Northwest Atlantic Fisheries Organization

Serial No. N1941 NAFO SCR Doc. 91/57

SCIENTIFIC COUNCIL MEETING - JUNE 1991

A Catch-rate Index for Large Shrimp in the Greenland Shrimp Fishery in NAFO Division 1B

D.M. Carlsson and H. Lassen

Greenland Fisheries Research Institute
Tagensvej 135, DK-2200 Copenhagen N, Denmark

INTRODUCTION

Since the first assessment of the offshore shrimp stock in NAFO Subarea 0 and 1 in 1976 catch rate indices have been used as indicators of the status of the stock. Until 1989 an index for the Greenland shrimp fishery in Subarea 1 based upon seven trawlers was used. This index was a simple average of the CPUE in the July-September period in NAFO Division 1B. The period was chosen as the fishery in these months is little influenced by ice coverage or 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 did not reflect changes between vessel coverage or changes in the relative importance of the fishing grounds between years. Neither was the shift in availability within years accounted for. Finally, during the 1980s the catch of these trawlers presented only a small and decreasing proportion of the total catch.

In 1990 a study of the usefulness of a multiplicative model to derive a series of standardized catch rates - based upon the same vessels as those included in the simple index - was made (Lassen & Carlsson, 1990). Catch rates of the entire year were included and data were disaggregated into four areas. Multivariate ANOVA was used to analyse the relationships between CPUE and various factors and to build a multiplicative model.

The new index had a number of advantages over the one used previously: It was based on a larger proportion of the total catch, it included an account of the seasonality, and it accounted for changes in the relative contribution of data from the various vessels and from the different areas. Furthermore, the index made it possible to follow the development in the catch rate month by month since observed catch rates could be corrected for systematic variations with area, season and vessel.

Interpretation of this catch rate series has, however, been complicated by a number of changes in the fishery during the period covered: gear technology has been improved with the introduction of larger trawls with high vertical opening and ability to work on a more rough bottom. In the early years of the fishery all catch was landed as fresh shrimp, while later on sorting of the catch and processing of cooked or frozen shrimp at sea have been introduced, resulting in a variable, unreported discard of especially smaller shrimp. In recent years most of the seven trawlers in the data base have been taken out of the fishery, so data represent now a very small part of the fishery and the index series cannot be continued with any meaning.

In 1985 a new logbook system was introduced for the Greenland shrimp vessels (over 50 GRT), with haul to haul information on the size categories of shrimp in the catch of sea-processing vessels. Since 1985 no significant changes in gears used have taken place. It is therefore appealing to use these data to create a new index covering a larger part of the catches and avoiding the influence of variable, unreported discard by including only the large shrimp catch component, for which discard is normally negligible. The present study is aimed to verify the usefulness of a multiplicative model to produce a new series of standardized catch rates based on 22 sea-processing trawlers and their catch of large shrimp (> 8.5 g). Multivariate ANOVAs were used to analyse the relationship between CPUE of large shrimp and various factors and to build a multiplicative model, in which interaction terms are also considered.

MATERIALS AND METHODS

Input Data

Greenland catch and effort statistics are collected through logbooks on a haul-by-haul basis since 1976. However, until the introduction in 1985 of a new Greenland logbook for the total offshore fishery by larger vessels (> 50 GRT), data available covered only a smaller part of the catches and not all seasons of the fishery. From 1987 the new logbook system covers more than 90% of the total offshore catch by larger vessels. The part of the fleet that is processing shrimp at sea is obliged to enter the production by size category for each haul, making it possible to calculate the catch of shrimp larger than a certain size. According to observers reports from the commercial fishery in 1990 discard of shrimp larger than 8.5 g (i.e. with a count of less than 120 shrimp per kg) is in general only about 6 to 7% of the catch, while smaller shrimp are discarded in larger amounts (Lehmann & Degel, 1991).

Based on the extent of fishing in Division 1B and sorting of catch in size groups 22 sea-processing vessels were selected for the present study. The catch in each single haul was split in catch of large shrimp and catch of other shrimp.

The data show a major haul-to-haul variation. Therefore catch (of large shrimp and total) and effort were aggregated by vessel, area, month and year. The marked diel variation in catch rates is 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. Both of the old indices were confined to Division 1B and this restriction is 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). As very little fishery is taking place in area 3 by this component of the fleet, this area was further excluded from the analysis.

Rather arbitrarily, all cells with less than or equal to 10 hours of efforts were excluded, not to allow cells with a single or a few hauls to affect the results. Furthermore, to avoid the influence of non-sorted catch all cells with 10% or more of the catch not being sorted by shrimp size were excluded. This brings the number of cells included in the analysis down to 761. Preliminary analysis suggested that 12 cells were marked outliers, and these observations were therefore excluded. Thus 749 cells out of a possible total of 3168 are included in the analysis.

The CPUEs of a cell were calculated simply by dividing total catch and catch of large shrimp, respectively, by total effort for that cell.

Analysis

The standard multiplicative model:

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

was investigated for both catch of large shrimp and total catch. This model has 37 parameters to estimate (3 years, 11 months, 2 areas and 21 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 by running the models with interaction terms and by graphical analysis. Attempts were also done to reduce the variability in data by omitting data fra January to April, when variation in ice cover from year to year occurs, from model runs, and to run the model with an effort limit by cell of 50 hours rather than 10 hours.

A series of standardized catch rates was finally produced for each catch category from the results of the multiplicative models without interaction terms.

RESULTS

Simple Multiplicative Models

The results are presented in Table 3 for the large shrimp component and in Table 4 for the total catch component for both the ANOVA scheme and the parameter estimates. The models explains 49% and 63% respectively of the variation, and all effects are highly significant.

Histograms, box- and probit plots of the residuals (Fig. 2 and 3) suggests that the residuals for both models 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 large shrimp catch rate, it is appropriate 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 missing cells not all combinations can be investigated within a given interaction. The table below gives the R-squares for the three interaction models for both catch components together with the R-squares from Table 3 and Table 4 for reference:

Interactions:

R-square	Without	Vessel*year	Area*year	Month*year
Large shr.	0.49	0.56	0.50	0.54
Total	0.63	0.68	0.56	0.68

Given the low improvement in R-square, the rather complicated vessel*year interaction was not analyzed further. The seasonality of catch rates by area is shown in Fig. 4. Apparently area 4 shows an abnormal behaviour in the second quarter compared to the other areas, while there are no data from the first quarter. Ice cover does in some years hinder the access to the fishing grounds in Div. 1B, especially to area 4, and this might increase the variability in the data. The model for the large shrimp component was therefore run again excluding the months from January to April, however without any significant changes in the R-square value or model estimates. Similarly, to investigate the variability introduced by setting the effort limit for inclusion of a cell in the analysis to above 10 hours the large shrimp model was run again excluding all cells with 50 hours effort or less, again without significant changes in the results.

The analysis above suggests that the most important contributors to the variability, which still might be explained within the dataset considered, are changes from one year to the next in the seasonality of the catch rates, and changes in vessel performance between years. The analyses made so far suggests that changes in the seasonality 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. 5 shows the seasonality by years for all areas together. The variability in the seasonality of catch rates 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 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 Fig. 7 these are shown normalized to the level for 1990, together with the corresponding indices for the total catch.

DISCUSSION

A number of problems are inherent when attempting to establish CPUE indices as a measure of development in a fish or shrimp stock. An index should e.g. be based on a substantial part of the total catch, it should include an account of seasonality and changes in the relative contribution of data from vessels and areas. Account should also be taken for changes in e.g. gears used and in discarding procedures.

The index presented in this paper is more advantageous regarding these demands when compared to indices hitherto used for the offshore shrimp stock in Subarea 1. However, the time series available is relatively short and the number of vessels included comprises less than 50% of the total number of large vessels (above 50 GRT) in the fishery. In recent years there has been a displacement of the fishery to Div. 1C and 1D - in 1990 the total catch in Div. 1C is almost as large as in Div. 1B. Future analyses should therefore include areas south of Div. 1B, the data base should be analyzed for the possibility of including more vessels, and e.g. gear type and size, which are recorded in the new logbook system, might also be included in the analysis.

Interactions in the model, especially variations in seasonality and vessel performance between years should be analyzed further.

To judge whether the index presented here represents the development in abundance of shrimp implies analysis of other abundance data. Taken by itself the present index suggests a decrease in large shrimp abundance from 1987 to 1989 and a relative stabilization between 1989 and 1990.

REFERENCES

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

Carlsson D. M. and P. Kanneworff, 1991. The shrimp fishery in NAFO Subarea 1 in 1990. NAFO SCR. Doc. 91/69, Ser.No. N2953.

Lassen, H. and D.M. Carlsson, 1990. A catch-rate index for the Greenland shrimp fishery in NAFO Subarea 1. NAFO SCR. Doc. 90/90, Ser.No. N1817.

Lehmann, K.M. and H. Dogel, 1991. An estimate of shrimp discard from shrimp factory trawlers in Davis Strait and Denmark Strait. NAFO SCR. Doc. 91/40, Ser. No. N1920.

Table 1. Total effort (trawl hours) as reported in logbooks for 22 Greenland trawlers. Only hauls in areas 4, 5 and 6 (Fig. 1) are considered. The period is 1987-1990.

Table 1a. Effort by vessel and year.

SAS 19:28 Wednesday, June 5, 1991 4

	YEAR			
	87	88	89	90
VESSEL				
OUIQ	684	2379	1383	1643
OUOQ	850	1158	785	638
OUPJ	458	594	239	540
OUTM	82	1438	1060	922
OUWH	607	780	998	569
OVUG	1108	1619	499	.
OWDV	.	1862	883	1271
OWPQ	898	2449	269	468
OWQU	.	1778	1329	1231
OWVM	269	1532	536	644
OWWP	1431	1186	1861	900
OWZR	978	997	.	.
OXSY	1045	1420	.	579
OYAQ	807	1864	1304	701
OYBZ	.	290	373	480
OYCK	111	1115	519	55
OYFF	1911	2107	1828	.
OYKK	456	442	586	761
OYNR	708	1039	236	728
OYRK	1851	3286	1341	2098
OYRT	622	832	360	807
OYZL	1072	1263	305	472
TOTAL	15948	31430	16694	15507

Table 1b. Effort by area and year.

SAS 19:28 Wednesday, June 5, 1991 5

	YEAR			
	87	88	89	90
AREA				
4	3011	13042	6610	6454
5	3956	6425	4910	4926
6	8981	11963	5174	4127
TOTAL	15948	31430	16694	15507

Table 1c. Effort by month and year.

SAS 19:28 Wednesday, June 5, 1991 6

	YEAR			
	87	88	89	90
MONTH				
1	18	656	77	42
2	.	260	12	25
3	1371	1270	459	.
4	2565	3285	945	17
5	3173	4576	3240	2038
6	2938	4053	4267	3895
7	2534	3650	2534	2024
8	2202	3321	2835	1499
9	559	3126	735	1222
10	97	1886	366	997
11	152	3484	978	2487
12	339	1863	246	1261
TOTAL	15948	31430	16694	15507

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

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

	YEAR			
	87	88	89	90
VESSEL				
OUIQ	6	15	16	16
OUOQ	7	14	7	9
OUPJ	5	7	4	4
OUTM	2	17	9	11
OUWH	5	9	9	8
OVUG	6	9	6	.
OWDV	.	18	10	15
OWPQ	9	21	7	9
OWQU	.	11	10	12
OWVM	5	12	6	8
OWWP	11	10	13	9
OWZR	6	7	.	.
OXSY	4	11	.	9
OYAQ	7	17	15	11
OYBZ	.	3	6	5
OYCK	3	9	9	2
OYFF	12	11	18	.
OYKK	5	6	5	8
OYNR	9	12	5	13
OYRK	13	22	11	19
OYRT	4	10	5	9
OYZL	8	12	7	7

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

	YEAR			
	87	88	89	90
AREA				
4	33	93	66	76
5	38	74	53	58
6	56	96	59	50

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

	YEAR			
	87	88	89	90
MONTH				
1	1	5	2	1
2	.	3	1	1
3	6	11	7	.
4	12	29	17	1
5	27	42	33	25
6	29	31	29	39
7	21	31	27	28
8	14	28	21	21
9	6	24	19	15
10	2	18	8	14
11	3	26	11	22
12	6	15	3	17

Table 3. CPUE for shrimp larger than 8.5 g. Analysis of variance (ANOVA) on log(CPUE) 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.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LNCPUE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	37	156.00831255	4.21644088	18.18	0.0	0.485062	9.0634
ERROR	714	165.61719935	0.23195686		ROOT MSE		LNCPUE MEAN
CORRECTED TOTAL	751	321.62551189			0.48161900		5.31389150

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
VESS	21	65.82721572	13.51	0.0001	21	72.34345952	14.85	0.0001
YR	3	60.26609566	86.61	0.0001	3	49.95671436	71.79	0.0001
MO	11	24.68477971	9.67	0.0001	11	24.39653144	9.56	0.0001
AREA	2	5.23022145	11.27	0.0001	2	5.23022145	11.27	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		4.81750055 B	40.98	0.0	0.11755000
VESS	OUIQ	0.32452077 B	3.02	0.0026	0.10734495
	OUOQ	0.06630763 B	0.58	0.5648	0.11510586
	OUPJ	0.56673892 B	4.12	0.0001	0.13760051
	OUTM	0.26490724 B	2.32	0.0205	0.11406050
	OUWH	0.22161174 B	1.84	0.0661	0.12039693
	OVUG	-0.53122185 B	-3.94	0.0001	0.13483738
	OWDV	0.23774180 B	2.12	0.0339	0.11189130
	OWTQ	-0.13603066 B	-1.23	0.2198	0.11075848
	OWQU	0.96208756 B	8.05	0.0001	0.11952386
	OWVM	0.14813847 B	1.23	0.2191	0.12043528
	OWWP	0.75784835 B	6.79	0.0001	0.11162541
	OWZR	-0.02423164 B	-0.15	0.8797	0.16008243
	OXSY	-0.14524446 B	-1.12	0.2635	0.12978805
	OYAQ	-0.10861686 B	-1.00	0.3184	0.10879180
	OYBZ	0.52207862 B	3.39	0.0007	0.15402937
	OYCK	0.14089634 B	1.07	0.2857	0.13188468
	OYFF	0.63980289 B	5.63	0.0001	0.11361601
	OYKK	0.29749604 B	2.29	0.0225	0.13005219
	OYNR	0.20759884 B	1.83	0.0684	0.11374764
	OYRK	0.47885314 B	4.66	0.0001	0.10273817
	OYRT	0.50347333 B	4.05	0.0001	0.12434373
	OYZL	0.00000000 B	.	.	.
YR	87	0.62911750 B	10.59	0.0001	0.05939963
	88	0.53230695 B	11.02	0.0001	0.04831490
	89	0.06255760 B	1.17	0.2417	0.05339388
	90	0.00000000 B	.	.	.
MO	1	0.23992113 B	1.32	0.1856	0.18108509
	2	0.07936830 B	0.34	0.7353	0.23469352
	3	0.21078223 B	1.64	0.1021	0.12875720
	4	0.36296126 B	3.52	0.0005	0.10320145
	5	-0.14719796 B	-1.63	0.1030	0.09015482
	6	-0.21054590 B	-2.34	0.0195	0.08993647
	7	-0.19878093 B	-2.16	0.0311	0.09202977
	8	-0.22736248 B	-2.37	0.0179	0.09578020
	9	-0.36296920 B	-3.64	0.0003	0.09978376
	10	-0.42656775 B	-3.92	0.0001	0.10868555
	11	0.00373542 B	0.04	0.9698	0.09853541
	12	0.00000000 B	.	.	.
AREA	4	-0.00031701 B	-0.01	0.9946	0.04642102
	5	0.18969172 B	3.97	0.0001	0.04781576
	6	0.00000000 B	.	.	.

Table 4. CPUE for total catches. Analysis of variance (ANOVA) on log(CPUE) 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.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LNCPUE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	37	185.38856340	5.01050171	33.01	0.0	0.632071	6.8042
ERROR	711	107.91465296	0.15177870		ROOT MSE		LNCPUE MEAN
CORRECTED TOTAL	748	293.30321636			0.38958785		5.72566798

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
VESS	21	109.46802053	34.34	0.0	21	110.60744220	34.70	0.0
YR	3	57.90111430	127.16	0.0001	3	49.17933804	108.01	0.0001
MO	11	15.19549673	9.10	0.0001	11	14.35862841	8.60	0.0001
AREA	2	2.82393184	9.30	0.0001	2	2.82393184	9.30	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		5.12885165 B	53.93	0.0	0.09510881
VESS	OUIQ	0.75672651 B	8.71	0.0001	0.08683980
	OUOQ	0.08684460 B	0.93	0.3544	0.09371797
	OUPJ	0.57439989 B	5.16	0.0001	0.11131767
	OUTM	0.22460941 B	2.42	0.0159	0.09292253
	OUWI	0.12346420 B	1.27	0.2053	0.09739208
	OVUG	-0.33031189 B	-3.03	0.0026	0.10908356
	OWDV	0.19606687 B	2.17	0.0306	0.09051804
	OWPQ	-0.08768247 B	-0.98	0.3281	0.08959938
	OWQU	1.13906996 B	11.78	0.0001	0.09669717
	OWVM	0.13544039 B	1.39	0.1649	0.09743093
	OWWP	0.95763959 B	10.60	0.0001	0.09030172
	OWZR	-0.22340286 B	-1.72	0.0850	0.12951021
	OXSY	-0.02223110 B	-0.21	0.8324	0.10500777
	OYAQ	-0.20346870 B	-2.30	0.0217	0.08841602
	OYBZ	0.35841790 B	2.88	0.0041	0.12460038
	OYCK	0.36427662 B	3.41	0.0007	0.10669258
	OYFF	0.83934671 B	9.13	0.0001	0.09191254
	OYKK	0.28317785 B	2.69	0.0073	0.10521401
	OYNR	0.00181909 B	0.02	0.9842	0.09201604
	OYRK	0.68418297 B	8.23	0.0001	0.08311220
	OYRT	0.42144632 B	4.19	0.0001	0.10059147
	OYZL	0.00000000 B	.	.	.
YR	87	0.78868459 B	16.37	0.0001	0.04819170
	88	0.34912991 B	8.90	0.0001	0.03924529
	89	0.08859032 B	2.04	0.0416	0.04340048
	90	0.00000000 B	.	.	.
MO	1	0.33291405 B	2.27	0.0234	0.14650649
	2	0.11038089 B	0.58	0.5612	0.18988233
	3	0.28002440 B	2.65	0.0082	0.10562922
	4	0.28188390 B	3.37	0.0008	0.08356840
	5	-0.06123759 B	-0.84	0.4026	0.07312064
	6	-0.02967256 B	-0.41	0.6836	0.07278698
	7	-0.04347649 B	-0.58	0.5604	0.07463597
	8	-0.18052337 B	-2.33	0.0201	0.07750494
	9	-0.25505223 B	-3.16	0.0016	0.08073130
	10	-0.32560228 B	-3.70	0.0002	0.08792310
	11	-0.05075834 B	-0.64	0.5245	0.07971725
	12	0.00000000 B	.	.	.
AREA	4	0.00250439 B	0.07	0.9470	0.03762659
	5	0.14100825 B	3.65	0.0003	0.03867933
	6	0.00000000 B	.	.	.

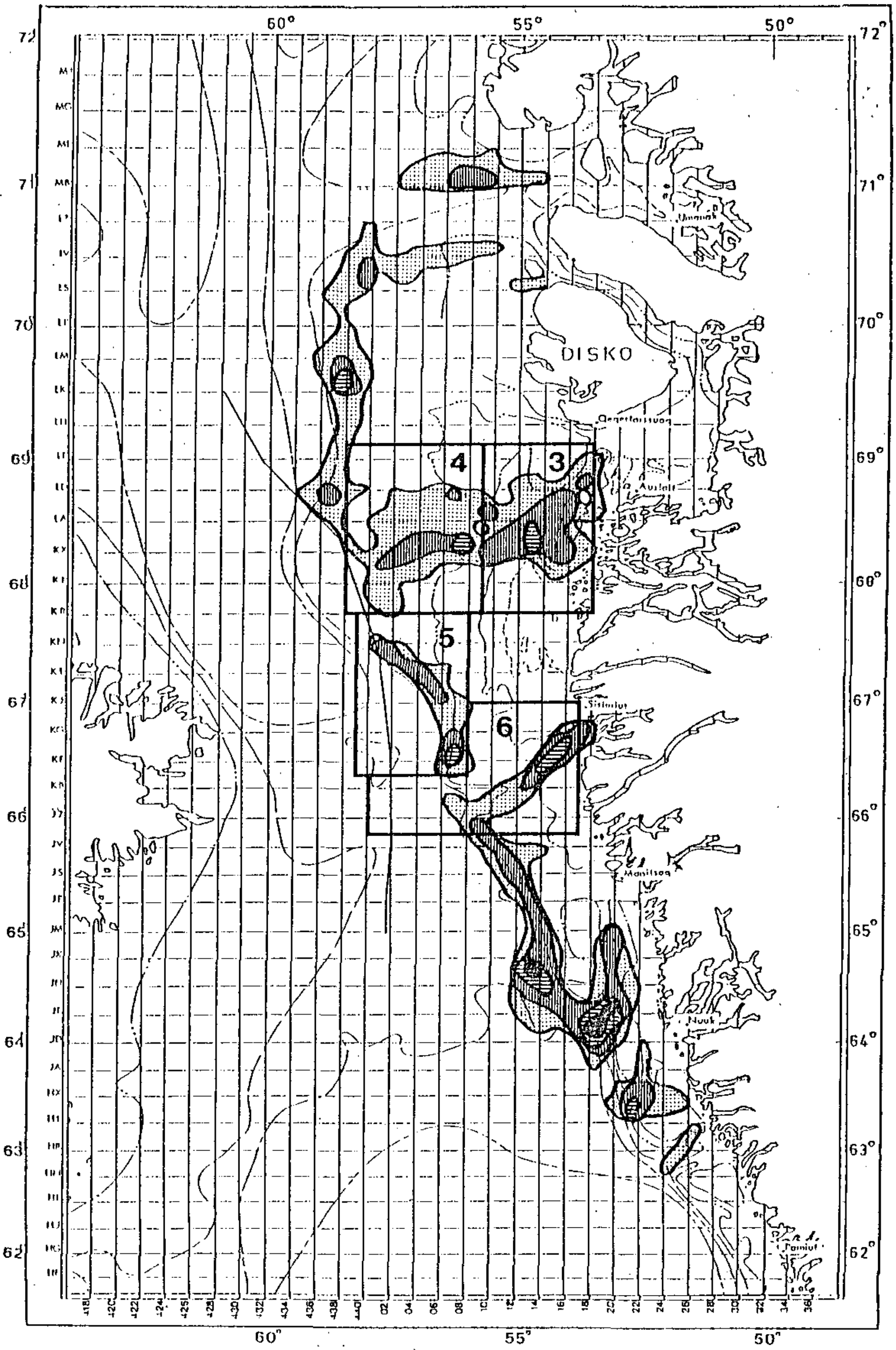

Fig. 1. Areas used in the multiplicative analyses. Only data from areas 4, 5, 6 are considered. The shadowed areas show distribution of total catches in the Greenland shrimp fishery in 1990 (from Carlsson and Kanneworff, 1991).

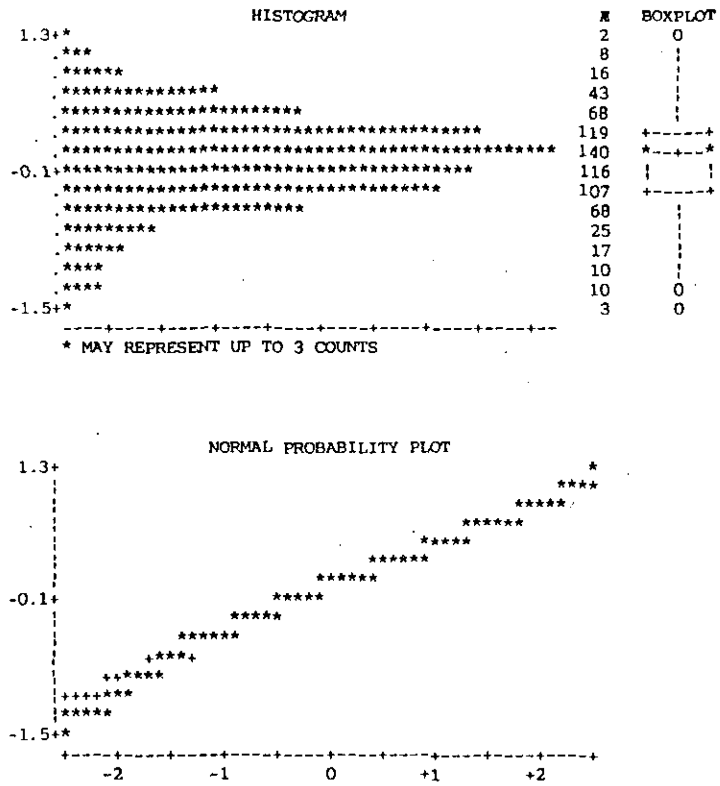

Fig. 2. Histogram, Box and Probit plots of the residuals from the multiplicative analysis in Table 3 (shrimp larger than 8.5 g).

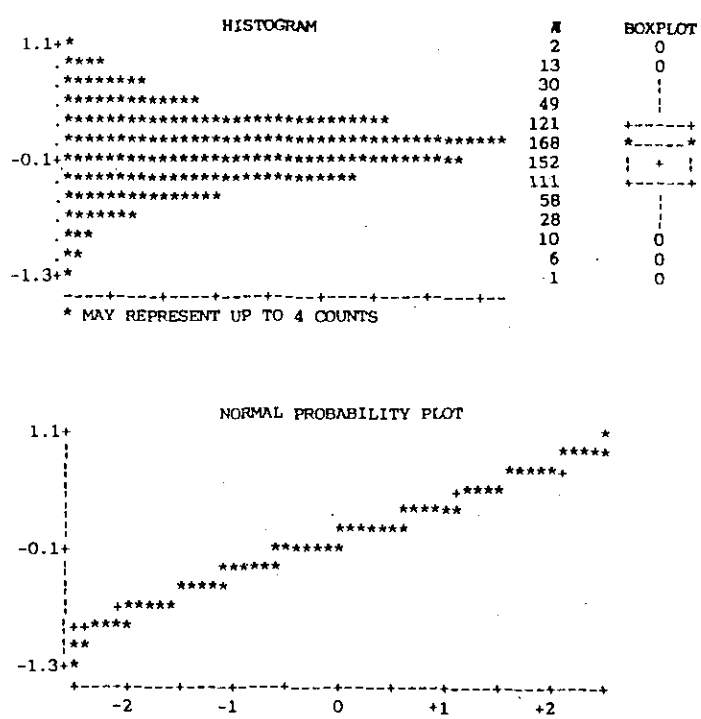

Fig. 3. Histogram, Box and Probit plots of the residuals from the multiplicative analysis in Table 4 (total catch of shrimp).

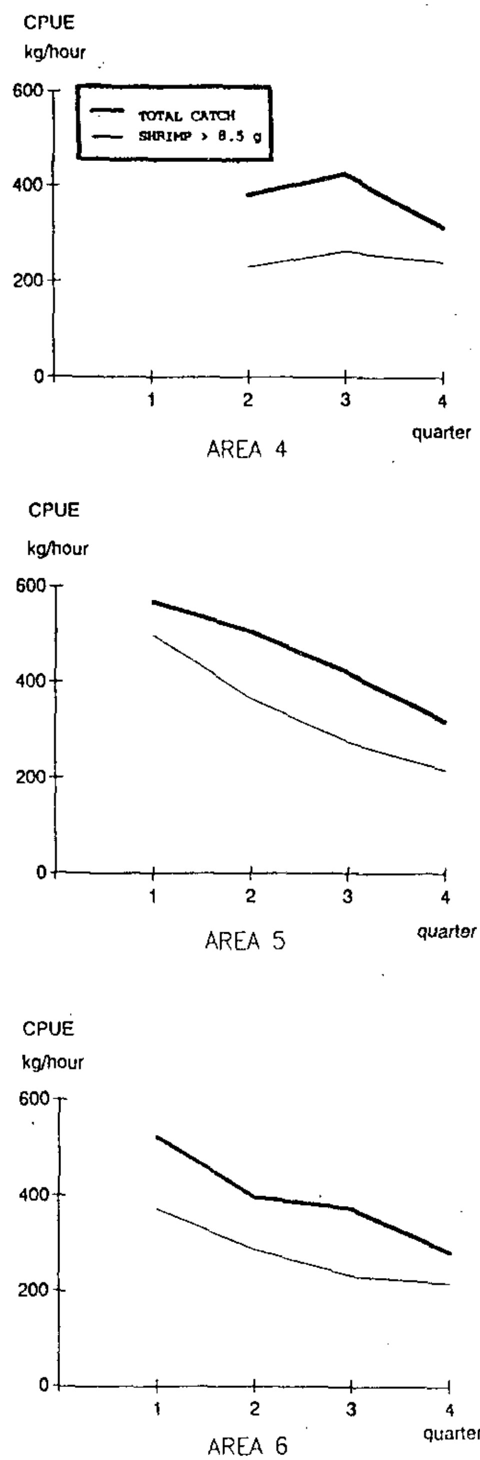

Fig. 4. Mean seasonality (by quarter) in the catch rates for shrimp > 8.5 g and for total catch, by areas.

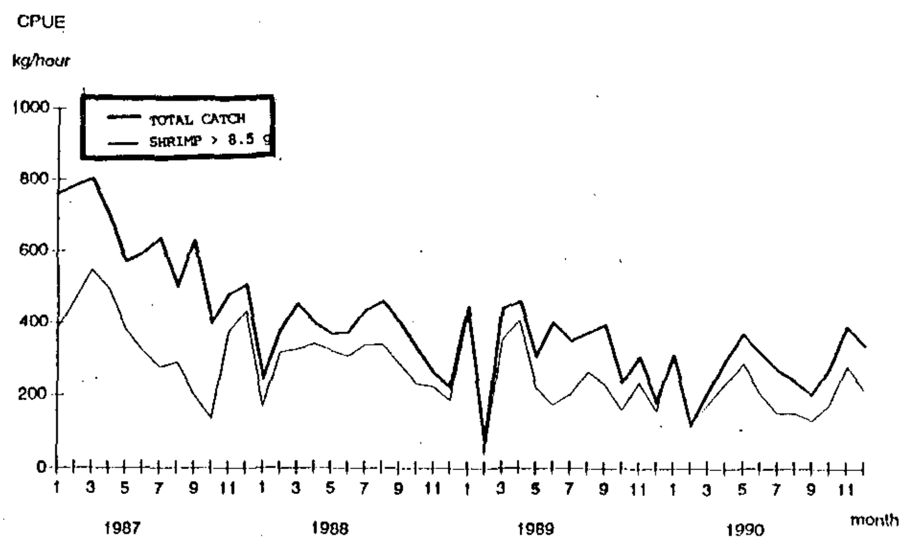

Fig. 5. Seasonality in the catch rates for shrimp > 8.5 g and for total catch, by years.

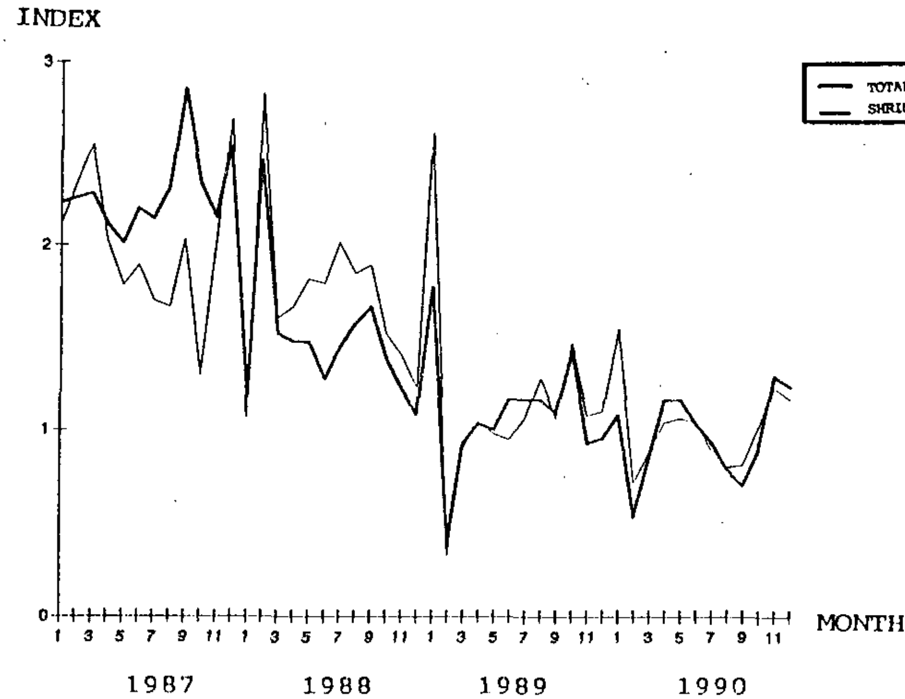

Fig. 6. Monthly CPUE-indices calculated for shrimp > 8.5 g and for total catch.

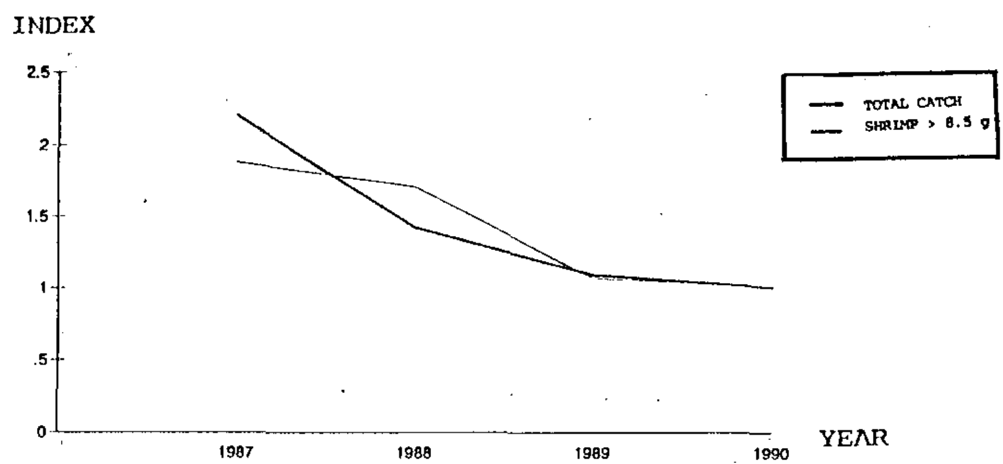

Fig. 7. Yearly CPUE-indices calculated for shrimp > 8.5 g and for total catch.