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Analysis of the Fishery Data for Northern Shrimp (*Pandalus borealis*) in Division 0A, 1979-1991

by

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INTRODUCTION

Quota reports (preliminary to December 31, 1991) show that 6788 t of shrimp were taken in Division 0A in 1991, 1712 t less than the TAC of 8500 t and 611 t more than the 1990 catch. The fishery began in the first week of July and continued into the third week of November. Thirteen vessels participated, compared to 14 in 1990. For several years prior to 1991, there were 16 licences in the Canadian northern shrimp fishery; in 1991 the number was increased to 17. The 1992 quota in Division 0A has been set at 8500 t.

Fishing logs from both foreign and domestic vessels were available for 1991, providing data on fleet performance. These were supplemented by observer data which covered most of the fishing activity. Unfortunately, much of the latter have not yet been processed. Available length frequency data obtained by observers in 1991 are included in this analysis. All 1990 data have been updated for comparison with previous years' information and that available for 1991. Catch/effort data and length frequency distributions of shrimp from the 1981 - 1991 commercial catches are compared and information is provided on discards and by catches.

MATERIALS AND METHODS

Catch (kilograms) and effort (hours fished) were compiled from vessel logs for the period 1979 to 1991. Since 1981, fishing has been restricted to NAFO Division 0A in an area extending from about 67° 30′ to 68° 30′ N and 58° to 59° W. The data, from 1981 onward, were summarized by year, month and vessel for effort standardization. Catch and effort were totalled and catch per unit effort (CPUE) calculated within each cell (n = 398). No vessel fished in every year.

Annual CPUE's were calculated two ways:

1. The catch reported in vessel logs from 1979 to 1991 was divided by the corresponding effort, providing unstandardized, weighted, annual catch rates.

2. All data from 1981 to 1991 (except for a single observation in April, 1984) were analyzed for year, month and vessel effects using SAS multiple regression procedures, producing predicted, annual catch rates.

The CPUE data were log (base e) transformed for standardization. Annual log CPUE estimates were retransformed and indexed to 1981. The method is the same as reported by Parsons and Veitch (1991) except that a different vessel was selected as the reference, based on its longevity in the fishery.

Size composition of the 1991 catches sampled by observers were summarized by month. The annual (1981 to 1991) length distributions of total numbers caught 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 monthly catch reported in 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 distributions. The number of age components in the catch and initial estimates of their mean lengths were based on the findings of Savard et al. (1989). Final runs were made with all coefficients of variation held fixed at an average value of 0.048. The rationale for this constraint is described in Parsons and Veitch (1991). Tables were constructed for mean length at age, 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. Catch rates for redfish and Greenland halibut were compared for the period 1981 to 1991. 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 1, 2 and 3, 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. Since 1987, the catch has been higher and less variable while effort has shown an increasing trend (Fig. 1 and 2).

The seasonality of the fishery is evident in the monthly CPUE data (Table 3). 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 was the pattern in 1991 except that, after the increase in October, CPUE declined again in November. Annual, unstandardized catch rates (Fig. 3) were relatively stable up to 1985, increased to a substantially higher level from 1986 to 1988 and declined to intermediate levels from 1989 to 1991.

The results of the multiple regression analysis to standardize the catch rates (Table 4a) show that this model explains 71% of the total variation. All three class variables (year, month and vessel) were highly significant. T-values suggest that 1981, 82, 83, 87 and 88 catch rates were higher than the 1991 estimate ($P < 0.05$) whereas 1984, 85, 86, 89 and 90 were not significantly different from 1991 ($P > 0.05$).

The standardized effort showed the same pattern as the unstandardized series except the increase since 1986 is more pronounced (Fig. 4). The log CPUE values were retransformed (Table 4b) 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 (Fig. 5). Also, the increase in CPUE between 1985 and 1986 is not as great. Both series clearly show a decreasing trend from 1987 to 1991. A complete summary of TAC, catch, effort and CPUE for the Canadian fishery is given in Table 5.

Catch increases with both unstandardized and standardized effort (Fig. 6), but for the former, no substantial increase in catch is seen beyond 12,000 hours. The standardized effort, on the other hand, does suggest continued increases in catch beyond 17,000 hours. Catch rates, standardized and unstandardized, are not clearly related to fishing effort (Fig. 7 and 8). A negative slope is evident, however, for the period 1987 to 1991.

Length distributions

Monthly length frequencies for the sampled catches (Fig. 9) show a prominent size group about 20 to 23 mm CL occurring in July, August and, especially, September. In October and November, ovigerous females comprised a greater proportion of the catch but the male (not ovigerous) component still dominated in these months. The modes of male shrimp representing ages are not clearly represented in the samples because overlap is severe due to the prominence of the mode at 21.5 mm.

Shrimp caught in 1991 were about the same average size as those caught in the previous year (Fig. 10) with the component at 21.5 mm (the 1985 year class) comprising most of the catch. The data show a decrease in the mean length of the female mode (composed of at least two ages) between 1983 and 1985, followed by a period of similar size composition, especially from 1987 to 1989. The length distribution in 1990 showed the relative importance of the 1985 year class (age 5) as it recruited to the fishery. This year class clearly dominated in the 1991 fishery and was strong enough to maintain catch rates at levels similar to the previous two years but substantially lower than in 1987 and 1988.

Previous ageing of research length distributions (Savard et al., 1989) provided estimates of mean lengths at 18.5, 20.6, 22.7, 24.9 and 26.3 mm CL for ages 4 to 8+, respectively. Using these as starting inputs and under the assumption of a fixed coefficient of variation = 0.048 (Parsons and Veitch, 1991), expected counts at length from the modal analysis of the 1981 - 1991 data were virtually identical ($P > 0.98$) to the observed (Fig. 10). Estimated mean lengths (Table 6) were in very good agreement with those from the previous ageing study and showed consistency from year to year. Although this might be expected, given the nature of the analysis, it is worth noting that input lengths are merely starting values and do not dictate what the final estimates will be or if an acceptable solution will be reached.

The estimated proportions of shrimp caught at age from 1981 to 1991 (Table 7) show that the relative contribution of females (ages 7 and 8+) to the catch declined from over 80% in 1981 to 46% in 1984. From 1986 to 1989, females accounted for about half the catch, but subsequently declined in 1990 and 1991 to 41 and 44%, respectively. 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 7 were applied to the total estimated catch numbers to derive a catch at age matrix (Table 8) and these data were subsequently divided by both the standardized and unstandardized fishing effort to produce age-specific indices of abundance (Tables 9 and 10). In 1991, female ages were separated by ages 7 and 8+, based on the results of modal analysis (Parsons and Veitch, 1991). It was cautioned, however, that the separation of female ages should be based on biological sampling data (i.e. the presence or absence of sternal spines) rather than modal analysis. Such biological data are lacking but, based on the samples that are available (D.M. Carlsson, pers. comm.) and on the results of the recent trawl surveys in Davis Strait (Carlsson and Kanneworff, 1991), it appears that the modal analysis did not properly separate the female age groups (D.G. Parsons, unpublished). Since the sampling data are insufficient to correct the time series, female ages are combined as 7+ in this analysis.

Catch rates for ages 4, 5 and 6 (males) show a generally increasing trend over the time series (Fig. 11) with indications (peaks) that relatively strong year classes were produced in 1981 and 1985. The 1985 year class (age 6 in 1991, age 5 in 1990) appears to be the most successful. Ages 7+, representing the female component of the stock, are targeted heavily by the fishery and the trend in the CPUE estimates for these animals resemble the catch rate series from the vessel log data. Particularly evident is the decline from 1987 to 1991.

Mean weight of shrimp caught (total catch weight/total numbers) declined from 9.9 g in 1981 to 7.9 g in 1984, increased to 8.7 g in 1985 and followed a steady decline to 7.4 in 1990. There was a slight increase to 7.6 g in 1991, reflecting the dominance of the 1985 year class in the catches in 1991.

Estimates of total mortality (Z) from the catch-at-age matrix were not possible because shrimp do not appear to be fully recruited till age 7 and there are no data currently available on which to base the separation of female ages 7 and 8+.

Shrimp discards

The percentages of shrimp discards as determined by observers from 1981 to 1991 (Table 11) show that estimates ranged from 2.24 % in 1987 to 5.54 % in 1984. In the years prior to 1986, discard rates were highest, from about 3 to more than 5 %. Percentages were lower from 1986 to 1988 (< 3 %) but increased again during the 1989 - 91 period. No monthly trends are evident in the data but, in the past three years, highest rates of discard occurred in September. There were no size composition data available from the discarded shrimp in 1991 for comparison with the random samples from the catches.

By catches

The observer data on catch composition for each month of the 1991 fishery (Table 12) show that by catch increased from 17 % of the total catch weight of all species in July to 38 % in November. Redfish was the most prevalent fish species in the catches, accounting for approximately 8 to 20 % of the total observed catch weight. Greenland halibut comprised 4 % or less of the catch in each month of the fishery. Typically, the incidence of Greenland sharks increased in November. The catch rates (kg/hour - unstandardized) for redfish and Greenland halibut from 1981 to 1991 are:

	Year										
	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91
Redfish	32	20	9	15	20	85	119	78	72	59	81
Gr. hal.	3	4	5	6	4	8	13	15	12	12	17

Redfish CPUE's increased substantially from 1983 to 1987, then decreased to 1990 but remain well above the levels observed prior to 1986. There was a noticeable increase in 1991. The declining trend from 1987 to 1990 is similar to that observed in the shrimp CPUE series. Catch rates for Greenland halibut show a gradual, increasing trend to 1988 and a period of higher and relatively stable CPUE's from 1987 to 1991. 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

The standardization of CPUE for Div. 0A shows fluctuating catch rates over the eleven year time series with an overall declining trend in the mean values. Two distinct periods of decline are evident - 1982 to 1985 and 1987 to 1991. The latter is also obvious in the unstandardized CPUE series and in the available observer catch rate data (D.G. Parsons, unpublished). The slight increase observed in 1990 was due to the partial recruitment of the 1985 year class which appeared to be strong. Considering the overall variability in the data, standardized catch rates in 1989 and 1990 did not differ substantially from the 1991 value.

A similar pattern is evident in the numbers caught per hour for females (ages 7+), the sizes targeted by the fishery. Animals at these ages are not likely subjected to discarding and this series can be considered comparable to the large shrimp index for Div. 1B (Carlsson and Lassen, 1991) which also showed a decrease from 1987 to 1990. Catch rates of male shrimp (ages 4 to 6), on the other hand, have shown an increasing trend since the early 1980's. This could reflect good recruitment over the long term but could also suggest that the fleet has had to target the younger ages (smaller sizes) to maintain catch rates as abundance of females declined.

Catch at age data indicate that one or more strong year classes were produced in the late 1970's - early 1980's and began to recruit to the fishery in 1984. Subsequently, catch rates increased in 1987 and 1988 but declined thereafter as their numbers were reduced through fishing and natural mortality. In 1988, age 3 males (the 1985 year class) 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 and clearly dominated at age 6 in 1991. Parsons and Veitch (1991) suggested that this year class was only partially recruited in 1990 and should have contributed further, as males, in 1991. It was also stated that catch rates could increase in the short term, similar to the situation in 1987 and 1988. Based on the 1991 catch composition, it appears that, although the 1985 year class is strong, it had little support from adjacent year classes. In 1987, the 1981 year class contributed substantially to the catches as age 6 males but the fishery success that year was mainly due to the high abundance of females (1980 and, to a lesser extent, the 1979 year classes). Catch rates remained high in 1988 when the 1981 year class became fully recruited as females. Although age 6 males in 1991 produced the highest catch rates in the series, age 7+ females produced the lowest. Thus, the 1991 fishery was heavily dependent on the 1985 year class which could only maintain catch rates at or slightly below the level of the previous two years.

The success of the 1992 fishery will also depend on the actual strength of this year class since neither 1984 (older females) or 1986 (oldest males) appear to be particularly strong. Contributing to the cumulative fishing pressure on these animals is the discarding in the Davis Strait fishery that has been orders of magnitude higher than reported in log books (Lehmann and Degel, 1991). Also, at age 7, more will be lost to mortality than gained in growth. NAFO (1991) noted that although the 1985 year class should have been fully selected by the gear in 1990, it was not fully recruited to the fishery. Catch at age data suggest that shrimp are not fully recruited till age 7 but, given the lower abundance of females in both 1990 and 1991, the fleets might have been forced to shift effort towards the smaller animals.

CONCLUSION

Faced with declining catch rates, an apparent decrease in the abundance of females since 1987, and the reliance on one year class to support the fishery in the short term, it is tempting to suggest a reduction in the TAC in Subareas 0+1 for 1993 in order for the stock to recover for future years. However, this might not be effective for two reasons. First, at age 8 in 1993, the 1985 year class would be well past the age at which yield per recruit might be considered. Mortality on females is believed to be high, as most do not survive beyond two years. Therefore, it does not seem appropriate to reduce the TAC with the hope of spreading what will remain of this year class, after 1992, over a period of reduced recruitment. Second, it is not possible at present to determine an appropriate reduction in TAC designed to maintain the spawning (female) biomass at a safe level. The shape of the stock-recruitment relationship has yet to be defined and the few reference points available suggest that year-class strength is related to more than simply the size of the brood stock.

Catch rates in Subareas 0+1 have fluctuated since the fishery began around 1970, probably in response to pulses of above-average recruitment. The problem is, we are not yet able to predict the recruitment in time to make effective management decisions. Advising a reduction in TAC for 1993, on the one hand, would be ineffective for maintaining the 1985 year class while, on the other, is short-sighted given our uncertainty about recruitment in 1993. Any reduction at this time would be purely arbitrary with no biological analysis for support. It might be argued, that a lower, long-term catch level could rebuild the stock and spawning biomass, producing some stability in landings, but this still might not provide the most effective protection for or utilization of the resource.

In order for a reduction in TAC to be more effective, the action should be initiated in 1992 and continued in the short term. In case of concerns for stock-recruitment, however, there would be no assurance that the reduction advised would produce the desired effect.

Recruitment is a vital issue. The 1991 commercial data do not indicate good recruitment, at least for 1992. However, markets for small "industrial" grade shrimp were very poor in 1991 and, at this point, it is uncertain if and how this affected fishing practices and performance.

This analysis again suffers from dealing only with a small proportion of the total stock. Nevertheless, it has been shown that trends in CPUE, size and age composition in Division 0A adequately reflect the events occurring throughout the stock area. Thus, with supporting data from the main fishery in Subarea 1 and the 1991 research survey, the interpretations made from the Canadian fishery data can and should be used in the overall assessment of the resource.

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Table 1. CATCH BY MONTH/YEAR - NAFO DIVISION 0A, 1979 - 1991.

YEAR	79	80	81	82	83	84	85	86	87	88	89	90	91	ALL
	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS	CATCH TONS
MON														
4	.	.	.	.	.	0	.	.	.	.	.	.	.	0
6	.	.	347	.	17	.	290	309	144	42	509	.	.	1659
7	.	54	756	373	752	379	924	603	505	763	2105	890	1003	9107
8	.	.	665	650	1241	354	604	363	1157	1284	1280	1200	1591	10389
9	42	.	585	458	798	398	414	241	1183	989	662	852	792	7413
10	71	.	833	335	992	324	582	242	2252	1294	1264	1214	1233	10637
11	248	.	743	249	257	40	255	604	2	531	607	1157	635	5326
12	16	62	72	.	.	.	.	.	.	7	.	.	.	156
ALL	376	116	4001	2064	4057	1495	3069	2362	5244	4910	6427	5314	5253	44688

Table 2. EFFORT BY MONTH/YEAR - NAFO DIVISION 0A, 1979 - 1991.

YEAR	79	80	81	82	83	84	85	86	87	88	89	90	91	ALL
	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT HOURS	EFFORT 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	1906	20240
8	.	.	2170	1836	4100	1360	2412	995	2341	3237	3738	3745	5482	31416
9	81	.	1968	1504	3151	1641	1784	731	2714	2595	1734	1826	3028	22757
10	325	.	3229	1248	3995	1370	1804	577	4944	2197	3210	3089	3233	29221
11	1072	.	2980	953	1074	129	827	1191	3	1167	1423	2370	2215	15404
12	114	203	483	.	.	.	.	.	.	50	.	.	.	850
ALL	1592	324	13380	6158	14281	5349	9926	5305	10687	10493	16433	13109	15864	122901

Table 3. CPUE BY MONTH/YEAR - NAFO DIVISION 0A, 1979 - 1991.

YEAR	79	80	81	82	83	84	85	86	87	88	89	90	91
	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR	CPUE KG/HR
MON													
4	.	.	.	.	.	122	.	.	.	.	.	.	.
6	.	.	466	.	508	.	486	656	868	720	543	.	.
7	.	445	419	604	390	448	369	450	973	642	391	428	526
8	.	.	306	354	303	260	250	365	494	397	342	321	290
9	513	.	297	304	253	243	232	330	436	381	382	466	261
10	218	.	258	268	248	236	323	419	456	589	394	393	381
11	231	.	249	261	239	311	308	507	522	455	426	488	287
12	140	306	149	.	.	.	.	.	.	130	.	.	.

TABLE 4A. STANDARDIZATION OF CPUE - MULTIPLICATIVE, YEAR-MONTH-VESSEL MODEL, 1981 - 1991.

DEP VARIABLE: LNCPUE

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	59	47.17798882	0.79962693	14.213	0.0001
ERROR	338	19.01578916	0.05625973		
C TOTAL	397	66.19377798			

ROOT MSE	0.2371913	R-SQUARE	0.7127
DEP MEAN	5.836357	ADJ R-SQ	0.6626
C.V.	4.06403		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	B	5.39527012	0.06748172	79.952	0.0001
YY81	B	0.29466622	0.08069395	3.652	0.0003
YY82	B	0.46681535	0.09432823	4.949	0.0001
YY83	B	0.17555269	0.07358021	2.386	0.0176
YY84	B	0.14884086	0.09924381	1.500	0.1346
YY85	B	0.01152277	0.10153912	0.113	0.9097
YY86	B	0.15544747	0.08907502	1.745	0.0819
YY87	B	0.43162418	0.06358046	6.789	0.0001
YY88	B	0.30436701	0.06122188	4.972	0.0001
YY89	B	0.06001071	0.0539496	1.112	0.2668
YY90	B	0.10384115	0.0534094	1.944	0.0527
YY91	0	0	.	.	.
MON6	B	0.46958254	0.06669668	7.041	0.0001
MON7	B	0.29458746	0.04030179	7.310	0.0001
MON9	B	0.02427174	0.03824069	0.635	0.5260
MON10	B	0.11744816	0.03674978	3.196	0.0015
MON11	B	0.07680278	0.04207165	1.826	0.0688
MON12	B	-0.385842	0.11315949	-3.410	0.0007
MON99	0	0	.	.	.
V1	B	-0.505355	0.10552110	-4.789	0.0001
V4	B	-0.220312	0.08793313	-2.505	0.0127
V5	B	0.09923454	0.06988179	1.420	0.1565
V7	B	-0.0827807	0.18144074	-0.456	0.6485
V10	B	0.15286248	0.08305861	1.840	0.0666
V11	B	0.03859558	0.09974559	0.387	0.6990
V13	B	-0.0722351	0.08050791	-0.897	0.3702
V14	B	-0.139875	0.09382889	-1.491	0.1370
V15	B	-0.369432	0.09281016	-3.981	0.0001
V16	B	-0.0730426	0.11879385	-0.615	0.5391
V17	B	-0.723843	0.15748936	-4.596	0.0001
V18	B	-0.482313	0.18184038	-2.652	0.0084
V19	B	-0.860168	0.18936669	-4.542	0.0001
V20	B	-0.728198	0.18875347	-3.858	0.0001
V21	B	-0.0516203	0.07105564	-0.726	0.4680
V22	B	-0.242764	0.18989115	-1.278	0.2020
V23	B	0.01559471	0.14798452	0.105	0.9161
V24	B	0.15832136	0.14030705	1.128	0.2600
V25	B	0.34238901	0.11381567	3.008	0.0028
V26	B	-0.464952	0.16559773	-2.808	0.0053
V27	B	0.25499229	0.14068121	1.813	0.0708
V28	B	0.16681897	0.14068121	1.186	0.2365
V29	B	0.45574427	0.07754868	5.877	0.0001
V30	B	0.37394371	0.09061401	4.127	0.0001
V31	B	-0.829671	0.25282238	-3.282	0.0011
V32	B	0.54385529	0.0780542	6.968	0.0001
V33	B	-0.0757118	0.0822215	-0.921	0.3578
V34	B	0.43445435	0.09925135	4.377	0.0001
V35	B	0.37095108	0.13127071	2.826	0.0050
V36	B	0.47565162	0.08658128	5.494	0.0001
V37	B	0.49044317	0.10502925	4.670	0.0001
V38	B	0.39543593	0.09642993	4.101	0.0001
V39	B	0.37703049	0.08555046	4.407	0.0001
V40	B	0.63432604	0.08108628	7.823	0.0001
V41	B	0.23952355	0.07562254	3.167	0.0017
V42	B	0.55729836	0.09658765	5.770	0.0001
V43	B	0.27610591	0.08212526	3.362	0.0009
V44	B	0.43459262	0.09287295	4.679	0.0001
V47	B	0.46597690	0.10163403	4.585	0.0001
V48	B	0.33423341	0.17936423	1.863	0.0633
V57	B	0.19476902	0.13483711	1.444	0.1495
V58	B	0.47785545	0.13498292	3.540	0.0005
V59	B	0.13401819	0.15157600	0.884	0.3772
V99	0	0	.	.	.

TABLE 4B. RETRANSFORMED MEAN ANNUAL CATCH RATES FROM STANDARDIZATION.

SUMMARY	LN TRANSFORM YHAT	YHATVAR	STDERR	RETRANSFORMED MEAN	VARIANCE	STDERR
INTERCEP	5.3953	.0045538	.0674817	226.1530	233.1713	15.2699
YY81	5.6899	.0050697	.0712021	303.5721	467.6218	21.6246
YY82	5.8621	.0071519	.0845689	360.2232	927.8910	30.4613
YY83	5.5708	.0041814	0.064664	269.6033	304.3367	17.4452
YY84	5.5441	.0080134	.0895175	261.9928	549.7178	23.4461
YY85	5.4068	.0086576	.0930465	228.3035	450.8473	21.2332
YY86	5.5507	.0076072	.0872192	263.7832	529.1171	23.0025
YY87	5.8269	.0042963	.0655465	348.2656	521.7645	22.8422
YY88	5.6996	.0041675	.0645562	306.6702	392.4656	19.8107
YY89	5.4553	.0042387	.0651051	240.1781	244.8292	15.6470
YY90	5.4991	.0042861	.0654684	250.9334	270.2315	16.4387
YY91	5.3953	.0045538	.0674817	226.1530	233.1713	15.2699

Table 5. Northern shrimp data from the Canadian fishery in NAFO Subareas 0 and 1, 1979 - 1991.

YEAR	TAC (T)	CATCH[1] (T)	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED INDEX	UNSTANDARDIZED EFFORT[2] (HR)	STANDARDIZED CPUE (KG/H)	STANDARDIZED INDEX	STANDARDIZED EFFORT[2] (HR)
1979	2000	1732	236		7339			
1980	2500	2726	358		7615			
1981	5000	5284	299	1.00	17672	304	1.00	17382
1982	5000	2064	335	1.12	6161	360	1.18	5733
1983	5000	5413	284	0.95	19060	270	0.89	20048
1984	5000	2142	280	0.94	7650	262	0.86	8176
1985	6120	3069	309	1.03	9932	228	0.75	13461
1986	6120	2995	445	1.49	6730	264	0.87	11345
1987	6120	6095	491	1.64	12413	348	1.14	17514
1988	6120	5881	468	1.57	12566	307	1.01	19156
1989	7520	7235	391	1.31	18504	240	0.79	30146
1990	7520	6177	405	1.35	15252	251	0.83	24610
1991	8500	6788	331	1.11	20508	226	0.74	30035

[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 and 1991 data - provisional.

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

Table 6. Mean carapace length (mm) at age for shrimp in NAFO Division 0A, 1981 - 1991.

AGE	_81	_82	_83	_84	_85	_86	_87	_88	_89	_90	_91
3	-	-	-	-	-	-	-	14.62	-	-	-
4	18.32	18.48	17.43	19.03	18.86	18.38	17.59	17.87	17.51	18.88	17.65
5	19.73	21.08	20.23	21.33	20.76	21.26	19.85	20.05	19.76	20.68	19.69
6	22.03	23.13	22.51	22.92	22.47	22.87	22.30	22.34	22.31	22.92	21.68
7	24.06	25.09	25.53	25.04	24.92	25.11	25.25	25.56	25.17	25.46	24.35
8+	26.97	26.82	27.27	27.22	27.38	27.61	27.54	27.80	27.22	27.29	27.12

Table 7. Proportion of shrimp caught at age as determined from commercial length frequency distributions - NAFO Division 0A, 1981 - 1991.

AGE	_81	_82	_83	_84	_85	_86	_87	_88	_89	_90	_91
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000
4	0.019	0.027	0.009	0.109	0.020	0.033	0.038	0.092	0.058	0.072	0.037
5	0.047	0.148	0.113	0.247	0.136	0.239	0.141	0.159	0.164	0.329	0.049
6	0.126	0.149	0.237	0.179	0.192	0.238	0.287	0.222	0.200	0.183	0.467
7	0.242	0.112	0.285	0.279	0.465	0.398	0.482	0.445	0.418	0.259	0.270
8+	0.566	0.564	0.356	0.186	0.187	0.092	0.052	0.062	0.160	0.158	0.177
TOT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.000

Table 8. Number of shrimp caught at age by year, (x 10 -³), unstandardized and standardized effort (hours fished) - NAFO Division 0A, 1981 - 1991.

AGE	81	82	83	84	85	86	87	88	89	90	91
3	0	0	0	0	0	0	0	14842	0	0	0
4	10185	5727	5227	29642	7042	12095	29070	68271	54333	60221	33232
5	25193	31393	65626	67170	47888	87594	107865	117991	153631	275177	44010
6	67540	31605	137640	48678	67607	87227	219554	164742	187355	153062	419442
7+	433111	143390	372267	126453	229581	179586	408509	376235	541457	348781	401479
TOTAL	536029	212115	580760	271943	352118	366502	764998	742081	936776	837241	898163
UNST f	17672	6161	19060	7650	9932	6730	12413	12566	18504	15252	20508
STAN f	17382	5733	20048	8176	13461	11345	17514	19156	30146	24610	30035

Table 9. Number of shrimp caught per hour (unstandardized) at age - NAFO Division 0A, 1981 - 1991.

AGE	81	82	83	84	85	86	87	88	89	90	91
3	0	0	0	0	0	0	0	1181	0	0	0
4	576	930	274	3875	709	1797	2342	5433	2936	3948	1620
5	1426	5095	3443	8780	4822	13015	8690	9390	8303	18042	2146
6	3822	5130	7221	6363	6807	12961	17687	13110	10125	10036	20453
7+	24508	23274	19531	16530	23115	26684	32910	29941	29262	22868	19577
TOTAL	30332	34429	30469	35548	35453	54457	61629	59055	50626	54894	43796

Table 10. Number of *shrimp* caught per hour (standardized) at age - NAFO Division 0A, 1981 - 1991.

AGE	81	82	83	84	85	86	87	88	89	90	91
3	0	0	0	0	0	0	0	775	0	0	0
4	586	999	261	3625	523	1066	1660	3564	1802	2447	1106
5	1449	5476	3273	8216	3558	7721	6159	6159	5096	11182	1465
6	3886	5513	6866	5954	5022	7689	12536	8600	6215	6220	13965
7+	24917	25011	18569	15466	17055	15830	23325	19641	17961	14172	13367
TOTAL	30838	36999	28969	33261	26158	32306	43680	38739	31074	34021	29903

Table 11. Shrimp discards (% of total shrimp catch) in Div. 0A, 1981-91, estimated by observers.

Month	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
May								0.7			
Jun	2.9		0.5		4.2	2.4	1.9	1.3	2.3		
Jul	2.7	2.6	1.6	6.9	3.1	2.4	1.8	1.8	1.9	9.8	3.2
Aug	4.6	3.5	3.0	5.4	3.6	2.6	3.5	1.6	3.1	4.8	4.4
Sep	5.8	3.6	3.6	6.1	3.2	2.2	1.6	2.5	6.2	5.2	4.8
Oct	5.8	3.7	5.2	3.3	4.0	2.0	2.1	3.3	3.5	2.4	3.6
Nov	3.6	3.3	5.8	6.7	2.4	2.3	2.0	4.2	3.6	2.2	2.7
Dec	3.3							1.2			
Mean[1]	4.31	3.30	3.41	5.54	3.48	2.31	2.24	2.57	3.26	4.36	3.78

[1] Weighted by observed catch in each month.

Table 12. By catch information from observer data for Div.0A, 1991.

Species	July		August		September		October		November	
	WT.(t)	%	WT.(t)	%	WT.(t)	%	WT.(t)	%	WT.(t)	%
SHARK (NS)	0.500	0.517	2.250	0.219	2.500	0.732	9.285	0.820	105.285	11.561
SKATE (NS)	0.791	0.818	10.591	1.029	3.612	1.058	10.267	0.907	12.065	1.325
COD	0.061	0.063	1.532	0.149	0.612	0.179	0.916	0.081	0.581	0.064
ARCTIC COD	1.415	1.462	9.530	0.926	2.504	0.733	7.581	0.670	4.749	0.521
WOLFFISH (NS)	0.158	0.163	1.527	0.148	0.312	0.091	0.642	0.057	0.551	0.061
EELPOUTS (NS)	0.221	0.228	1.821	0.177	0.807	0.236	1.708	0.151	0.978	0.107
REDFISH (NS)	7.820	8.082	122.188	11.867	51.901	15.196	226.218	19.987	160.942	17.673
SCULPINS	1.915	1.979	19.714	1.915	4.233	1.239	9.082	0.802	7.974	0.876
LUMPFISHES	.	.	.	.	.	.	0.046	0.004	0.004	0.000
G. HALIBUT	3.245	3.354	31.286	3.039	9.025	2.642	45.916	4.057	33.013	3.625
SHRIMP (P.B)	79.967	82.647	821.478	79.784	264.159	77.342	790.291	69.826	564.811	62.022
OTHER	0.664	0.686	7.715	0.749	1.883	0.551	29.855	2.638	19.707	2.164
Total	96.757	100.000	1029.63	100.000	341.548	100.000	1131.81	100.000	910.660	100.000

NAFO Div. 0A, 1979-1991

Fig. 1 Catch per year.

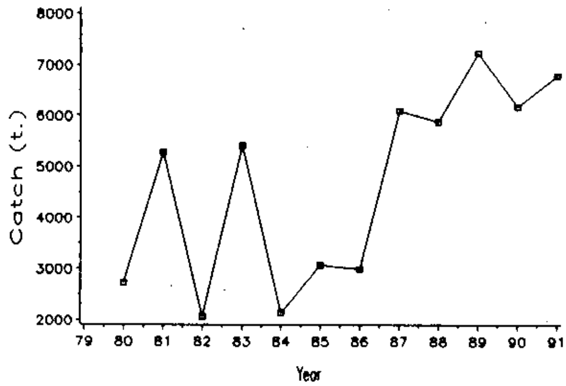


Fig. 2 Unstandardized effort per year.

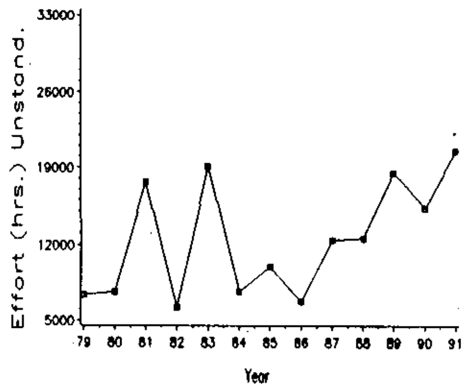


Fig. 4 Standardized effort per year.

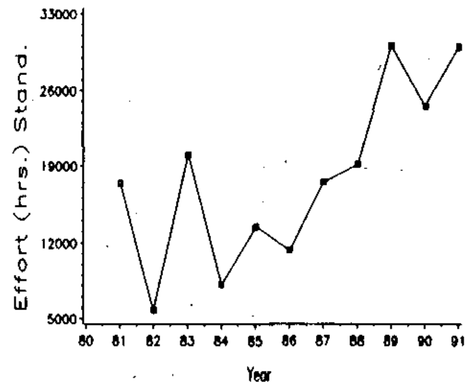


Fig. 3 CPUE (unstandardized) per year.

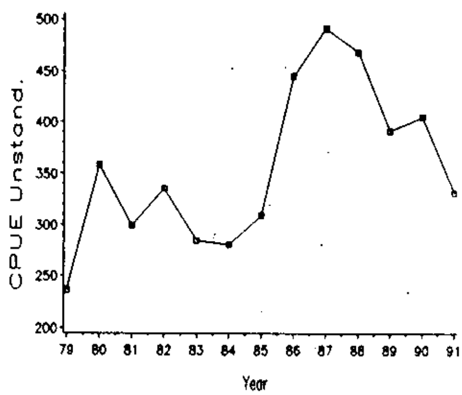
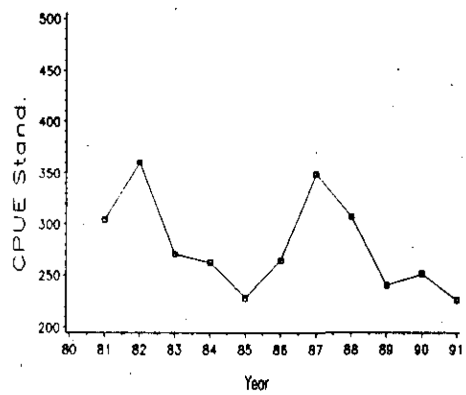


Fig. 5 CPUE (standardized) per year.



NAFO Div. 0A,1979-1991

Fig.6a Shrimp catch vs. unstandardized fishing effort

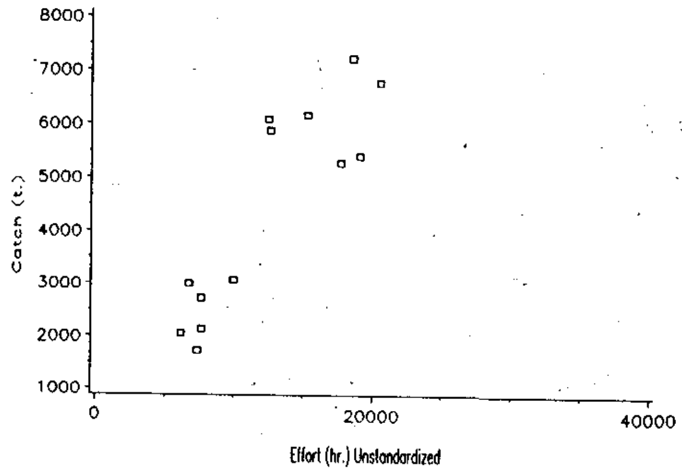
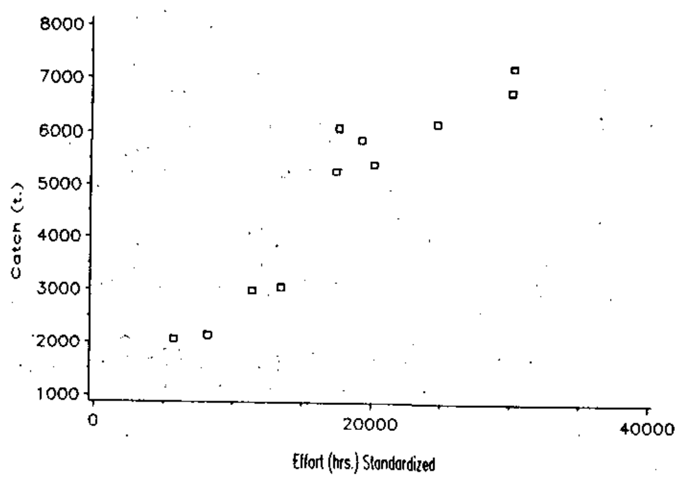


Fig.6b Shrimp catch vs. standardized fishing effort



NAFO Div. 0A, 1979-1991

Fig.7a. CPUE vs. effort (Unstandardized)

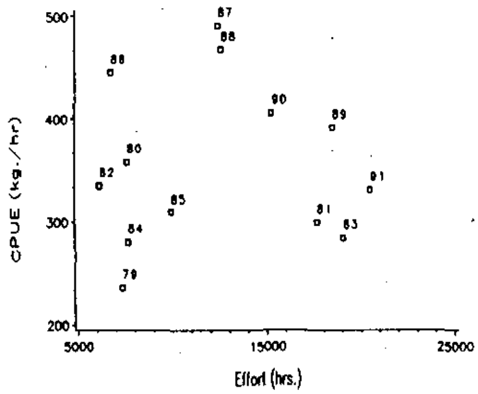


Fig.7b. CPUE vs. effort (Unstandardized 2 year average)

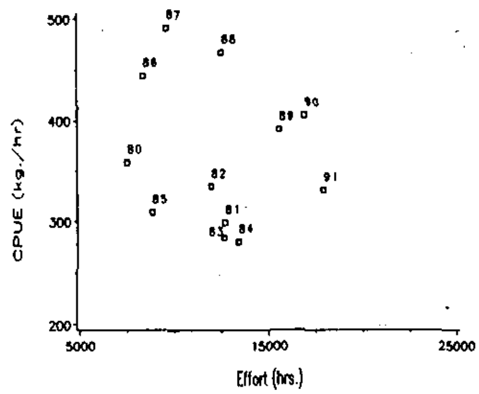


Fig.7c. CPUE vs. effort (Unstandardized 3 year average)

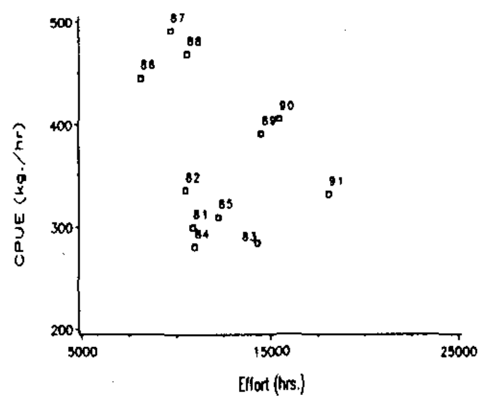


Fig.8a. CPUE vs. effort (Standardized)

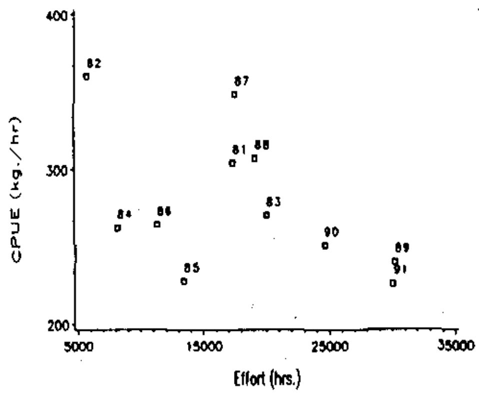


Fig.8b. CPUE vs. effort (Standardized 2 year average)

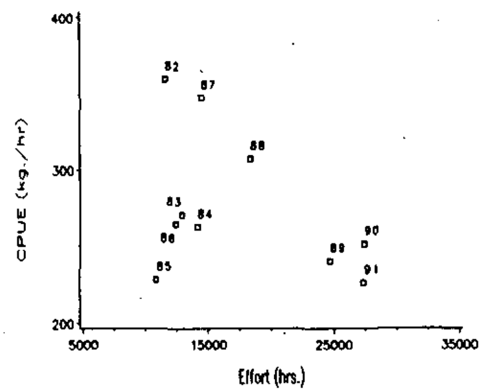
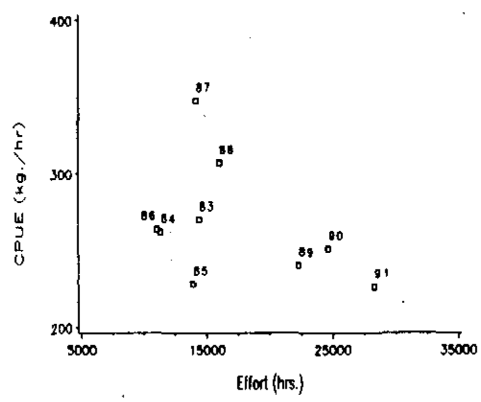
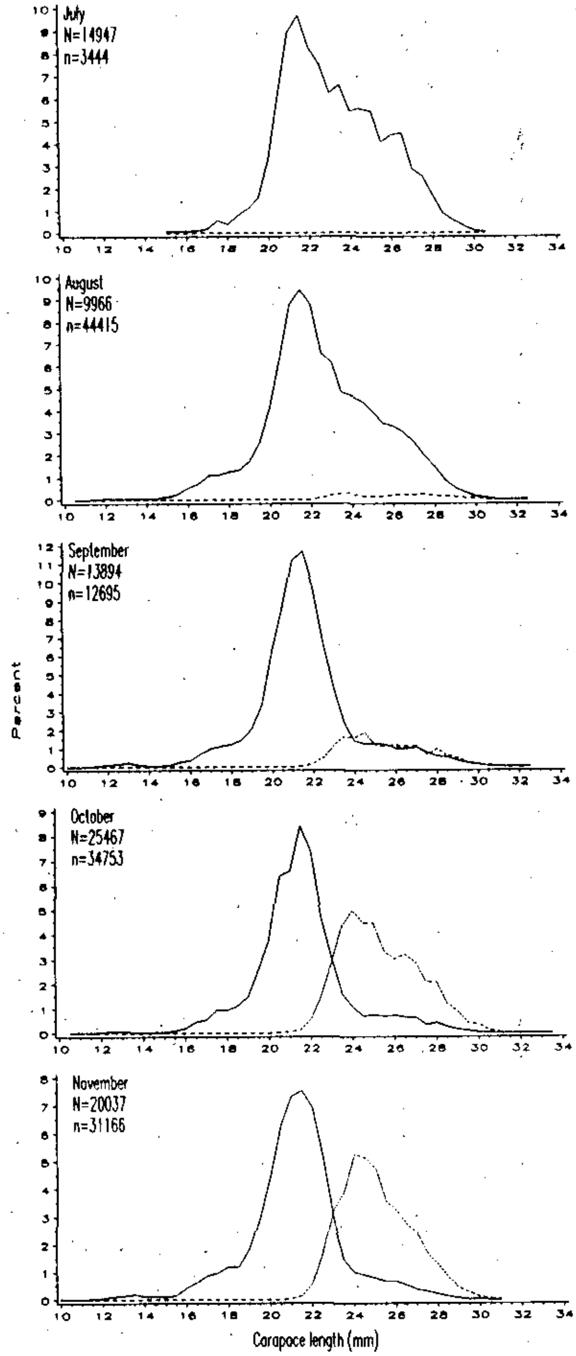


Fig.8c. CPUE vs. effort (Standardized 3 year average)



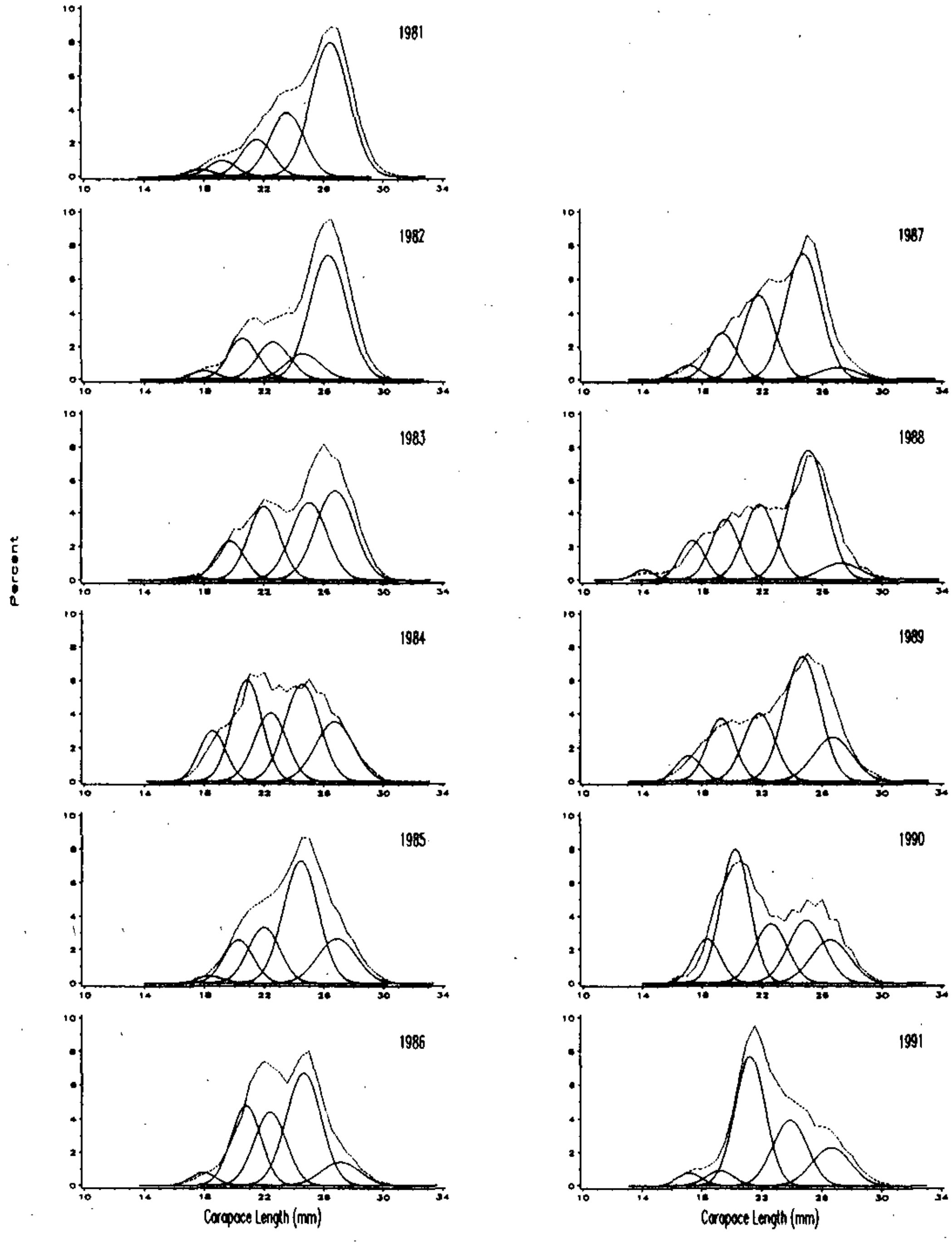
NAFO Div. 0A

Fig. 9 Commercial length frequencies for shrimp by month, 1991 (N=number per hour, n=number measured, ------ ovigerous.)



NAFO Div. 0A, 1981–1991

Fig. 10 Separation of ages from commercial length frequency data (broken line = commercial frequency).



NAFO Div. 0A, 1981-1991

Fig. 11 Number caught per hour at age.