Northwest Atlantic Fisheries Organization

Serial No. N1913 NAFO SCR Doc. 91/33

SCIENTIFIC COUNCIL MEETING - JUNE 1991

The Canadian Fishery for Northern Shrimp (*Pandalus borealis*) in Division 0A, 1990

by

D. G. Parsons and P. J. Veitch

Science Branch, Department of Fisheries and Oceans
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

INTRODUCTION

Quota reports (preliminary to May 1, 1991) show that 6177 t of shrimp were taken in Division 0A in 1990, 1343 t less than the TAC of 7520 t and 1058 t less than the 1989 catch. The fishery began in the first week of July and continued to the middle of November. Fourteen vessels participated in 1990, compared to 16 in 1989. For the past several years, there have been 16 licences in the Canadian northern shrimp fishery; in 1991 there will be 17. The 1991 quota in Division 0A has been set at 8500 t.

Fishing logs from both foreign and domestic vessels were available for 1990, providing data on fleet performance. These were supplemented by observer data which covered most of the fishing activity. Unfortunately, processing of the latter is incomplete. All 1989 data have been updated in this paper for comparison with previous years' information and that available for 1990. Catch/effort data and length frequency distributions of shrimp from the 1981-1990 commercial catches are analyzed and information on discards and by-catches are provided.

MATERIALS AND METHODS

Catch (kilograms) and effort (hours fished) were compiled from vessel logs for the period 1979 to 1990. The distribution of observations by year and month are given in Table 1. From 1981 to 1990, fishing was restricted to Division 0A in an area extending from about 67°30' to 68°30'N and 58° to 59°W (Fig. 1). These data were further summarized by vessel, month and year for standardization. Catch and effort were totalled and catch per unit effort (CPUE) calculated within each cell (n = 347). The data set also included information on the horse power and tonnage of each vessel. No vessel fished in every year.

Annual CPUE's were calculated two ways:

1. Total catch for each year from 1979 to 1990 was divided by the total effort to give an unstandardized, weighted catch rate.

2. All data from 1981 to 1990 (except for a single observation in May, 1984) were analyzed using SAS multiple regression procedures to produce predicted, annual catch rates.

The final run for the latter was made by vessel because this variable tended to reveal an effect not sufficiently explained using tonnage class and/or horse power. Also the vessel model produced a higher r-square value and was not so heavily influenced by interactions. Other class variables included in the model were year and month. The CPUE data were log (base e) transformed. Log CPUE estimates were retransformed and indexed to 1981.

Size composition of the 1990 catches sampled by observers were summarized by month and 100 m depth intervals. The length distributions of numbers caught from 1981 to 1990 also were constructed. This was done in several steps: 1. The number in the sample was adjusted (by ratio of weight) to the number caught in the set. 2. Numbers from all sets for the month were totalled and adjusted (by weight) to the total catch from vessel logs. 3. The numbers from all months were totalled and adjusted (by weight) to the total catch for the year.

The catch at length for each year was converted to catch at age by modal analysis (Macdonald and Pitcher, 1979) of the composite length frequency distribution. The number of components representing ages in the catch and their mean lengths were based on the findings of Savard *et al.* (1989). Initial analyses were done estimating as many parameters as possible (proportions, means and standard deviations) without constraints. In several cases, the standard deviations for some components were clearly overestimated due to the overlap in the length distributions. The data were reviewed and it was noted that this parameter increased with mean length. Also, the coefficients of variation for the best fits (low standard errors) were about 0.05. Final runs were made with the constraint that all CV's be held fixed at an average value of 0.048 (0.043 to 0.052 for ages 5+). This constraint reduced the possibility of misrepresenting the proportion of a component due to the fitting procedure, itself. It also insured that standard deviations for each component increased with mean size. Tables were constructed for proportions and numbers caught at age and numbers caught per hour at age.

Data on by-catches were compiled as percentages of the total observed catch in each month and catch rates for the major by-catch species were compared for the period 1981 to 1990. Estimates of the proportions of discarded shrimp also were derived from the observer data.

RESULTS

Catch, effort and CPUE

The shrimp catch, effort and CPUE by month and year as derived from the available vessel logs are given in Tables 2, 3 and 4, respectively. The fishery typically occurs from June to November but most of the catch is taken and most of the effort expended in the July to October period. The data reflect the sporadic fishing pattern in the early years when the fishery was developing, up to the mid 1980's when economic conditions were unfavourable. Since 1987, both catch and effort have been higher and less variable (Fig. 2 and 3).

The seasonality of the fishery is evident in the monthly CPUE data (Table 4). In most years, catch rates are relatively high during the June-July period, decline during August-September and either stabilize or increase again in October and November. This pattern did not hold in 1990 as catch rates fluctuated inversely with effort, resulting in a high CPUE in September. Annual catch rates (Fig. 4) were relatively stable up to 1985, increased to a substantially higher level from 1986 to 1988 and declined to an intermediate level in 1989 and 1990.

The annual CPUE's were standardized to account, in part, for the seasonality of the fishery and the increase in fishing power over time. Since the fishery began in 1979, the smaller, less powerful vessels have been replaced by larger vessels (Table 5), capable of towing larger trawls with higher vertical openings. Data on trawl size was not sufficient for inclusion in the multiple regression model. The results of the analysis of variance (Table 6a) show that this model explains 72% of the total variation with all three variables highly significant. T-values suggest that 1981, 82, 83, 87 and 88 catch rates were significantly higher than in 1990. The appropriateness of the model can be evaluated further by the distribution of residuals (Fig. 5 and 6).

The log CPUE values were retransformed (Table 6b) to provide the standardized estimates in the original units (kg/hr). The interpretation of the mean catch rates differs from the unstandardized series in that the long-term trend is decreasing rather than increasing (Fig. 7). Also, the increase in CPUE between 1985 and 1986 is not so pronounced. It is noted that CV's were about 20% each year and within this range of imprecision, several interpretations might be possible. A complete summary of TAC, catch, effort and CPUE for the Canadian fishery is given in Table 7.

Catch increases in a linear fashion with both unstandardized and standardized effort (Fig. 8), although the points tend to occur in clusters. Unstandardized catch rates are not related to fishing effort in a given year and neither are there any clear relationships for two and three year averages on effort (Fig. 9). The standardized series (Fig. 10) shows a slightly negative slope which becomes less obvious when moving averages of effort are used. A negative slope is obvious for the period 1987 to 1990 as is a positive slope from 1983 to 1988.

Length distributions

Length frequencies for the sampled catches by month and depth interval (Fig. 11) show a prominent size group about 19 to 22 mm CL occurring in most instances. Only in deeper water (>400 m) do the females (>23 mm) comprise most of the catches. The modes of male shrimp present in the samples are not clear as, in most cases, overlapping is severe due to the prominence of a mode around 20 mm. Catch rates (number caught per hour) were highest in the shallow water (200-300 m) in July and August where the smaller male shrimp were abundant. From September to November, catch rates improved in the deeper water (>300 m) but the proportion of male shrimp remained high at these depths as well.

Shrimp caught in 1990 were smaller than those caught in previous years (Fig. 12) with the component at 20 mm (assumed to represent the 1985 year-class) comprising a large proportion of the catch. The data show a decrease in the size of the female mode between 1983 and 1985, followed by a period of similar size composition, especially from 1987 to 1989. The size composition in 1990 was similar to that of 1984 except that the mode at 20 mm was more prominent in 1990.

Despite the overlap of size groups in the pooled, annual length distributions and that some growth must occur between June and November, the modal structure (assumed to reflect year-classes) is fairly well maintained. Previous ageing of research length distributions (Savard *et al.*, 1989) estimated mean lengths at 18.5, 20.6, 22.7, 24.9 and 26.3 mm CL for ages 4 to 8+, respectively. Components with similar mean lengths can be inferred in several instances in Fig. 12. Under the assumption of a fixed CV = 0.048, expected counts at length from the modal analysis were virtually identical to the observed (P >0.99 in all but one distribution). Estimated mean lengths were in good agreement with those from the previous ageing study. In three instances, it was necessary to hold a mean fixed at a previously estimated value in order to keep the parameters within a realistic range. The expected values for each normal component are superimposed on the total distributions in Fig. 13.

The estimated proportions of shrimp caught at age from 1981 to 1990 (Table 8) show that the relative contribution of females (ages 7 and 8+) to the catch declined from over 80% in 1981 to 47% in 1984. After 1986, females accounted for approximately half the catch up to 1990 when they reached the lowest observed level of 36%. Also, the estimated proportions of age 8+ females decreased from 56% in 1981 and 1982 to about 5% in 1987 and 1988, then increased to 15% in 1989 and 1990. Three year old male shrimp did not contribute substantially to the catch in any year but formed an identifiable mode in the 1988 length distribution (the 1985 year-class).

The proportions in Table 8 were applied to the total estimated catch numbers to derive a catch at age matrix (Table 9) and these data were subsequently divided by both the standardized and unstandardized fishing effort to produce age specific indices of abundance (Tables 10 and 11). Catch rates for ages 4, 5 and 6 (males) show a generally increasing trend over the time series (Fig. 14) with indications (peaks) that relatively strong year-classes were produced in the early and mid 1980's. CPUE's for age 7 females increased from 1982 to 1987 but have since declined. Again, the strong year-classes of the early 1980's are evident. The estimated abundance of age 8+ females declined sharply between 1982 and 1984, levelled off up to 1988 and increased again slightly in 1989 and 1990. Catch rates (standardized and unstandardized) over all ages (Fig. 15) show the same tendencies as the CPUE by weight data except that the declining trend in the standardized series is not evident.

Mean weight of shrimp caught (total weight caught/total numbers) declined from 9.9 g in 1981 to 7.9 g in 1984, increased to 8.7 g in 1985 and followed another decline to 7.3 in 1990. This trend is reflected in the means of the annual catch at length data which showed an overall decrease from 24.8 mm in 1981 to 22.6 mm in 1990.

The data in Tables 10 and 11 suggest that shrimp are not fully recruited till age 7 since, in every instance, number caught per hour increases from age 6 in one year to age 7 the next. Total mortality (Z) can be estimated by comparing age 7+ in year i with 8+ in year i+1. The results indicate that mortality on females increased substantially up to 1987 and declined in 1988 and 1989.

	1981	1982	1983	1984	1985	1986	1987	1988	1989
UNST f	0.23	0.76	1.08	0.91	1.53	2.12	2.19	1.35	1.22
ST f	0.16	0.87	1.13	1.12	1.79	1.95	2.27	1.47	1.23

There is no clear relationship between Z and total effort (Fig. 16).

Shrimp discards

The percentages of shrimp discards as estimated by observers in 1990 (Table 12) show that levels were lower than in the previous two years, despite the decrease in mean size, and similar to those observed in 1986 and 1987, averaging about 2%. In the years prior to 1986, discard rates were higher, ranging from about 3 to more than 5%. There were no size composition data available from the discarded shrimp in 1990 for comparison with the random samples from the catches.

By-catches

The available observer data on catch composition for each month of the 1990 fishery (Table 13) show that by-catch ranged from 12% to 23% of the total catch weight of all species. Redfish was the most abundant fish species in the catches, accounting for approximately 6 to 15% of the total observed catch weight. Greenland halibut comprised 2.5% or less of the catch in each month of the fishery. Typically, the incidence of Greenland sharks increased in November. By-catch composition was similar to that observed in 1989. The catch rates (kg/hour - unstandardized) for redfish and Greenland halibut from 1981 to 1990 are:

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Redfish	32	20	9	16	20	90	107	74	70	50
Turbot	3	4	5	6	4	8	11	14	11	9

Redfish CPUE's increased substantially from 1983 to 1987, then decreased to 1990 but remain well above the levels observed prior to 1986. Catch rates of Greenland halibut remain much lower than those for redfish. There was a gradual increasing trend to 1988, followed by slight decreases in 1989 and 1990. No length frequency data are available for either species to further interpret the catch rate data. Generally, in the past, the by-catches of both consisted of mostly small animals.

DISCUSSION

Although the Canadian shrimp fishery in Division 0A represents less than 15% of the total annual landings in Subarea 0+1, we felt that a thorough analysis and interpretation of the available data would be useful in the overall assessment of the resource. Events occurring throughout the population might be reflected sufficiently in a specific area. For example, Carlsson (1990) noted a more southern distribution of shrimp in 1989 from survey data. If such observations are correct, they should be evident in the fishery performance data for a fleet confined to the more northern grounds.

The standardization of CPUE for Div. 0A shows fluctuating catch rates over the ten year period with an overall declining trend in the mean values. The same pattern is evident in the numbers caught per hour for females, the sizes targeted by the fishery. Over the same period, catch rates of younger, male shrimp have been increasing. The increase in CPUE in 1990 is due to the partial recruitment of the 1985 year-class. Catch increases linearly with effort and plots of CPUE against effort tend to be inconclusive in the sense of general production modelling.

Catch at age data indicate that one or more strong year-classes were produced in the early 1980's and began to recruit to the fishery in 1984. As these animals grew and became fully recruited as females, catch rates increased in 1987 and 1988 but declined subsequently as their numbers were reduced through fishing and natural mortality. In 1988, age 3 males were identifiable in the catches for the first time. They did not appear to contribute substantially to the catches in 1989 but were very abundant as 5 year olds in 1990. Assuming the fishing pattern was not altered to target this year-class, it was only partially recruited in 1990 and should contribute further, as males, in 1991 and in 1992 and, to some extent, 1983 as females. Catch rates should, therefore, increase in the short term.

NAFO (1990) observed a decrease in mean size of shrimp between 1988 and 1989. The Canadian fishery data show an overall decrease in mean size from 1981 to 1990 due to the decrease in the proportion of females in the catch. This is reflected in average weight, average length and proportion at age. If the variations in CPUE seen over time were only a reflection of variations in recruitment, as intermittent strong year-classes enter and pass through the fishery, such a decline might not be expected. Therefore, it is possible that the fishery, directed towards female shrimp, has had some impact on the population.

Despite a long and intensive fishery in Subarea 0+1, there has been no evidence of recruitment failure. Total offshore catches have been in the range of 45,000 to 50,000 t only since 1986. Offspring from females present in those years are just now recruiting to the fishery. Therefore, it is not yet clear whether or not these higher levels of catch have adversely affected recruitment.

The estimation of catch at age from commercial length frequency data appears to provide some insight into events occurring within the population. The strong year-classes of the early 1980's can be traced through the fishery but, because of the imprecision in the ageing (i.e. overlapping of components), it is not certain whether there is only one very strong year-class (i.e. 1980) or several which are stronger than average (e.g. 1979-1981). Also, separation of females into primiparous and multiparous groups was not based on biological data. This is normally done by observing the presence or absence of sternal spines but is only useful when the females are not bearing eggs. The proportions for ages 7 and 8+ in this analysis are dependent on the modal analysis, without biological support and, therefore, the apparent change in the ratio of the female groups might not be correct. Mean lengths at age, however, were in close agreement with those obtained from the previous analyses of several years of research data.

CONCLUSION

The history of the fishery in Division 0A is now extensive enough to detect trends that might show natural fluctuations in the population or be related to fishing pressure. Some changes are apparent (i.e. decrease in mean size, variable catch rates, changes in sex ratio) but it is not clear how these are related to natural or fishery induced events (i.e. the relative importance of M and F). The data do not reflect any systematic migration or shift in the distribution to southern areas but, if this has occurred over the Subarea as a whole, it could explain some of the perceived fishery effects. Despite these uncertainties, it is clear that no recruitment failures have occurred over the decade and there is no indication of a decrease in the age at sex reversal. Given the presumed high natural mortality and the slow growth of females, growth overfishing also seems unlikely. However, because the offspring of females fished heavily in the late 1980's have not yet entered the fishery and the impact on recruitment cannot be evaluated at this time, catches in the short term (one or two years) throughout Subarea 0+1 should not exceed current levels.

REFERENCES

Carlsson, D. M. 1990. Data and preliminary assessment of shrimp in Subareas 0+1. NAFO SCR Doc. 90/65, Ser. No. N1787: 9p.

MacDonald, J. K., and J. F. Collins. 1990. Canada's Northern Shrimp Industry: An Economic Assessment of the Fishery. Economic and Commercial Analysis Report No. 79: 94p.

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

NAFO. 1990. Scientific Council Reports. pp 96 - 100.

Savard, L., D. G. Parsons, and D. M. Carlsson. 1989. Age and growth of northern shrimp (*Pandalus borealis*) in Davis Strait (NAFO SA 0+1). NAFO SCR Doc. 89/94, Ser. No. N1694: 14p.

TABLE 1. DISTRIBUTION OF CATCH AND EFFORT OBSERVATIONS BY MONTH AND YEAR - NAFO SUBAREAS 0 AND 1, 1979 - 1990

	YR												
	79	80	81	82	83	84	85	86	87	88	89	90	ALL
	N	N	N	N	N	N	N	N	N	N	N	N	N
MON													
4	.	.	.	.	.	1	.	.	.	.	.	.	1
6	.	.	4	.	1	.	2	2	1	1	6	.	17
7	.	2	5	3	6	3	7	4	2	5	12	8	57
8	.	.	6	4	9	4	7	2	8	9	13	12	74
9	1	.	9	5	9	5	4	2	10	8	7	8	68
10	6	.	9	5	9	3	5	3	13	10	12	11	86
11	4	.	8	2	7	1	3	3	1	6	8	9	52
12	3	1	5	.	.	.	.	.	.	1	.	.	10
ALL	14	3	46	19	41	17	28	16	35	40	58	48	365

TABLE 2. SHRIMP CATCH (FROM VESSEL LOGS) BY MONTH/YEAR - NAFO SUBAREA 0+1, 1979 - 1990.

	YR												
	79	80	81	82	83	84	85	86	87	88	89	90	ALL
	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH	CATCH
	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS
MON													
4	.	.	.	.	.	0	.	.	.	.	.	.	0
6	.	.	347	.	17	.	290	309	144	42	480	.	1630
7	.	54	756	373	752	379	924	603	505	763	2021	890	8020
8	.	.	665	650	1241	354	604	363	1157	1284	1234	1199	8752
9	42	.	585	458	798	398	414	241	1183	989	651	852	6611
10	71	.	833	335	992	324	582	242	2252	1294	1208	1036	9169
11	248	.	743	249	257	40	255	604	2	531	607	986	4520
12	16	62	72	.	.	.	.	.	.	7	.	.	156
ALL	376	116	4001	2064	4057	1495	3069	2362	5244	4910	6202	4962	38859

TABLE 3. FISHING EFFORT (FROM VESSEL LOGS) BY MONTH/YEAR - NAFO SUBAREAS 0+1, 1979 - 1990.

	YR												
	79	80	81	82	83	84	85	86	87	88	89	90	ALL
	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT	EFFORT
	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS	HOURS
MON													
4	.	.	.	.	.	4	.	.	.	.	.	.	4
6	.	.	746	.	33	.	597	471	166	59	937	.	3009
7	.	121	1804	617	1928	845	2502	1340	519	1188	5391	2079	18334
8	.	.	2170	1836	4100	1360	2412	995	2341	3237	3738	3745	25934
9	81	.	1968	1504	3151	1641	1784	731	2714	2595	1734	1826	19729
10	325	.	3229	1248	3995	1370	1804	577	4944	2197	3210	2764	25663
11	1072	.	2980	953	1074	129	827	1191	3	1167	1423	2066	12885
12	114	203	483	.	.	.	.	.	.	50	.	.	850
ALL	1592	324	13380	6158	14281	5349	9926	5305	10687	10493	16433	12480	106408

TABLE 4. SHRIMP CPUE (FROM VESSEL LOGS) BY MONTH/YEAR - SUBAREAS 0+1, 1979 - 1990.

	YR											
	79	80	81	82	83	84	85	86	87	88	89	90
	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE
	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR	KG/HR
MON												
4	.	.	.	.	.	122	.	.	.	.	.	.
6	.	.	466	.	508	.	486	656	868	720	513	.
7	.	445	419	604	390	448	369	450	973	642	375	428
8	.	.	306	354	303	260	250	365	494	397	330	320
9	513	.	297	304	253	243	232	330	436	381	375	466
10	218	.	258	268	248	236	323	419	456	589	376	375
11	231	.	249	261	239	311	308	507	522	455	426	477
12	140	306	149	.	.	.	.	.	.	130	.	.

TABLE 5a. DISTRIBUTION OF CATCH AND EFFORT OBSERVATIONS BY HORSE POWER AND YEAR - NAFO SUBAREAS 0 AND 1, 1979 - 1990

	YR												ALL
	79	80	81	82	83	84	85	86	87	88	89	90	
	N	N	N	N	N	N	N	N	N	N	N	N	N
HPOWER2													
1	5	1	15	7	14	3	5	.	.	.	.	.	50
2	.	.	7	.	.	.	.	1	.	.	.	6	14
3	6	.	10	4	13	9	7	.	7	2	3	2	63
4	2	2	7	4	10	.	6	.	3	8	5	.	47
5	.	.	7	4	4	3	7	2	6	11	19	19	82
6	.	.	.	.	.	.	3	7	10	10	16	11	57
7	1	.	.	.	.	2	.	6	9	9	15	10	52
ALL	14	3	46	19	41	17	28	16	35	40	58	48	365

TABLE 5b. DISTRIBUTION OF CATCH AND EFFORT OBSERVATIONS BY TONNAGE CLASS AND YEAR - NAFO SUBAREAS 0 AND 1, 1979 - 1990

	YR												ALL
	79	80	81	82	83	84	85	86	87	88	89	90	
	N	N	N	N	N	N	N	N	N	N	N	N	N
GRT2													
1	.	.	10	2	5	4	5	.	.	.	.	.	26
2	7	1	10	.	7	1	1	1	2	.	.	2	32
3	3	2	21	15	14	2	1	.	2	.	3	5	68
4	4	.	5	2	15	10	13	2	14	21	27	14	127
5	.	.	.	.	.	.	5	7	8	11	10	2	43
6	.	.	.	.	.	.	3	6	9	8	18	25	69
ALL	14	3	46	19	41	17	28	16	35	40	58	48	365

TABLE 6A. STANDARDIZATION OF CPUE - MULTIPLICATIVE, YEAR MONTH VESSEL MODEL, 1981 - 1990

DEP VARIABLE: LNCPUE

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	55	47.53228991	0.86422345	13.633	0.0001
ERROR	291	18.44652198	0.06339011		
C TOTAL	346	65.97881189			

ROOT MSE	0.2517739	R-SQUARE	0.7204
DEP MEAN	5.830763	ADJ R-SQ	0.6676
C.V.	4.318027		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	B	5.84030065	0.17950101	32.536	0.0001
YY81	B	0.30940757	0.08550792	3.618	0.0003
YY82	B	0.49366896	0.10079641	4.898	0.0001
YY83	B	0.21655232	0.07866167	2.753	0.0063
YY84	B	0.15447405	0.10606341	1.456	0.1464
YY85	B	0.04552466	0.10808200	0.421	0.6739
YY86	B	0.14502499	0.09419964	1.540	0.1248
YY87	B	0.41140321	0.06642711	6.193	0.0001
YY88	B	0.29036983	0.06394523	4.541	0.0001
YY89	B	-0.0489874	0.05509387	-0.889	0.3747
YY90	0	0	.	.	.
MON6	B	0.44696808	0.07169702	6.234	0.0001
MON7	B	0.28067553	0.04585009	6.122	0.0001
MON9	B	0.0174768	0.04363914	0.400	0.6891
MON10	B	0.10378801	0.04230254	2.453	0.0147
MON11	B	0.10275596	0.04917212	2.090	0.0375
MON12	B	-0.332541	0.12092872	-2.750	0.0063
MON99	0	0	.	.	.
V1	B	-0.977675	0.21652160	-4.515	0.0001
V4	B	-0.686317	0.20721628	-3.312	0.0010
V5	B	-0.333912	0.19650827	-1.699	0.0903
V7	B	-0.539155	0.26696023	-2.020	0.0443
V10	B	-0.316861	0.20504263	-1.545	0.1233
V11	B	-0.423185	0.21344062	-1.983	0.0483
V12	B	-0.43413	0.19288472	-2.251	0.0251
V13	B	-0.51182	0.20067789	-2.550	0.0113
V14	B	-0.617566	0.21052069	-2.934	0.0036
V15	B	-0.842772	0.20986649	-4.016	0.0001
V16	B	-0.548701	0.22515430	-2.437	0.0154
V17	B	-1.20548	0.25019278	-4.818	0.0001
V18	B	-0.931857	0.26810019	-3.476	0.0006
V19	B	-1.35957	0.27400423	-4.962	0.0001
V20	B	-1.20623	0.27449062	-4.394	0.0001
V21	B	-0.71312	0.19603651	-3.638	0.0003
V22	B	-0.6832	0.27551623	-2.480	0.0137
V23	B	-0.436444	0.24441314	-1.786	0.0752
V24	B	-0.309315	0.23808287	-1.299	0.1949
V25	B	-0.106789	0.21912628	-0.487	0.6264
V26	B	-0.932529	0.25593871	-3.644	0.0003
V27	B	-0.222357	0.23844961	-0.933	0.3518
V28	B	-0.310531	0.23844961	-1.302	0.1938
V29	B	0.01574426	0.19878939	0.079	0.9369
V30	B	-0.0152892	0.20051332	-0.076	0.9393
V31	B	-1.25062	0.32480560	-3.850	0.0001
V32	B	0.16336190	0.19381373	0.843	0.4000
V33	B	-0.516579	0.20137939	-2.565	0.0108
V34	B	0.04935232	0.20623450	0.239	0.8110
V35	B	-0.0534125	0.22655947	-0.236	0.8138
V36	B	0.09070177	0.19992658	0.454	0.6504
V37	B	0.11871934	0.20918034	0.568	0.5708
V38	B	0.05470335	0.19918362	0.275	0.7838
V39	B	0.06346556	0.20097880	0.316	0.7524
V40	B	0.29325196	0.19643960	1.493	0.1366
V41	B	-0.102865	0.19435428	-0.529	0.5970
V42	B	0.0883731	0.21239974	0.416	0.6777
V43	B	0.01430996	0.19794656	0.072	0.9424
V44	B	0.04624629	0.20407286	0.227	0.8209
V47	B	0.22857022	0.21940799	1.042	0.2984
V48	0	0	.	.	.

TABLE 6B. RETRANSFORMED MEAN ANNUAL CATCH RATES FROM STANDARDIZATION.

	LN TRANSFORM			RETRANSFORMED		
SUMMARY	YHAT	YHATVAR	STDERR	MEAN	VARIANCE	STDERR
INTERCEP	5.8403	.0322206	0.1795	349.3027	3881.7	62.3036
YY81	6.1497	0.039573	0.1989	474.2135	8754.7	93.5666
YY82	6.3340	0.042373	0.2058	569.3608	13494.4	116.1655
YY83	6.0569	.0383905	0.1959	432.4193	7066.2	84.0606
YY84	5.9948	.0435381	0.2087	405.3435	7023.5	83.8063
YY85	5.8858	.0439157	0.2096	363.4334	5694.1	75.4593
YY86	5.9853	.0412825	0.2032	401.9861	6557.1	80.9761
YY87	6.2517	.0365073	0.1911	525.9423	9949.8	99.7488
YY88	6.1307	.0362877	0.1905	466.0385	7766.2	88.1262
YY89	5.7913	.0353405	0.1880	332.0834	3842.2	61.9854
YY90	5.8403	.0322206	0.1795	349.3027	3881.7	62.3036

Table 7. Northern shrimp data from the Canadian fishery in NAFO Subareas 0 and 1, 1979 - 1990.

			UNSTANDARDIZED			STANDARDIZED		
YEAR	TAC (T)	CATCH[1] (T)	CPUE (KG/H)	INDEX	EFFORT[2] (HR)	CPUE (KG/H)	INDEX	EFFORT[2] (HR)
1979	2000	1732	236		7339			
1980	2500	2726	358		7615			
1981	5000	5284	299	1.00	17672	474	1.00	11148
1982	5000	2064	335	1.12	6161	569	1.20	3627
1983	5000	5413	284	0.95	19060	432	0.91	12530
1984	5000	2142	280	0.94	7650	405	0.85	5289
1985	6120	3069	309	1.03	9932	363	0.77	8455
1986	6120	2995	445	1.49	6730	402	0.85	7450
1987	6120	6095	491	1.64	12413	526	1.11	11587
1988	6120	5881	468	1.57	12566	466	0.98	12620
1989	7520	7235	377	1.26	19191	332	0.70	21792
1990	7520	6177	398	1.33	15520	349	0.74	17699

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery (MacDonald and Collins, 1990) or vessel logs, whichever is the greater. Division 0A only from 1981 to 1990, inclusive. 1990 data - provisional.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data. Reference month for standardization is August.

Table 8. Proportion of shrimp caught at age, number caught as determined from length frequency distributions, raw and standardized effort. NAFO Division 0A, 1981 - 1990.

AGE	_81	_82	_83	_84	_85	_86	_87	_88	_89	_90
3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01996	0.00000	0.00000
4	0.01871	0.02748	0.00914	0.10876	0.01977	0.03318	0.03811	0.09208	0.05848	0.10615
5	0.04694	0.14793	0.11293	0.24682	0.13606	0.23916	0.14122	0.15892	0.16364	0.35633
6	0.12634	0.14855	0.23693	0.17907	0.19171	0.23765	0.28654	0.22202	0.19985	0.17734
7	0.24170	0.11178	0.28516	0.27915	0.46543	0.39779	0.48196	0.44493	0.41845	0.20797
8	0.56632	0.56426	0.35584	0.18620	0.18703	0.09223	0.05217	0.06210	0.15958	0.15221
TOTAL	1.00001	1.00000	1.00000	1.00000	1.00000	1.00001	1.00000	1.00001	1.00000	1.00000
NUMBER	536029228	212116364	580759573	271942902	352118085	366501813	764997778	742081010	936777376	847666072
EFFORT	17672	6161	19060	7650	9932	6730	12413	12566	19191	15520
ST/EFFORT	11148	3627	12530	5289	8455	7450	11587	12620	21792	17699

Table 9. Number of shrimp caught at age by year. NAFO Division 0A, 1981 - 1990.

AGE	_81	_82	_83	_84	_85	_86	_87	_88	_89	_90
3	0	0	0	0	0	0	0	14811937	0	0
4	10029107	5828958	5308142	29576510	6961375	12160530	29154065	68330819	54782741	89979754
5	25161212	31378374	65585179	67120947	47909187	87652574	108032986	117931514	153294250	302048851
6	67721933	31509886	137599366	48696815	67504558	87099156	219202463	164756826	187214959	150325101
7	129558264	23710367	165609400	75912861	163886320	145790756	368698329	330174104	391994493	176289113
8	303564072	119688780	206657486	50635768	65856645	33802462	39909934	46083231	149490934	129023253
TOTAL	536034588	212116365	580759573	271942901	352118085	366505478	764997777	742088431	936777377	847666072

Table 10. Number of shrimp caught per hour (unstandardized) at age . NAFO Division 0A, 1981 - 1990.

AGE	_81	_82	_83	_84	_85	_86	_87	_88	_89	_90
3	0	0	0	0	0	0	0	1179	0	0
4	568	946	278	3866	701	1807	2349	5438	2855	5798
5	1424	5093	3441	8774	4824	13024	8703	9385	7988	19462
6	3832	5114	7219	6366	6797	12942	17659	13111	9755	9686
7	7331	3848	8689	9923	16501	21663	29703	26275	20426	11359
8	17178	19427	10842	6619	6631	5023	3215	3667	7790	8313
TOTAL	30333	34428	30469	35548	35454	54459	61629	59055	48814	54618

Table 11. Number of shrimp caught per hour (standardized) at age. NAFO Division 0A 1981 - 1990.

AGE	_81	_82	_83	_84	_85	_86	_87	_88	_89	_90
3	0	0	0	0	0	0	0	1174	0	0
4	900	1607	424	5592	823	1632	2516	5414	2514	5084
5	2257	8651	5234	12691	5666	11765	9324	9345	7034	17066
6	6075	8688	10982	9207	7984	11691	18918	13055	8591	8493
7	11622	6537	13217	14353	19383	19569	31820	26163	17988	9960
8	27230	32999	16493	9574	7789	4537	3444	3652	6860	7290
TOTAL	48084	58482	46350	51417	41645	49194	66022	58803	42987	47893

Table 12. Shrimp discards (% of total shrimp catch) in Div. 0A, 1980-90, estimated by observers.

Month	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
May	18.0								0.6		
Jun	15.5	2.7		0.6		4.0	2.2	1.6	1.3	2.1	
Jul	15.7	2.6	2.4	1.6	6.5	2.9	2.3	1.7	1.7	1.7	1.6
Aug	6.0	4.4	3.3	3.0	4.9	3.4	2.4	3.4	1.5	2.8	2.1
Sep	2.5	5.6	3.4	3.3	5.8	2.9	2.2	1.5	2.3	5.6	2.8
Oct		5.7	3.4	4.6	2.8	3.8	1.7	1.8	3.2	3.2	1.7
Nov	0.0	3.3	2.9	5.3	6.0	6.6	2.0	2.0	4.0	3.3	2.1
Dec	1.3	4.2							1.2		
Average[1]	5.26	4.13	3.06	3.22	5.09	3.68	2.12	2.10	2.43	2.93	2.05

[1] Weighted by observed catch in each month.

Table 13. Catch composition from observer data - NAFO Div. OA, 1990.

Species	July WT.(t)	July Percent	August WT.(t)	August Percent	September WT.(t)	September Percent	October WT.(t)	October Percent	November WT.(t)	November Percent
SHARK (NS)	0.770	0.3072			0.800	0.1620	9.650	1.1027	57.48	7.5161
SKATE (NS)	4.120	1.6438	3.850	0.6289	4.149	0.8403	2.616	0.2989	5.36	0.7005
COD	0.330	0.1317	0.210	0.0343	0.385	0.0780	1.642	0.1876	0.63	0.0829
ARCTIC COD	0.736	0.2937	9.313	1.5212	10.095	2.0445	11.435	1.3067	1.56	0.2039
WOLLFISH (NS)	0.396	0.1580	0.610	0.0996	0.332	0.0672	0.913	0.1043	0.66	0.0866
EELPOUTS (NS)	0.677	0.2701	0.877	0.1433	0.471	0.0954	0.611	0.0698	0.94	0.1232
REDFISH (NS)	21.183	8.4517	72.315	11.8124	71.773	14.5360	50.057	5.7202	55.67	7.2801
SCULPINS	1.036	0.4133	2.597	0.4242	2.006	0.4063	8.954	1.0232	3.68	0.4807
G. HALIBUT	3.158	1.2600	9.518	1.5547	12.504	2.5324	16.385	1.8724	8.28	1.0825
SHRIMP (P.B)	216.270	86.2881	500.704	81.7879	378.786	76.7146	767.230	87.6745	616.17	80.5773
OTHER	1.961	0.7824	12.204	1.9935	12.459	2.5233	5.596	0.6395	14.27	1.8661
	250.637		612.198		493.760		875.089		764.69	
									2996.37	

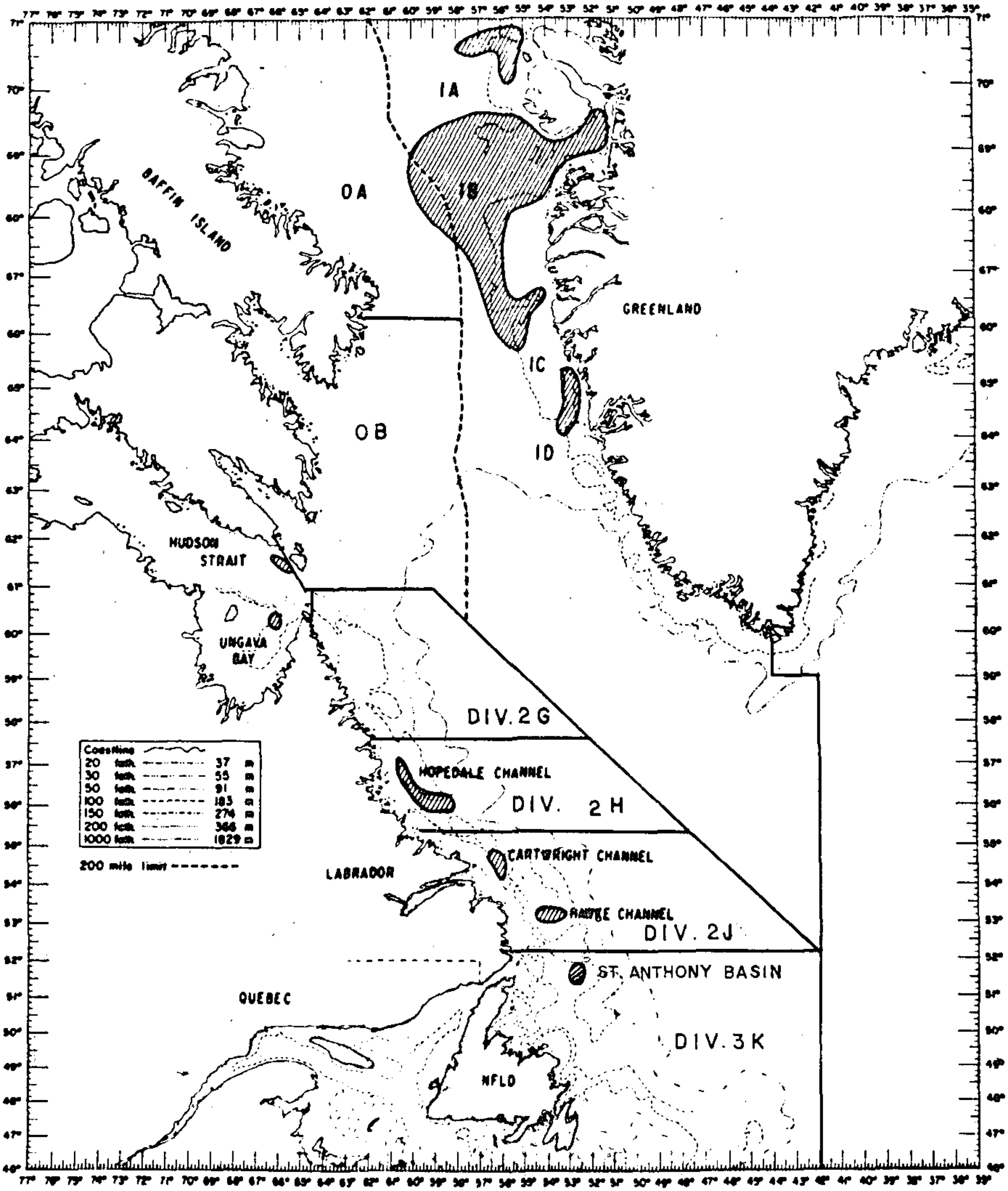


Fig. 1. Area fished for shrimp by Canada in NAFO Division OA.

Fig. 2. Shrimp Catch (T) from Davis Strait 1979-1990, - Canada.

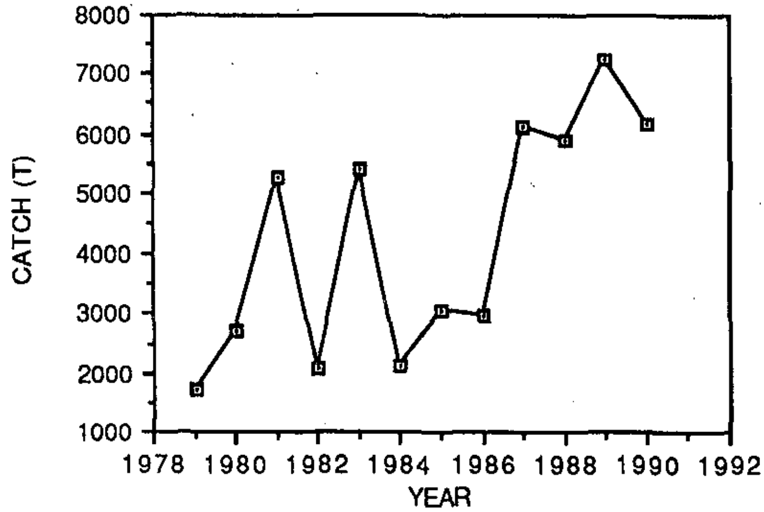


Fig. 3. Total fishing effort (unstandardized) for shrimp in Davis Strait,1979-1990, - Canada.

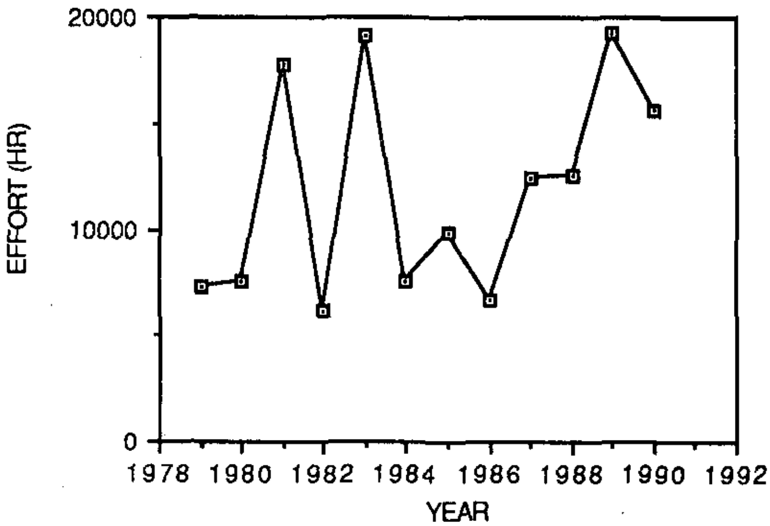


Fig. 4. Catch per hour (unstandardized) for shrimp in Davis Strait.1977-1990, - Canada.

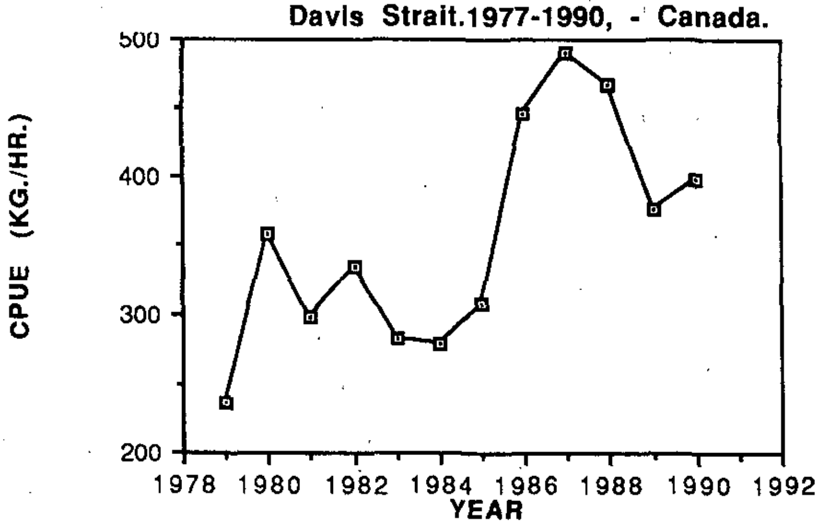


FIG. 5. PLOTS OF RESIDUALS - MULTIPLICATIVE, YEAR MONTH VESSEL MODEL, 1981 - 1990.

UNIVARIATE

VARIABLE=R RESIDUALS

MOMENTS

N	347	SUM WGTS	347
MEAN	3.999E-17	SUM	1.388E-14
STD DEV	0.230897	VARIANCE	0.0533136
SKEWNESS	-0.0561047	KURTOSIS	0.0207676
USS	18.4465	CSS	18.4465
CV	99999	STD MEAN	0.0123952
T:MEAN=0	3.227E-15	PROB>|T|	1
SGN RANK	-221	PROB>|S|	0.906135
NUM ^= 0	347		
D:NORMAL	0.0425479	PROB>D	0.128

QUANTILES(DEF=4)

100% MAX	0.561407	99%	0.53148
75% Q3	0.159811	95%	0.404261
50% MED	-0.0146401	90%	0.295253
25% Q1	-0.146373	10%	-0.284553
0% MIN	-0.748976	5%	-0.346762
		1%	-0.596857
RANGE	1.31038		
Q3-Q1	0.306185		
MODE	-0.748976		

EXTREMES

LOWEST	HIGHEST
-0.748976	0.494853
-0.648535	0.524973
-0.604126	0.537487
-0.588983	0.544405
-0.571905	0.561407

```
            HISTOGRAM                          #        BOXPLOT
 0.55+**                                       4           |
     .*******                                 14           |
     .********                                15           |
     .*******************                     38           |
     .*********************                   42        +-----+
     .************************                48        |     |
     .**********************************      68        *--+--*
     .*****************************           57        +-----+
     .****************                        32           |
     .********                                16           |
     .***                                      6           |
     .**                                       4           |
     .*                                        2           0
-0.75+*                                        1           0
      ----+----+----+----+----+----+----
     * MAY REPRESENT UP TO 2 COUNTS
```

```
                   NORMAL PROBABILITY PLOT
 0.55+                                                  +***
     |                                              *******
     |                                           ****+
     |                                      ******
     |                                  ****
     |                              ****
     |                         ******
     |                    ******
     |               ******
     |          *****+
     |      +***
     |++****
     |**
-0.75+*
      +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

FIG. 6. PLOT OF RESIDUALS AGAINST PREDICTED VALUES - MULTIPLICATIVE, YEAR MONTH VESSEL MODEL, 1981 - 1990

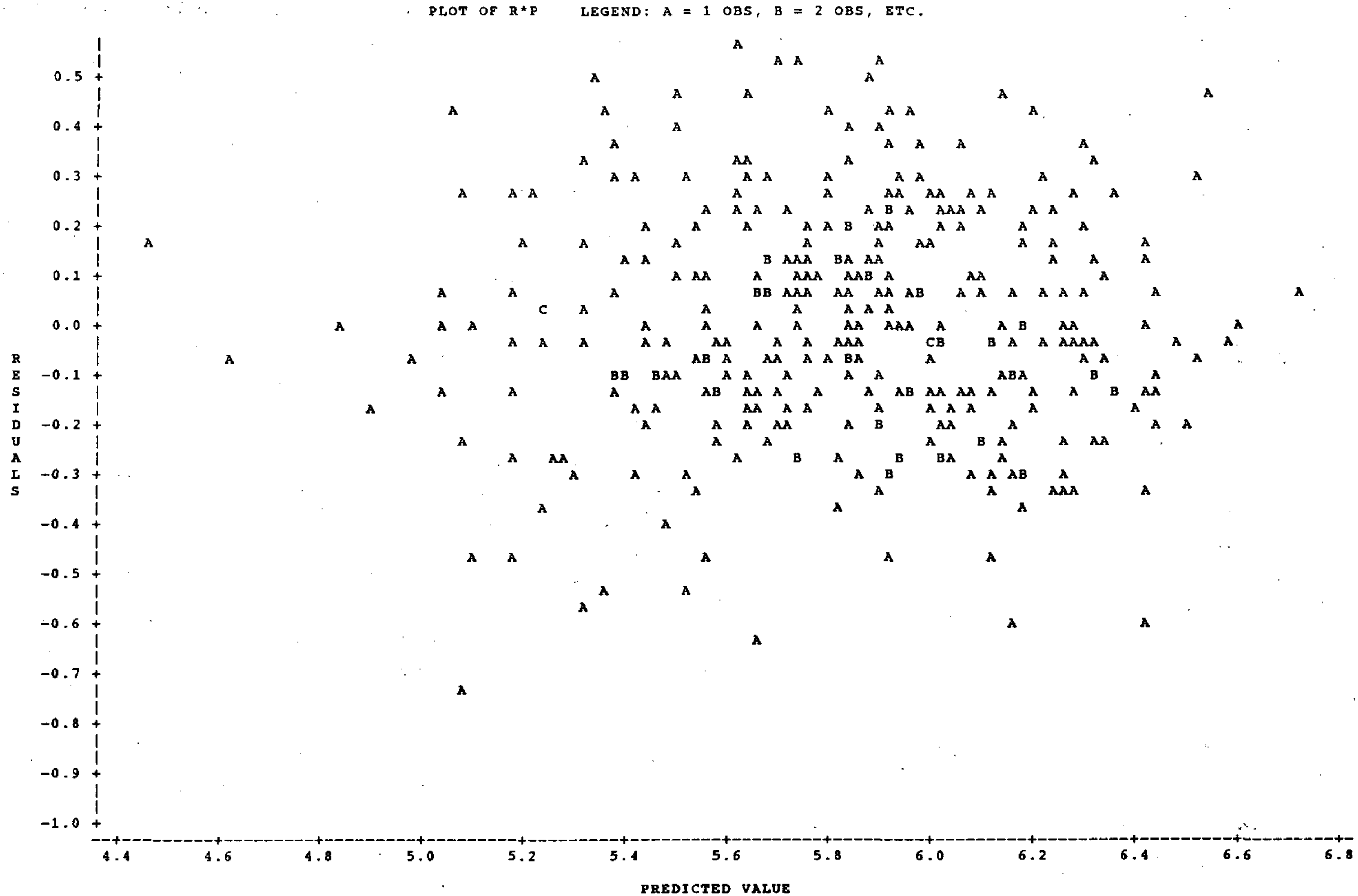


Fig. 7a Catch per hour for shrimp in Davis Strait. 1979-1990, - Canada. (standardized and unstandardized)

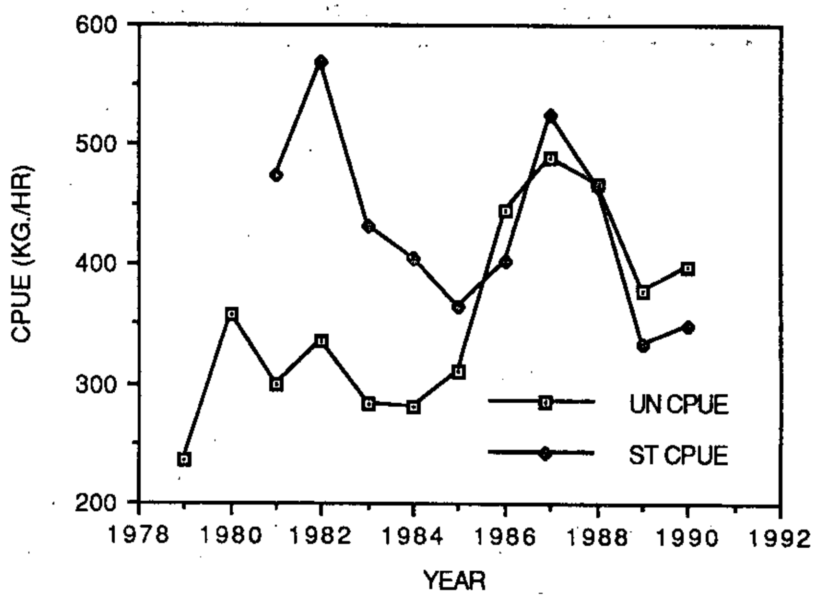


Fig. 7b CPUE Index for shrimp in NAFO Div. OA, 1981-1990. (standardized and unstandardized)

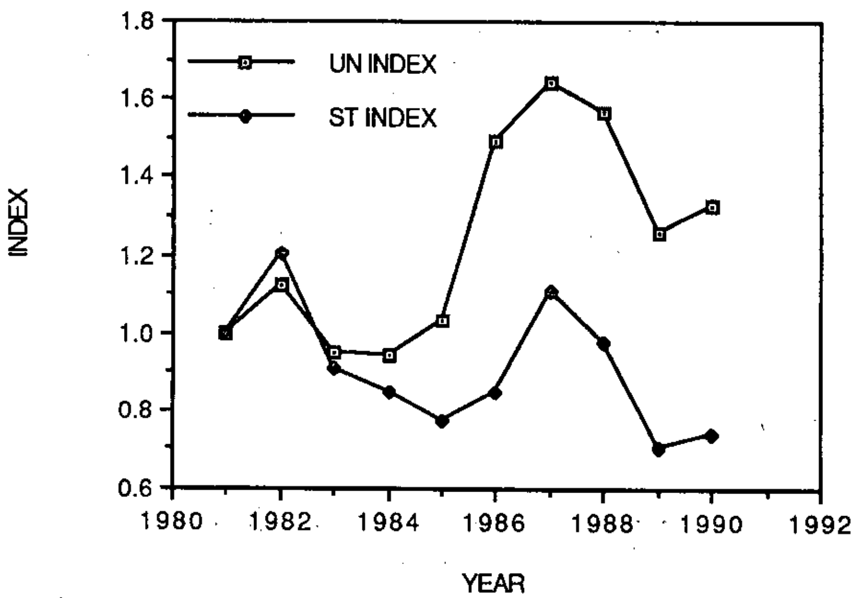


Fig.8a Shrimp catch versus unstandardized fishing effort. Davis Strait, 1979-1990,-Canada.

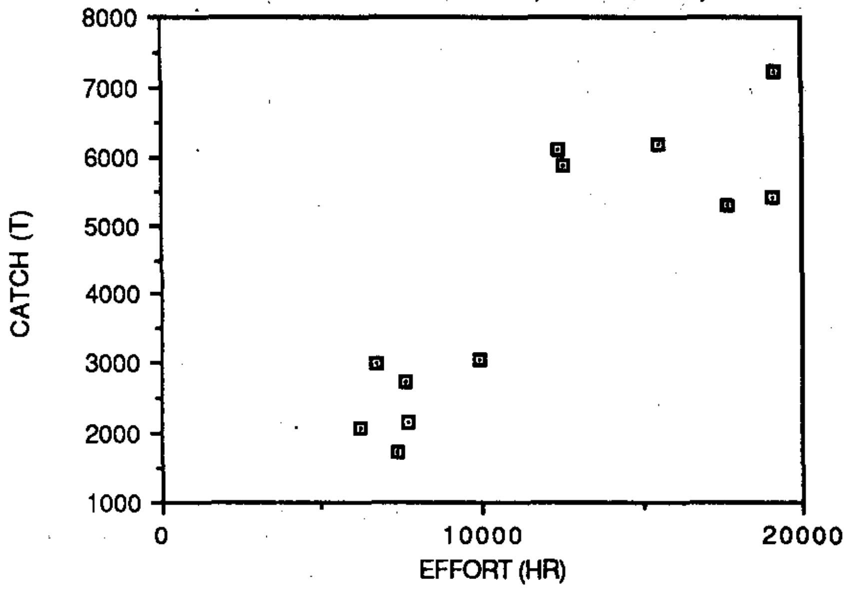


Fig. 8b Shrimp catch versus standardized fishing effort, NAFO Div. OA, 1981-1990.

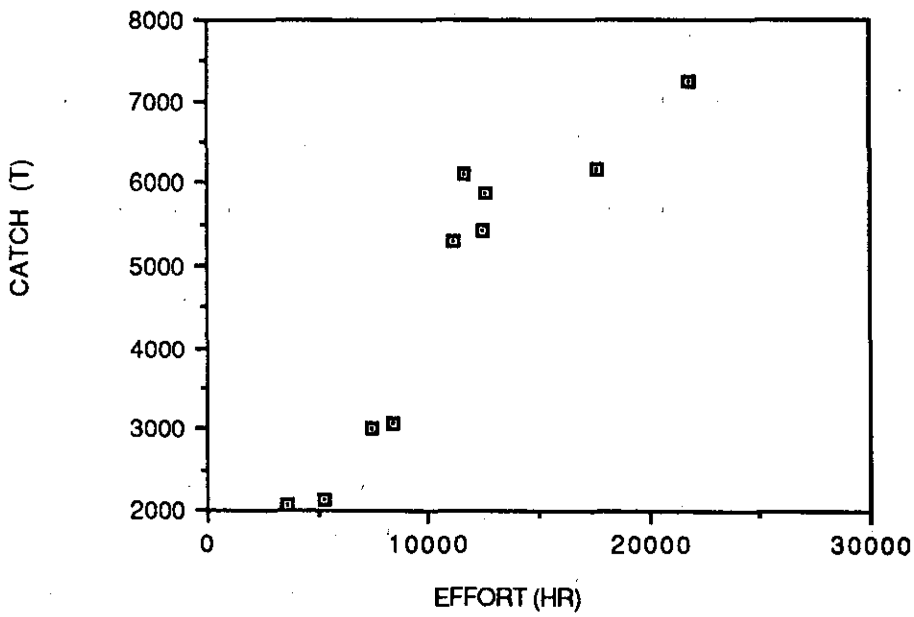


Fig. 9a Shrimp CPUE versus effort
(Unstandardized)
Davis Strait,1979-1990,-Canada.

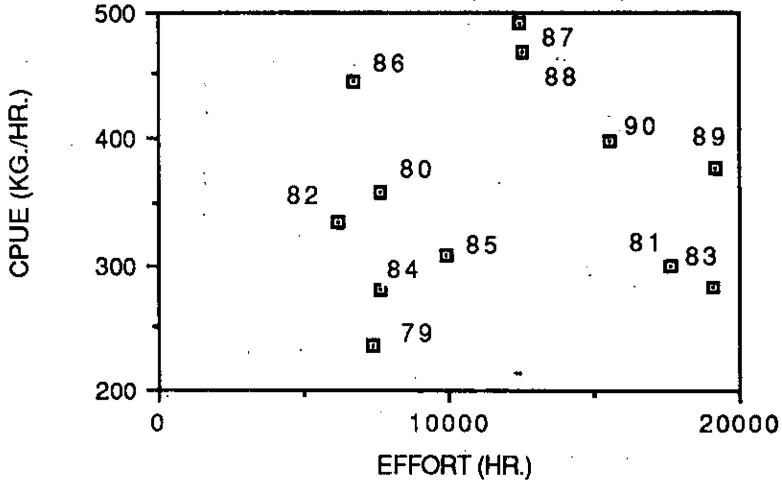


Fig. 9b Shrimp CPUE versus effort
(unstandardized 2 yr. average)
Davis Strait,1980-1990,- Canada.

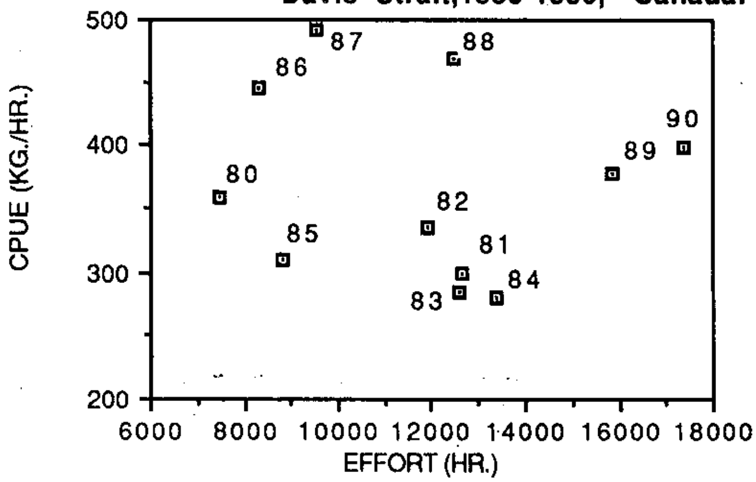


Fig. 9c Shrimp CPUE versus effort
(unstandardized 3 yr. average)
Davis Strait,1981-1990,- Canada.

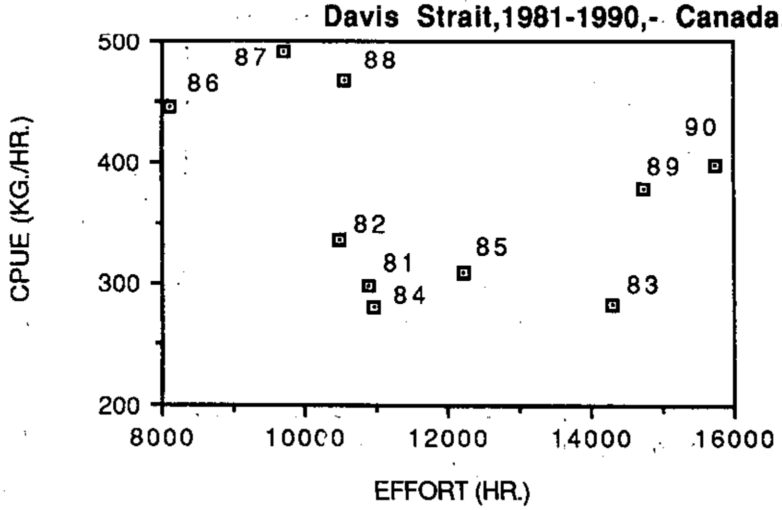


Fig. 10a Shrimp CPUE versus effort (standardized)-NAFO Div. OA, 1981-1990.

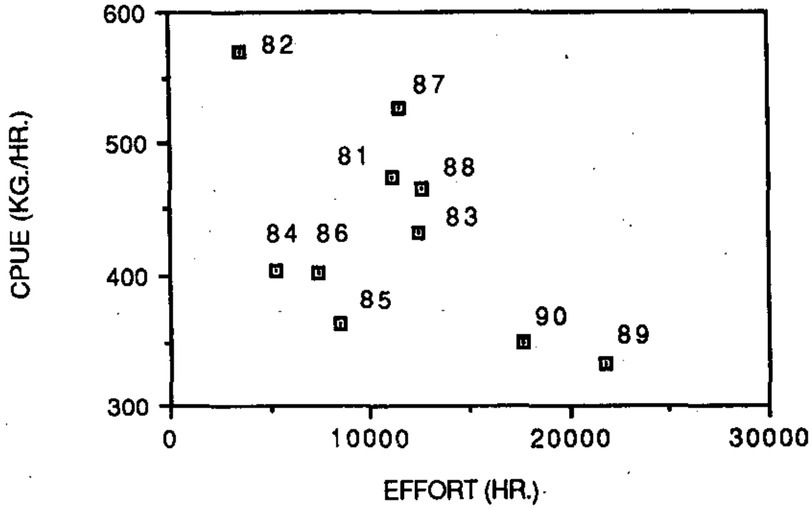


Fig. 10b Shrimp CPUE versus effort (standardized 2 yr. average) NAFO Div. OA,1982-1990.

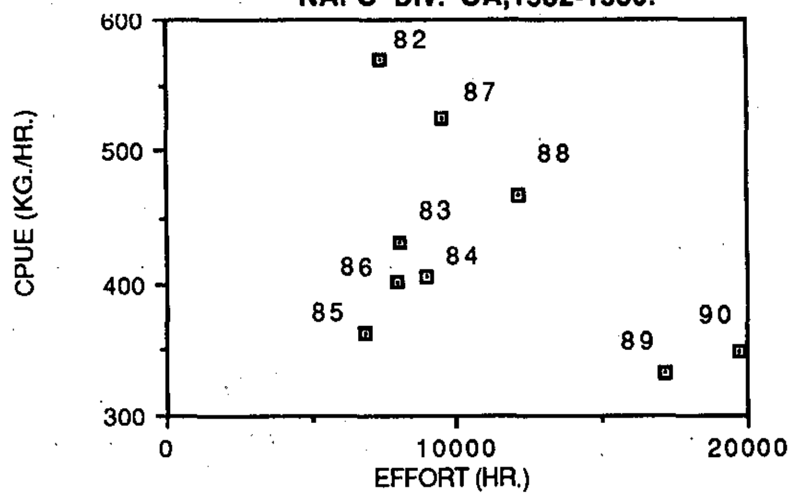
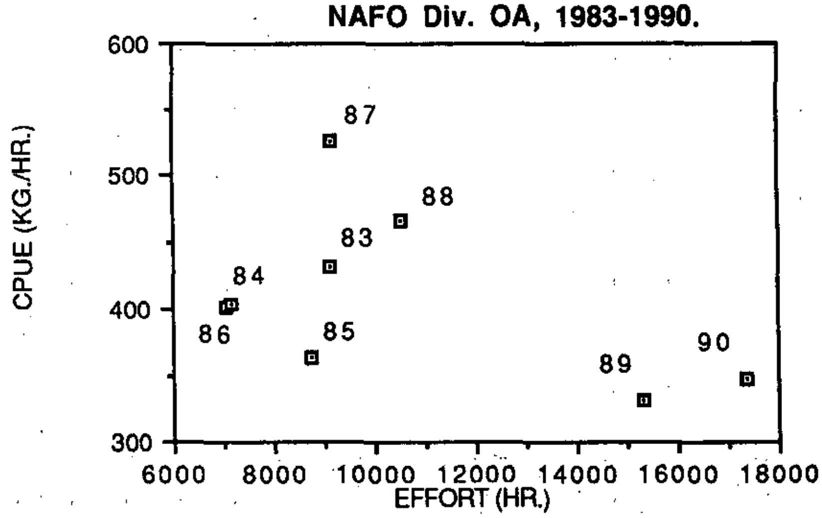


Fig. 10c Shrimp CPUE versus effort (standardized 3 yr. average) NAFO Div. OA, 1983-1990.



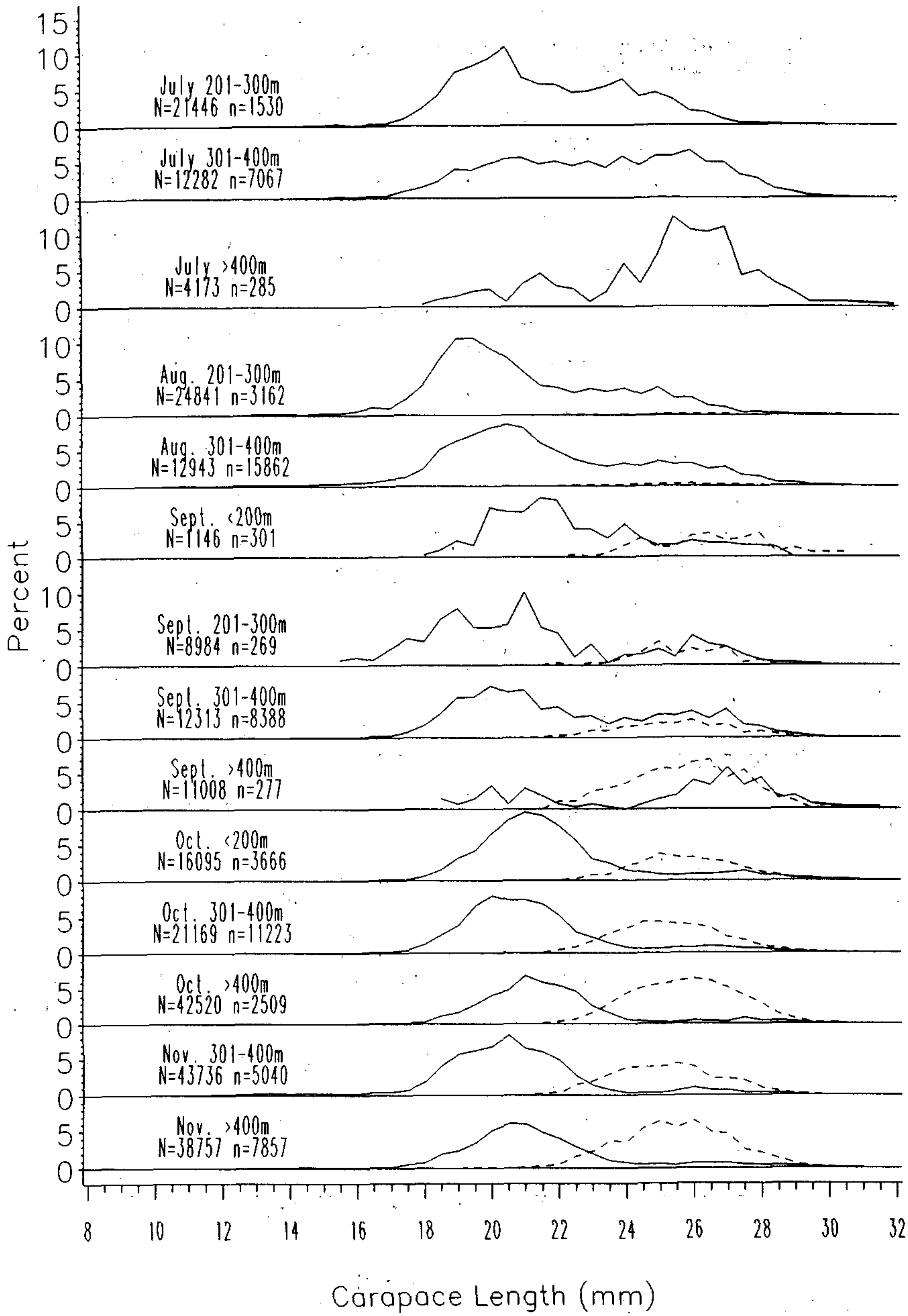


Fig. 11. Commercial length frequencies for shrimp by month and depth, 1990. (N = number per hour, n = number measured, ---- = ovigerous.)

Fig. 12. Percent of shrimp caught at length in the Canadian fishery - NAFO Div. 0A, 1981 - 1990.

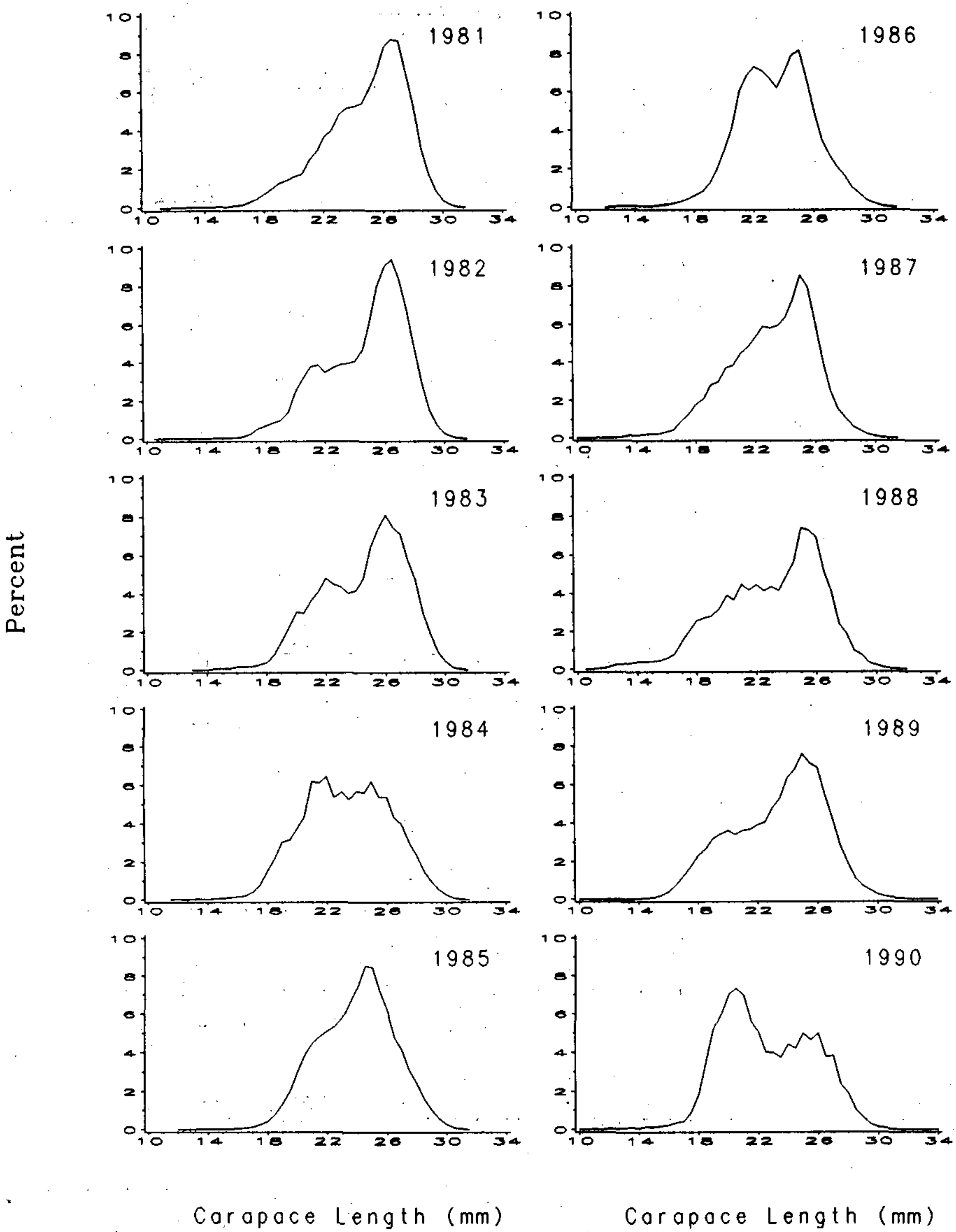
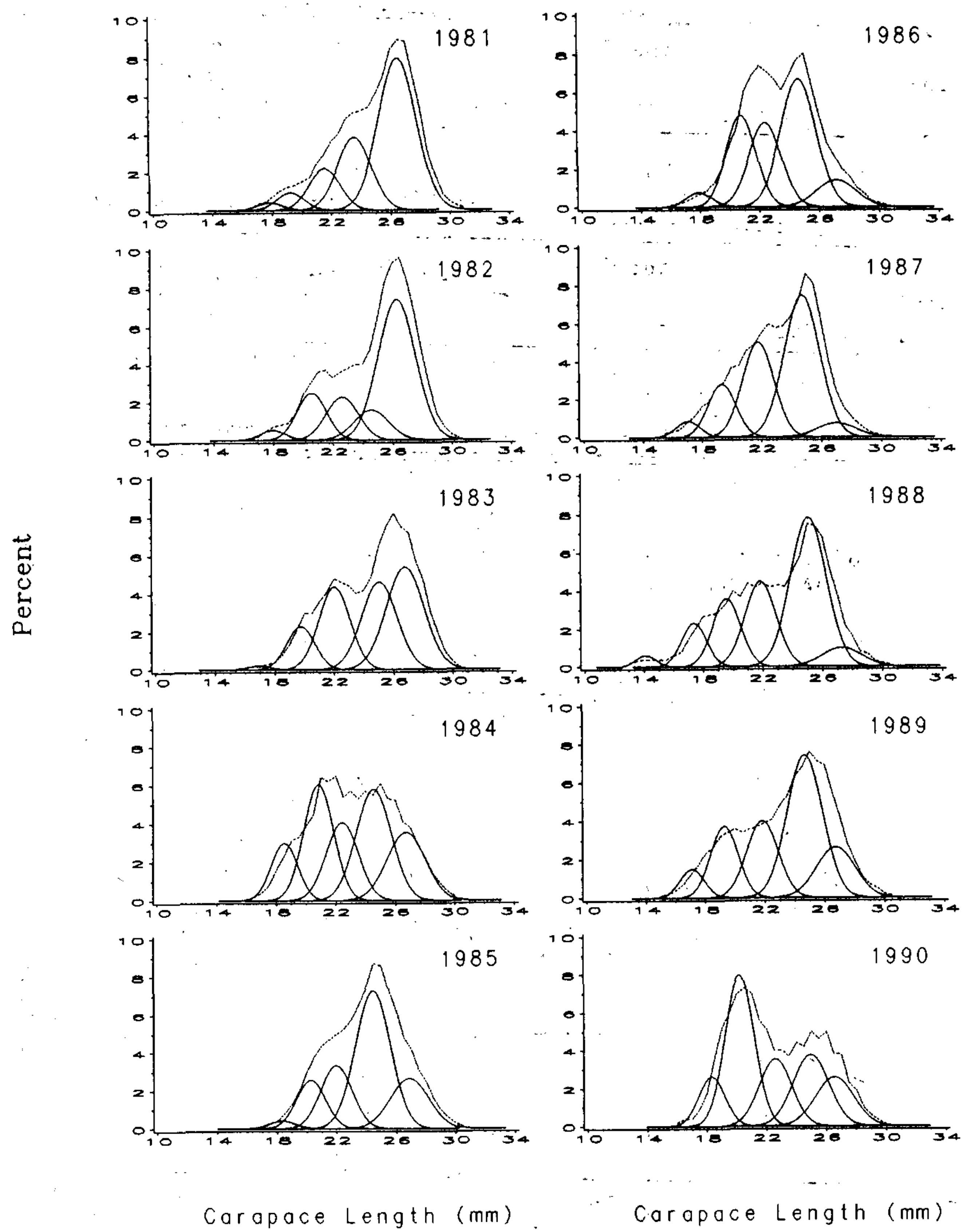


Fig. 13. Separation of ages from commercial length frequency data - NAFO Div. 0A, 1981 - 1990.



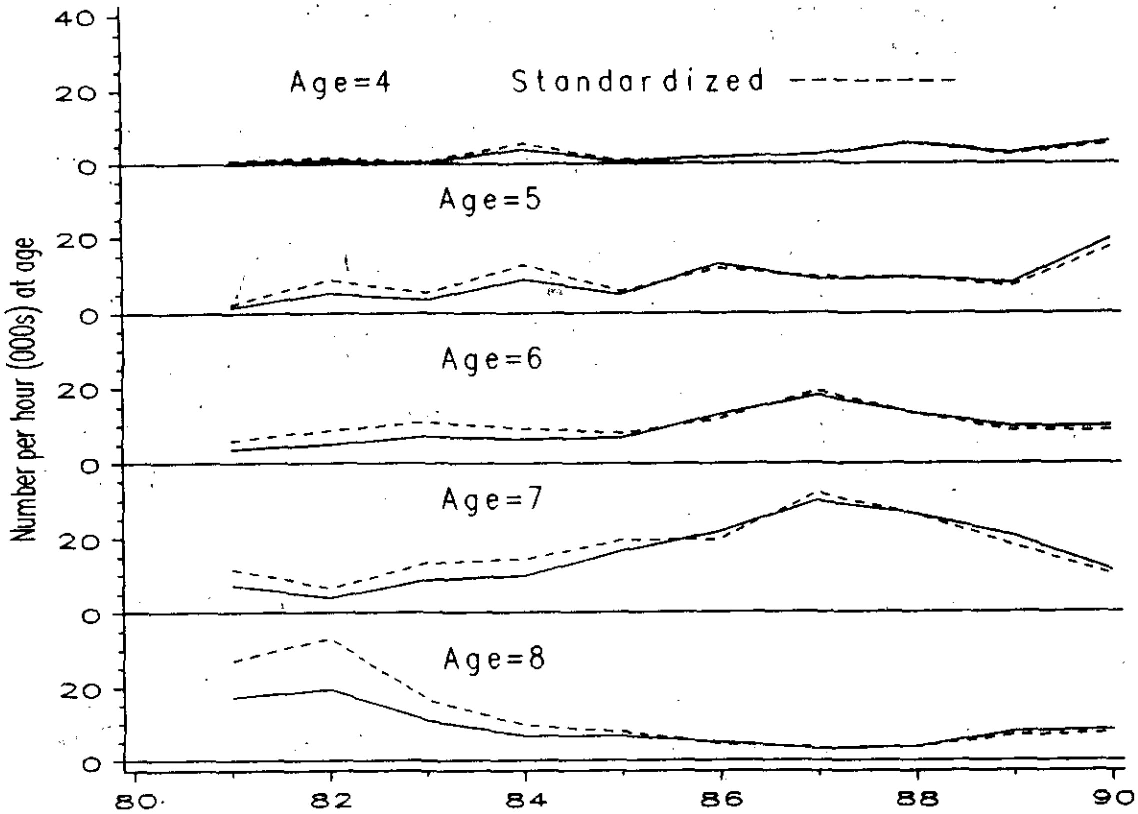


Fig. 14 Number of shrimp caught per hour at age, NAFO Div.0A, 1981-90.

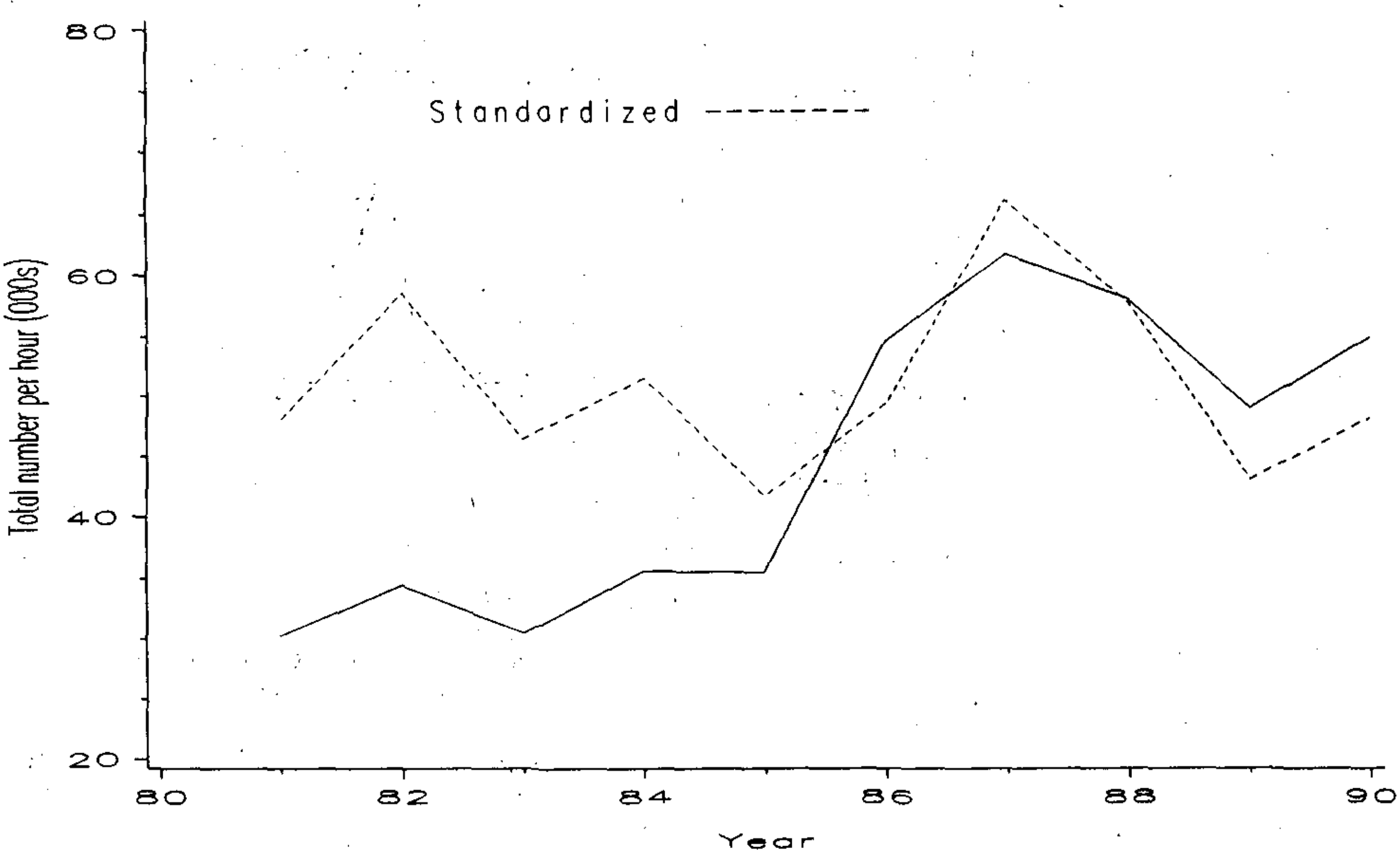


Fig. 15 Number of shrimp caught per hour, NAFO Div.0A, 1981-90.

Fig. 16a Total mortality (Z) versus unstandardized effort for shrimp in NAFO Div. OA, 1981-1989.

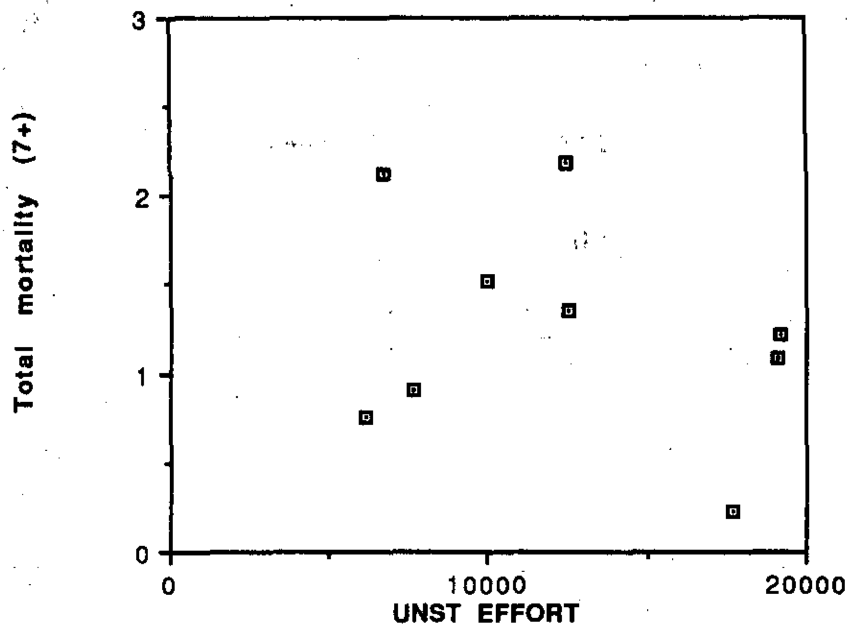


Fig. 16b Total Mortality (Z) versus standardized effort for shrimp in NAFO Div. OA, 1981-1990.