NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N1817

NAFO SCR Doc. 90/90

SCIENTIFIC COUNCIL MEETING - JUNE 1990

A Catch-rate Index for the Greenland Shrimp Fishery in NAFO Subarea 1

by

H. Lassen and D. M. Carlsson

Greenland Fisheries Research Institut, Tagensvej 135, 1.sal
DK-2200 Copenhagen N, Denmark

INTRODUCTION

NAFO Scientific Council (Anon., 1988) uses an index of catch rate for the Greenland shrimp fishery in Subarea 1 based upon logbook records from seven trawlers (721-1,000 GRT) from the Greenland Home Rule Trawler Company (GHT). The catch rate index is a simple average of the CPUE as reported over this set of vessels for the July-September period in NAFO Division 1B. The July-September period has been used since the fishery in these months is less influenced by ice coverage of the fishing grounds and by catch restrictions due to quota regulations. Division 1B has throughout the history of the offshore shrimp fishery contained the most important fishing grounds. However, the index does not account for changes between vessel coverage or for changes in the relative importance of the fishing grounds between years. Neither is the shift in availability inside years from year to year accounted for. Furthermore, the catch on which the index is based, is in the most recent years only a small proportion of the total catch.

Therefore, it was considered important that new CPUE indices be investigated (Anon. 1988). This present study is aimed to verify the usefulness of a multiplicative model to derive a new series of standardized catch rates. The analysis presented in this paper is based upon the same set of vessels as those included in the simple index used at present. The time period has been extended to cover the entire year and the data have been disaggregated into four areas. Multivariate ANOVA were used to analyse the relationships between CPUE and various factors and to build a multiplicative model in which interaction terms are also considered.

The interpretation of trends in any cpue index in terms of abundance is made difficult by the development in shrimp trawl technology which has taken place throughout the eighties. The introduction of new technology was gradual and the improvement in efficiency of the trawlers was not synchronized in time and the relative efficiency between trawlers may therefore may vary with time.

MATERIALS AND METHODS

INPUT DATA

Greenland catch and effort statistics are collected through logbooks on a haul-by-haul basis since 1976. However, the logbook system did not provide total coverage for the entire period and also marked fleet changes are seen over this period. The logbooks from seven trawlers from the Royal Greenland Trawler Division (RGT), formerly Greenland Home Rule Trawler Company (GHT) are available for the entire period and these data form the most consistent CPUE dataseries available. Six of the vessels are sisterships (721-857 GRT) and all built around 1970, and one is a trawler of about 1,000 GRT that was built in 1982. However some of the vessels have been in and out of the shrimp fishery over time, Table 1.

The data show a major haul-to-haul variation. Therefore catch and effort were summed in cells defined by vessel, area, month and year. This sum is taken over all hauls within the cell and the marked diel variation in catch rates is therefore not considered in this analysis, but will add to the variability in the data. Catch and effort data were broken down into areas based on a general knowledge on the distribution of the offshore shrimp fishery in NAFO Subarea 1 and particularly on the distribution of total catches in 1988 (Carlsson and Kanneworff, 1989). These areas are considered to reflect abundance differences. The old index is confined to Division 1B and this restriction was largely maintained for the new index to allow for comparisons. Therefore only data referring to the stratification areas 3, 4, 5 and 6 as shown in Fig. 1 were included in the database (Table 2). Catch and effort data were also broken by month and year (Table 3).

Because several cells have only a single or few hauls, they were discarded from the analysis as the large haul-to-haul variation will dominate the CPUE estimated for these cells. Rather arbitrarily, all cells with less than or equal to 10 hours of efforts were deleted which brings the number of cells included in the analysis down to 1157. If instead a limit of e.g. 11 hours had been used an extra 17 cells would have been deleted. Preliminary analysis suggested that one cell was a marked outlier, and this observation was therefore deleted from the dataset used in the analyses. Thus 1156 cells out of a possible total of 4368 are included in the analysis.

The CPUE of a cell was calculated simply by dividing total catch by total effort for a that cell.

ANALYSIS

The standard multiplicative model (Gavaris 1980):

log(CPUE) = a0 + a1(year) + a2(month) + a3(area) + a4(vessel) + e
(e being the stochastic term).

was investigated. This model has 32 parameters to estimate (12 years, 11 months, 3 areas and 6 vessels) since each variable is only estimated relatively. Inspection of the estimable functions shows that all parameters can be estimated with the given dataset.

The goodness-of-fit was checked by investigating the variation explained (r-squared) and by the degree to which the residuals are normally distributed. The latter analysis was done graphically by histogram, box- and probit plots.

Interactions between vessels and years, areas and years and months and years were also investigated. These comparisons were done graphically.

A series of standardized catch rates was finally produced from the results of the multiplicative model without interaction terms.

RESULTS

Simple Multiplicative Model

The results are presented in Table 3 for both the ANOVA scheme and the parameter estimates. The model explains 40 % of the total variation. The effects are in order of ability to explain the variation in the data: seasonality (*month*), annual differencies (year) while area and vessel effects although significant at the 5 % level are of less importance.

Histograms, Box- and probit plots of the residuals (Fig. 2) suggests that the residuals are normally distributed and no marked outliers are indicated. The residuals do not show any obvious tendencies with time.

Interactions between Year and month, area and vessel.

Before the multiplicative analysis presented in Table 3 can be used for constructing an index of catch rate, it is appropiate to investigate whether there are deviations in particular years of the seasonality as contrasted to the overall seasonality pattern (year*month interaction), or whether there are deviations from the overall pattern of CPUE by area or by vessels in particular years. With the given database these interactions can only be investigated one by one and hence the results obtained will be confounded by interactions of other types than that under investigation. Further because of misssing cells not all combinations can be investigated within a given interaction. The table below gives the R-square for the three interaction models together with the R-square from Table 3 for reference:

	Without	Vessel*year	Area*year	Month*year
R-square	0.40	0.46	0.46	0.56

Inspection of the parameter estimates for the three runs shows that vessel 32 and 64 are the two vessels most often involved in significant interaction terms, while there does not seem to be any tendencies among the areas. However, given the low improvement in R-square, it was not considered of major importance to trace the vessel problem. To illustrate the area*month interaction, logarithmic means after standardizing ships and years based on the effects found in table 3 were calculated. Fig. 3 shows these logarithmic means for the four areas. It is apparent that area 6 shows an abnormal behaviour compared to the other three areas. The interactions between vessel and year and area and year were considered to have a minor contribution to the explanation of the variability of the data.

Analysis of the year-month interaction might suggest that 1986 could be a cause for concern. However, removing 1986 from the dataset and rerunning the analysis did not change the R-square of the basic run appreciably while the R-square including the year-month interaction also remained largely unchanged. The analysis above suggests that the most important contributor to the variability, which still might be explained within the dataset considered, is changes from one year to the next in the seasonality of the catch rates. The analyses made so far suggests that this feature has little regularity e.g. there does not seem to be years where the pattern is drastically changed as compared to the overall seasonal pattern. Fig. 4 shows the seasonality by year for division 1B. From this fig. the variability in the seasonality of catchrates is apparent. However, even if the analyses showed there are significant interactions between year-month, year-vessel and year-area, these interactions were included to the random noise in the data and the basic multiplicative model was assumed to be a good description of the variability in the data set.

A Catch Rate Index

Accepting for the time being the analysis presented in Table 3 as the basic for a new index, the time series can be constructed by taking the antilog of the annual effects. In Table 3 these are normalized to the level for 1989 (effect = 0 or after taking antilog effect in 1989 is equal to 1). Fig. 5 shows the old (Anon 1990) and new indices together with the total catch vs. time.

Discussion

The new index has a number of advantages over the one used previously. The index presented is based on a larger porportion of the total catch, it includes an explicit account of the seasonality, (from Table 3 there is a systematic decrease in catch-rate from July to September) and it accounts for changes in the relative contribution of data from the various vessels and from the different areas. Furthermore, since the new index uses data from all months, it is posssible with this type of index to follow the development in the catch rate month by month since observed catch rates can be corrected for systematic variations with area, season and vessel. Also the new index is based on a more stringent analysis than was the old one.

The interaction between month and year as demonstrated above suggests that the model does not explain all systematic variability in the data, particularly the seasonality varies between years. If based on data for say the first half of the year, a prediction of the annual level was made, this interaction would appear as an added source of uncertainty to that index.

Whether the new index represents the development in abundance can of course not be addressed since the multiplicative analysis is done within the CPUE data. To discuss that problem, alternative data which reflects the abundance must be available. However, improvement in gear technology, has taken place since around 1980. The introduction of new technology was gradual and the improvement in efficiency of the trawlers was not synchronized in time and the relative efficiency between trawlers may therefore may vary with time.

Comparing the time development in the new and the old indices in fig. 5 indicates that some part of the CPUE increase which is seen in the old index from 1984-1987 is due to changes in season, within July-September, and spatial changes in the distribution of the effort over this time span. However both indices suggest that 1987 was well above 1986 and that the subsequent drop in 1988 has brought the index back to the 1985-86 level.

REFERENCES

Anon., 1988. Scientific Council Report.
Northwest Atlantic Fisheries Organization,
Dartmouth, Canada 149 p.

Anon., 1990. Scientific Council Report.
Northwest Atlantic Fisheries Organization,
Dartmouth, Canada xxx p.

Carlsson D. M. and P. Kanneworff, 1989. The shrimp fishery in
NAFO Subarea 1 in 1988.
NAFO SCR.Doc. 89/53, Ser.No. N1633.

Gavaris S., 1980. Use of a multiplicative model to estimate catch
rate and effort from commercial data.
Can. J. Fish. Aquat. Sci. 37: 2272-2275.

	vessel						
	1	32	47	49	54	61	64
	EFF	EFF	EFF	EFF	EFF	EFF	EFF
year							
76	.	1811	.	.	.	.	.
77	.	4117	1550	1544	1055	770	.
78	.	3479	1617	1051	1362	1494	.
79	.	2171	2561	2799	845	1395	636
80	.	2935	1436	1935	1662	1227	199
81	.	3917	1505	3414	2536	2858	430
82	.	3004	1700	47	1552	2121	.
83	454	3404	2703	2163	718	.	.
84	368	2631	1851	1654	2571	1508	814
85	1057	3312	1329	1449	2684	3123	468
86	1356	3886	3300	2132	1773	1156	1225
87	692	1999	1309	2424	1945	1883	1098
88	2382	3936	.	325	2115	3308	.
89	1444	539	.	.	2197	1341	.

Table 1. Total effort (trawl hours) as reported on logbooks for seven RGT trawlers. Only hauls in areas 3, 4, 5 and 6 (Fig. 1) are considered. The period is 1976 - 1989.

Table 1a. Effort by vessel and year.

	AREA			
	3	4	5	6
	EFF	EFF	EFF	EFF
year				
76	.	104	1438	269
77	33	1357	6623	1023
78	1419	3174	3903	507
79	2583	3232	3975	617
80	4560	2506	1801	527
81	2603	5036	4482	2539
82	4869	1503	960	1092
83	5400	1323	1226	1493
84	3904	1686	2558	3249
85	4423	1551	2200	5248
86	3850	2087	1905	6986
87	1804	2346	1088	6112
88	1877	5235	2452	2502
89	58	2290	2191	982

Table 1b. Effort by area and year.

	month											
	1	2	3	4	5	6	7	8	9	10	11	12
	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF
year												
76	199	28	.	.	.	252	323	309	371	329	.	.
77	177	331	271	399	646	837	812	981	1033	1295	1297	957
78	233	.	.	77	885	1233	1227	1325	871	1279	1166	707
79	100	30	799	832	1044	1104	1234	1518	895	915	933	1003
80	1162	1072	813	1121	1427	134	1094	1055	1038	478	.	.
81	1219	853	484	793	1095	1223	1907	1846	1554	1515	1258	913
82	305	.	.	460	1039	996	1340	1302	934	1268	731	49
83	.	.	.	124	1201	1205	1275	1356	1429	1473	1147	232
84	.	.	.	724	2151	1781	1868	718	391	1857	1469	438
85	64	218	684	790	1418	1138	1456	1404	1613	1809	1763	1065
86	1704	1642	568	1084	1910	1521	1645	1721	1209	711	620	493
87	1055	537	1841	1220	1251	1004	1737	1921	406	.	144	234
88	444	257	556	782	694	1397	1842	1896	1331	1316	1147	404
89	40	.	145	164	691	1317	737	1128	262	364	644	29

Table 1c. Effort by month and year.

	vessel						
	1	32	47	49	54	61	64
year							
76	.	11	.	.	.	.	.
77	.	24	12	11	8	4	.
78	.	26	17	10	15	15	.
79	.	19	29	26	5	15	5
80	.	22	10	22	14	13	3
81	.	28	16	27	21	24	4
82	.	20	16	2	14	19	.
83	3	21	24	21	10	.	.
84	3	29	21	19	27	20	10
85	10	27	15	15	25	28	6
86	12	26	29	18	14	9	9
87	6	15	12	17	12	14	4
88	18	21	.	3	14	25	.
89	15	8	.	.	19	11	.

Table 2. Number of cells (year, month, vessel, area) with observations. The data base is as described in Table 1.

Table 2a. Numbers of cells with data by vessel and year.

	AREA			
	3	4	5	6
year				
76	.	2	5	4
77	3	17	31	9
78	17	26	29	11
79	18	33	35	13
80	28	29	17	10
81	21	34	34	31
82	25	17	15	14
83	25	21	16	17
84	38	20	30	41
85	31	22	26	47
86	22	24	23	48
87	13	22	14	31
88	17	25	20	19
89	2	14	20	17

Table 2b. Number of cells with data by area and year.

	month											
	1	2	3	4	5	6	7	8	9	10	11	12
year												
76	1	1	.	.	.	2	3	1	1	2	.	.
77	2	2	1	3	6	5	4	6	10	7	6	7
78	2	.	.	1	8	13	11	8	9	13	8	10
79	1	1	10	8	8	9	9	10	13	9	9	12
80	6	5	5	10	15	5	10	11	10	7	.	.
81	11	4	6	3	12	12	17	13	13	15	5	9
82	5	.	.	3	6	9	11	11	8	10	6	2
83	.	.	.	4	9	11	11	9	11	9	12	3
84	.	.	.	9	18	20	22	10	6	19	14	11
85	2	2	6	5	11	11	16	14	16	15	17	11
86	10	13	7	6	18	15	13	12	9	6	5	4
87	4	3	6	7	10	13	14	11	8	.	2	2
88	2	1	4	7	3	7	13	13	9	12	7	3
89	1	.	2	4	6	7	7	9	7	4	5	1

Table 2c. Number of cells with data by month and year.

Table 3

SAS 20:42 SUNDAY, JUNE 3, 1990 3

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LNCPUE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	33	103.31245571	3.13068048	23.82	0.0	0.404357	5.8638
ERROR	1158	152.18570582	0.13142116		ROOT MSE		LNCPUE MEAN
CORRECTED TOTAL	1191	255.49816133			0.36252057		6.18237485

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
VESS	6	6.24508122	7.92	0.0001	6	6.04952990	7.67	0.0001
YR	13	24.94073873	14.60	0.0001	13	18.04592702	10.56	0.0001
MO	11	67.83412446	46.92	0.0	11	66.73636926	46.16	0.0
AREA	3	4.29251130	10.89	0.0001	3	4.29251130	10.89	0.0001

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		5.60803135	B	62.18	0.0	0.09019282
VESS	1	-0.00723228	B	-0.10	0.9231	0.07485965
	32	0.14564999	B	2.36	0.0185	0.06174226
	47	-0.02042073	B	-0.32	0.7465	0.06316623
	49	-0.02229841	B	-0.35	0.7246	0.06328550
	54	-0.02038220	B	-0.32	0.7480	0.06341881
	61	-0.03774912	B	-0.59	0.5522	0.06348909
	64	0.00000000	B	.	.	.
YR	76	0.05347747	B	0.43	0.6646	0.12330639
	77	0.24090274	B	3.37	0.0008	0.07150505
	78	0.01220091	B	0.18	0.8542	0.06639308
	79	-0.07200406	B	-1.10	0.2719	0.06550340
	80	0.04557266	B	0.68	0.4949	0.06675064
	81	0.06555403	B	1.05	0.2937	0.06240096
	82	0.23385957	B	3.42	0.0006	0.06830539
	83	0.17956674	B	2.65	0.0081	0.06765654
	84	0.09131944	B	1.47	0.1405	0.06191572
	85	0.21985693	B	3.60	0.0003	0.06109226
	86	0.15386315	B	2.46	0.0139	0.06248762
	87	0.43754960	B	6.62	0.0001	0.06608285
	88	0.23659751	B	3.65	0.0003	0.06473960
	89	0.00000000	B	.	.	.
MO	1	0.33061013	B	4.76	0.0001	0.06942119
	2	0.44723233	B	5.62	0.0001	0.07961069
	3	0.80715207	B	11.68	0.0001	0.06908095
	4	0.72781753	B	11.83	0.0001	0.06153071
	5	0.57148488	B	10.66	0.0001	0.05360666
	6	0.57371630	B	10.82	0.0001	0.05304115
	7	0.49283901	B	9.50	0.0001	0.05189056
	8	0.41026667	B	7.69	0.0001	0.05335452
	9	0.16404935	B	3.05	0.0023	0.05370490
	10	0.01307248	B	0.24	0.8073	0.05359033
	11	0.08500508	B	1.51	0.1323	0.05643541
	12	0.00000000	B	.	.	.
AREA	3	0.16317828	B	5.15	0.0001	0.03169656
	4	0.01311382	B	0.41	0.6787	0.03165015
	5	0.04168620	B	1.34	0.1812	0.03115878
	6	0.00000000	B	.	.	.

Table 3. **Analysis of variance (ANOVA) with a four factor model** (year, month, area and vessel). The ANOVA table and the parameter estimates together with their calculated standard errors are given.

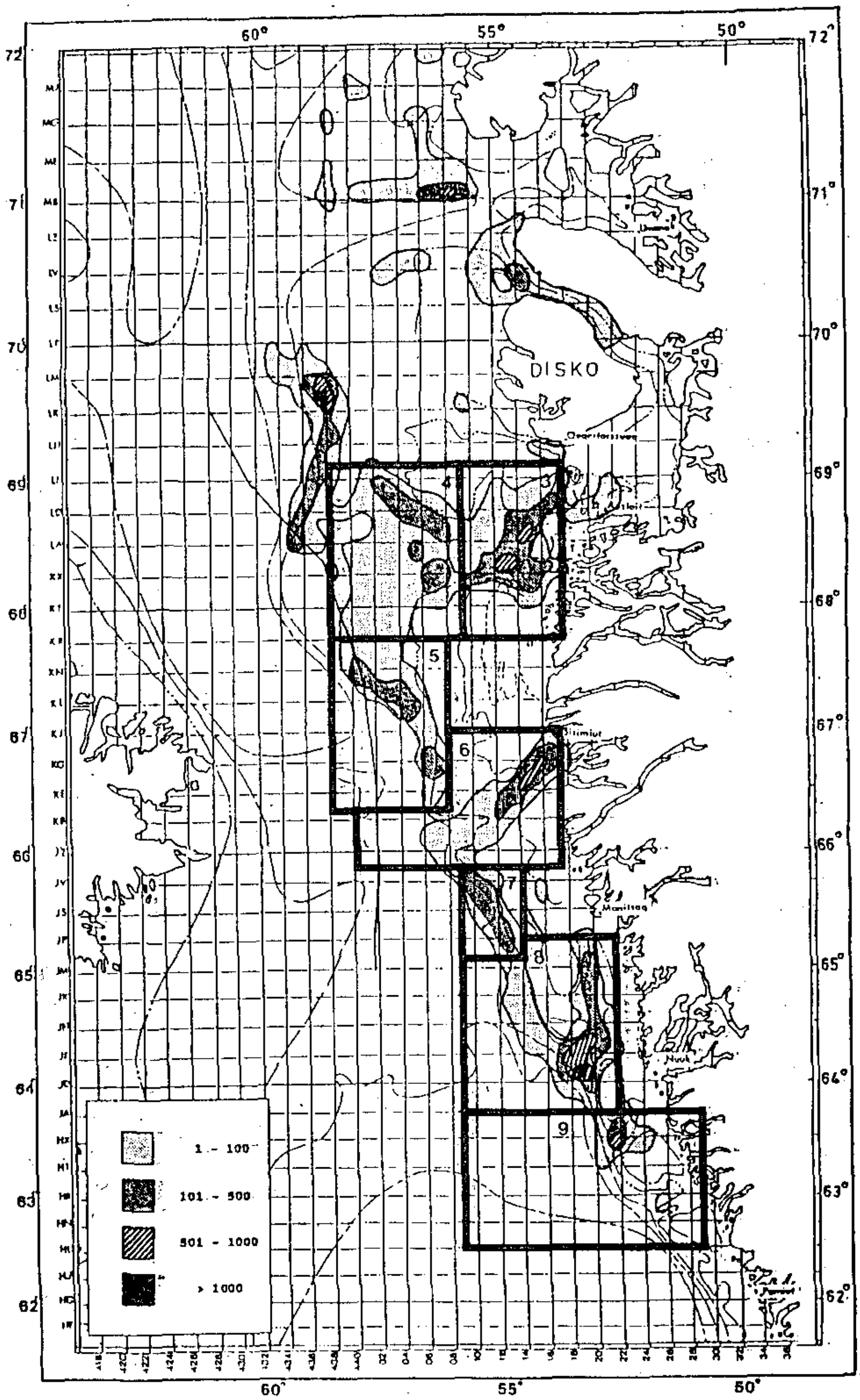

Fig. 1. Areas used in the multiplicative analyses. Only data from areas 3, 4, 5, 6 area considered. The shadowed areas show distribution of total catches in the Greenland shrimp fishery in 1988 (from Carlsson and Kanneworff, 1989).

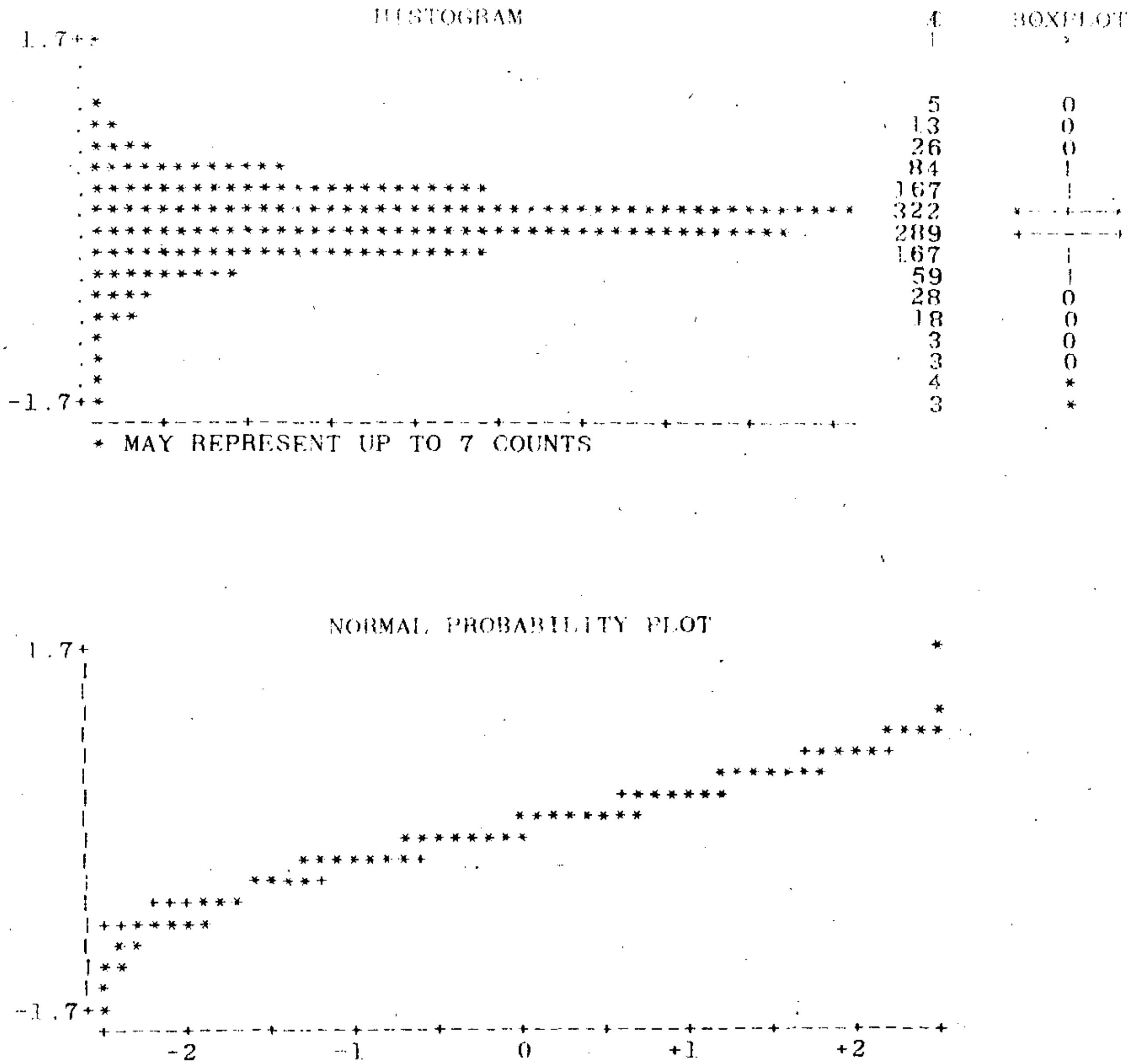

Fig. 2. Histogram, Box- and Probit plots of the residuals from the multiplicative analysis in Table 3.

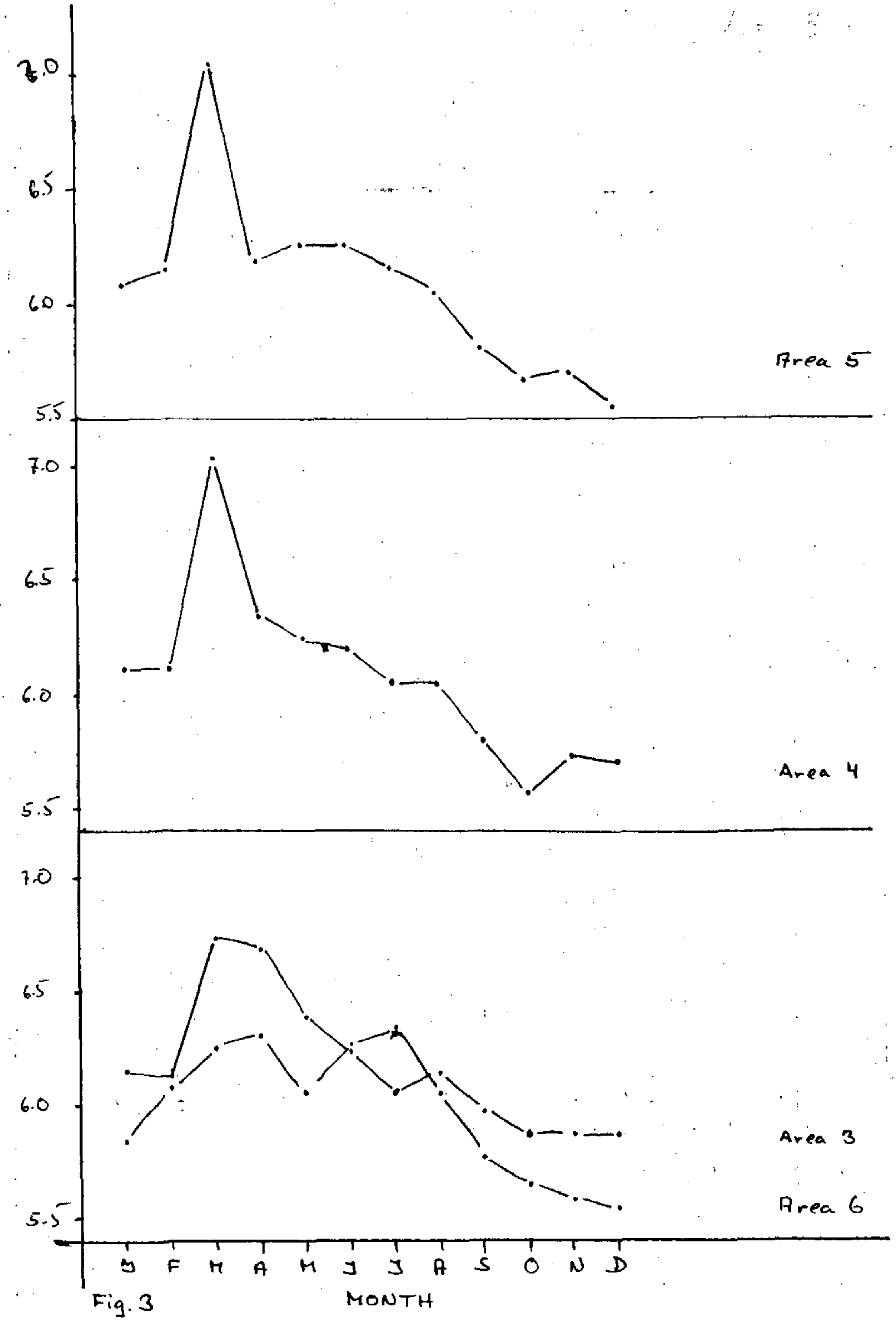

Fig. 3 Seasonality in the catch rates by areas.

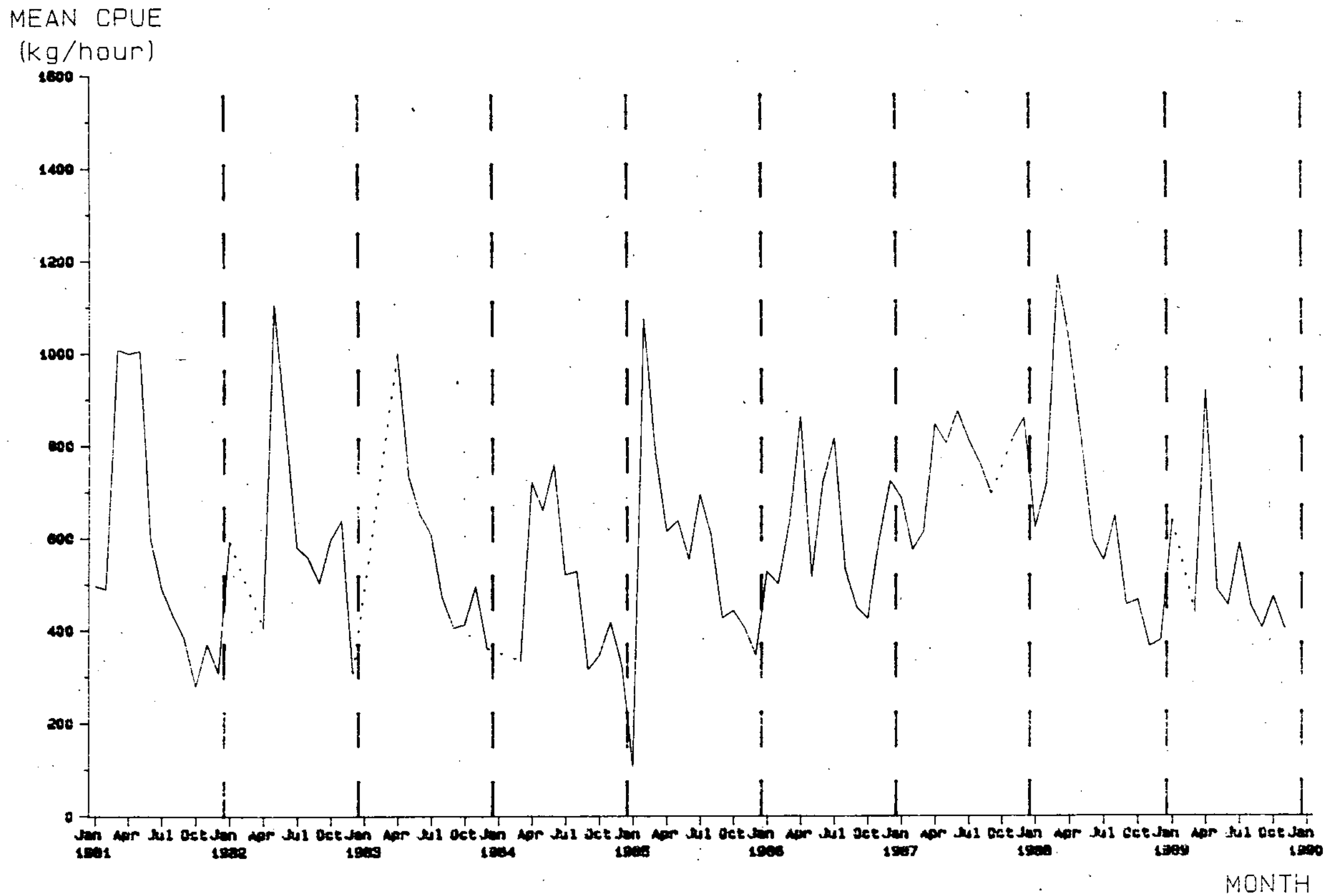

Fig. 4 Seasonality in the catch rates by years.

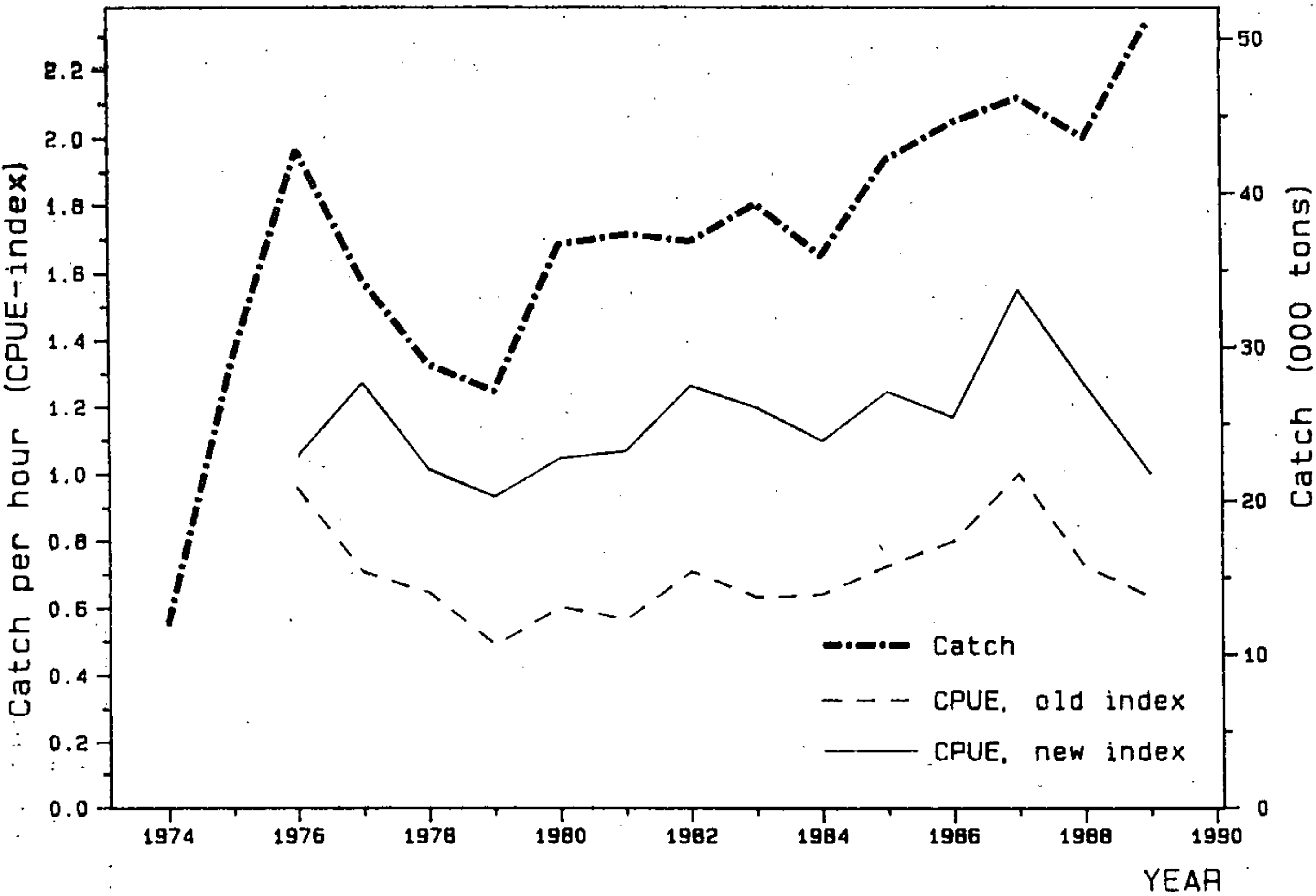

Fig. 5. Shrimp CPUE-indices from Division 1B together with total offshore catches in Subarea 0+1 (excluding catches in the Northwest Greenland shrimp fishery). The new index is based on the calculations presented in Table 3, the old index is from Anon. (NAFO) 1990.