2		2		1	1		1
36	1												
Total	1000	1000	1001	1001	999	996	1000	1003	1000	1000	1000	0	1000

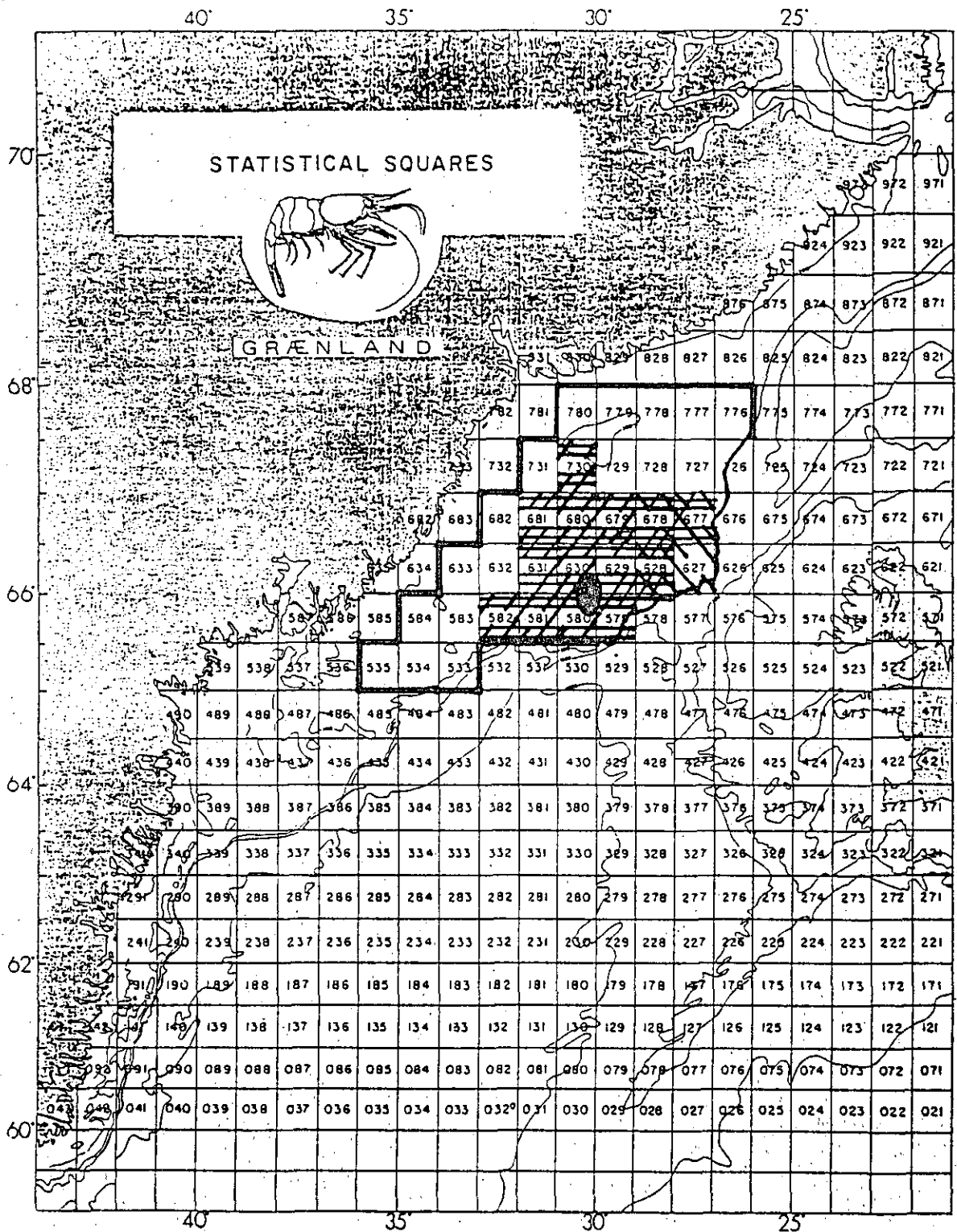Table 3. Norwegian observer samples in the years 1981-91.

Fig. 1. The strata numbers in the Denmark Strait. The fishery area
of 1991 is shaded and the area coverd by the Norwegian
observer is the black spot. A much wider area of likely
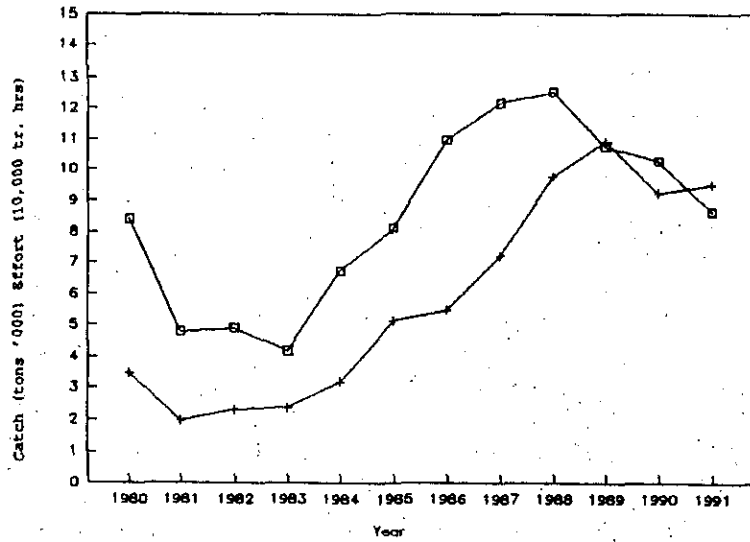distribution is indicated by a solid line.

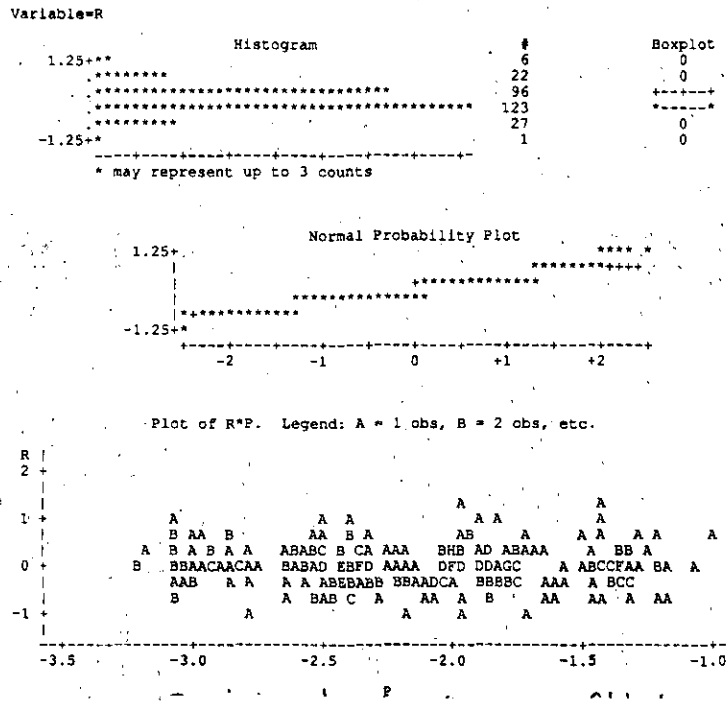Fig. 2. Catch and effort from the logbooks weighted by nominal catches.

```
Variable=R
                             Histogram             #        Boxplot
 1.25+**                                           6           0
     |********                                     22          0
     |***********************************          96        +--+--+
     |******************************************   123       *--+--*
     |*********                                     27          0
-1.25+*                                             1           0
     ----+----+----+----+----+----+----+----+----+-
     * may represent up to 3 counts
```

```
                        Normal Probability Plot
 1.25+                                              **** .*
     |                                      ********+++
     |                          +************
     |               ****************
     |*+************
-1.25+*
     +----+----+----+----+----+----+----+----+----+----+
         -2        -1         0        +1        +2
```

```
 Plot of R*P.   Legend: A = 1 obs, B = 2 obs, etc.

R |
2 +
  |
  |              A              A  A          A           A
1 +              B AA  B          AA  B A        AB     A     A A   A A       A
  |          A  B A B A A    ABABC B CA AAA    BHB AD ABAAA    A  BB A     A
0 +          B  BBAACAACAA  BABAD EBFD AAAA   DFD DDAGC    A ABCCFAA BA  A
  |          AAB    A A   A A ABEBABB BBAADCA  BBBBC  AAA  A BCC
-1 +          B         A    A  BAB C  A    AA  A  B    AA   AA  A AA
  |
  --+---------+---------+---------+---------+---------+---------+-
 -3.5      -3.0      -2.5      -2.0      -1.5      -1.0
```

Fig. 3. Residuals of the multiple regression.

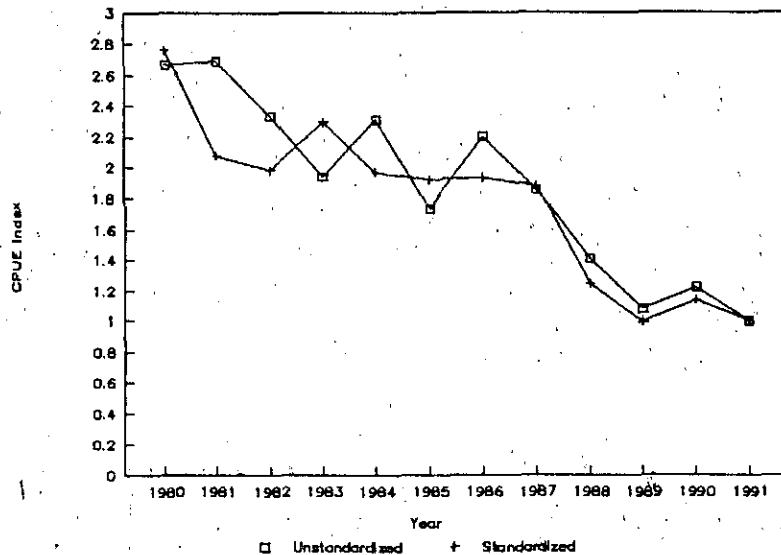□ Unstandardized   + Standardized

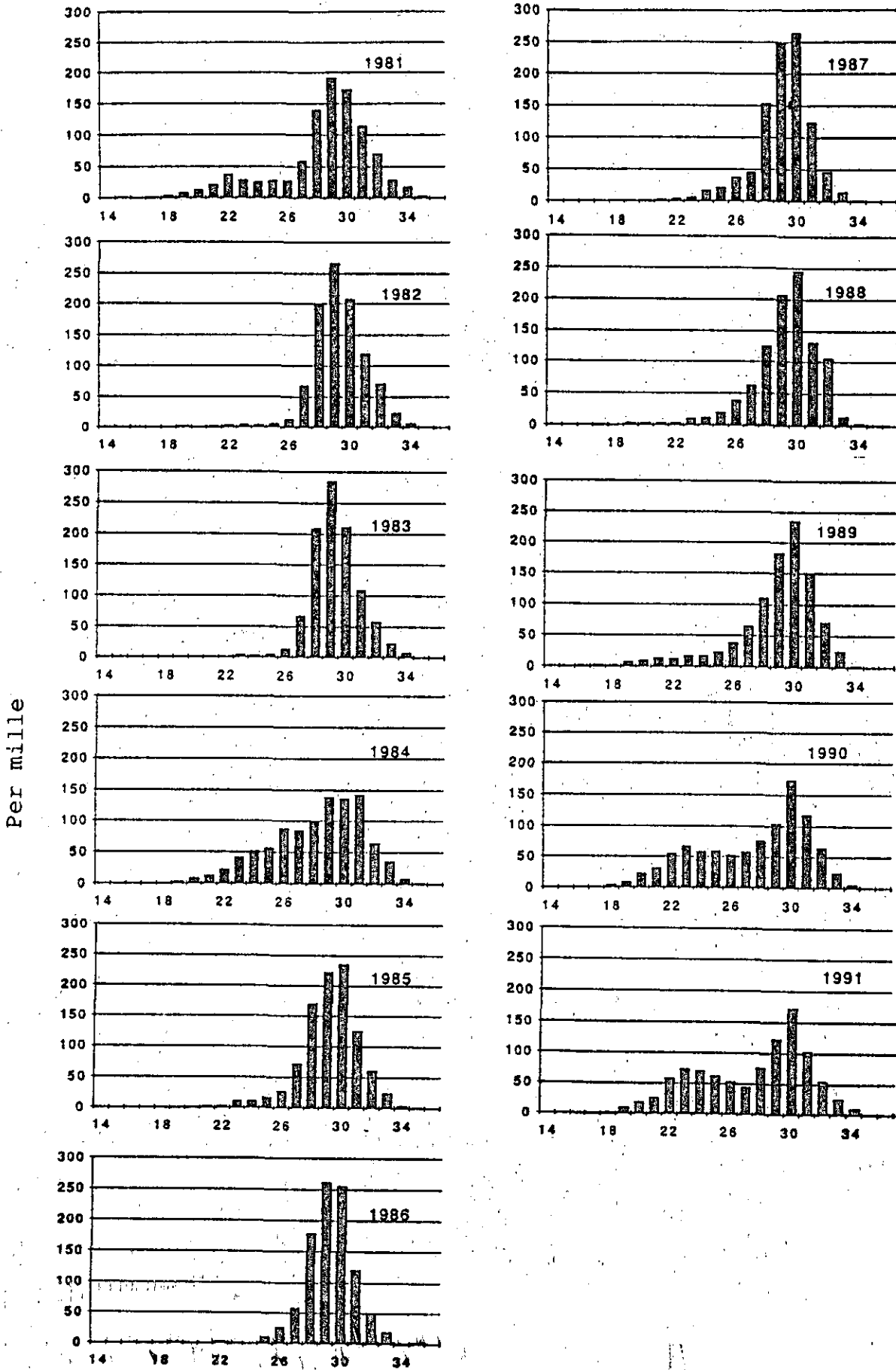Fig. 4. Catch rate indices.

Per mille

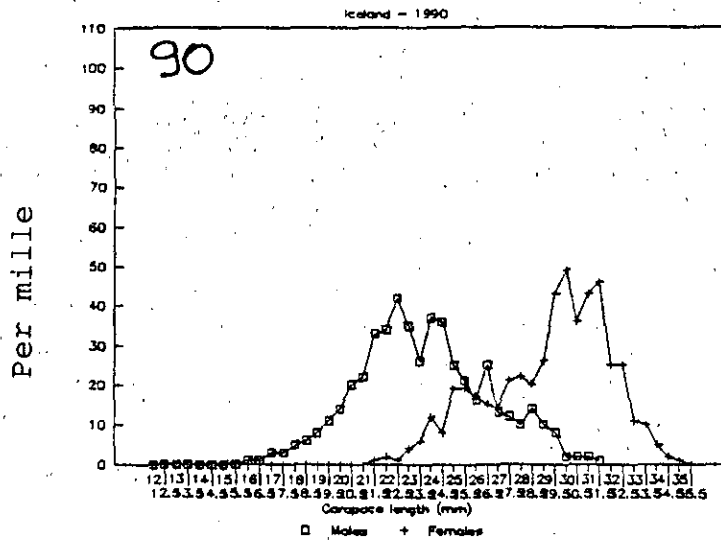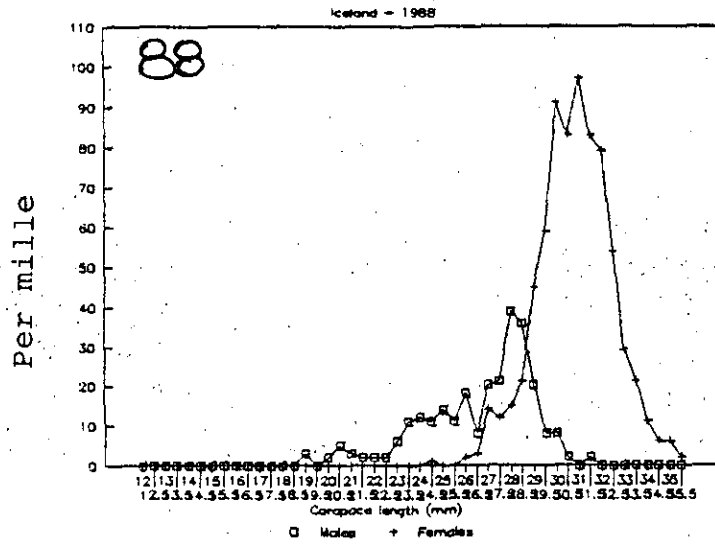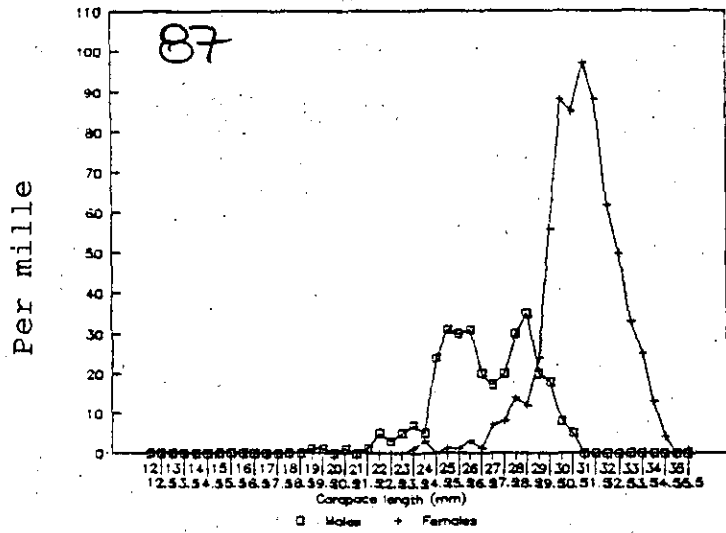Fig. 5.   The length frequency distributions (per mille) of Norwegian observer samples in February-March.

Fig. 6a.   The Icelandic samples (per mille) in the years 1987, 1988 and 1990 in the autumn in the eastern part of the area.   There were less than 1% transitionals + immature females, so these were omitted from the figure.   All females shown were without sternal spines.
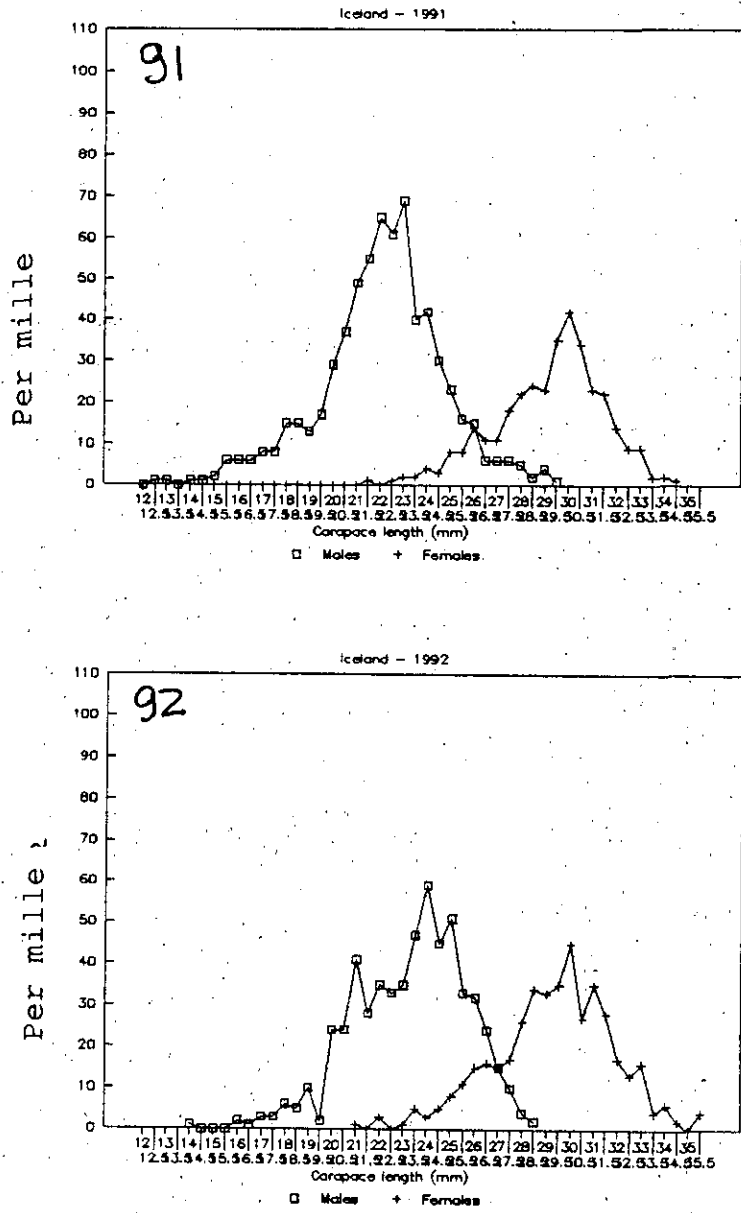
Fig. 6b.   The Icelandic samples (per mille) in the years 1991 and 1992 in spring in the eastern part of the area.
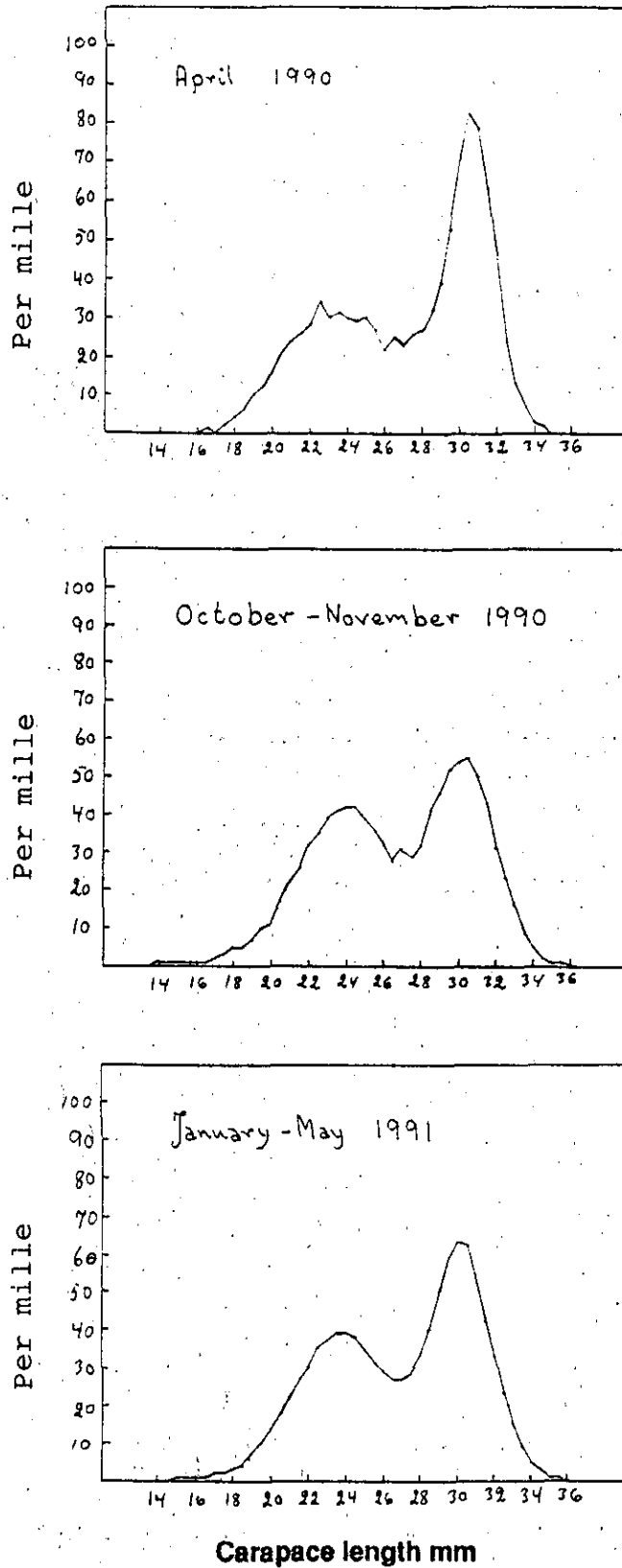
Fig. 7. The Greenlandic observer samples (per mille) in the years
1990 April top, 1990 October to November combined and
finally January to May combined.