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Investigating the Potential of Sequential Population Analysis for Northern Shrimp (*Pandalus borealis*) in Division 0A

by

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INTRODUCTION

A catch at age matrix was provided for shrimp from the Canadian commercial fishery data from 1981 to 1990 in Division 0A (Parsons and Veitch, 1991). It was felt the data could be used in an analytical model to obtain estimates of population numbers and fishing mortalities. A cohort analysis was therefore performed on the data and was calibrated age by age using the adaptive framework of Gavaris (1988). This paper presents the first results of the analysis, providing information on the potential for its use on shrimp data rather than producing a formal analytical assessment.

INPUT DATA

Catch at age

A catch at age matrix for ages 3 to 8 was obtained from modal analyses of length frequency data, for 1981 to 1990 (Parsons and Veitch, 1991). Because age 3 individuals were very poorly represented in the catch, they were omitted from the catch at age matrix used in the cohort analysis (Table 1).

Abundance index

The abundance index used for the calibration of the cohort analysis was the number at age caught per hour (Table 2). This was obtained by dividing the catch at age values by the total standardized yearly effort (Parsons and Veitch, 1991).

Mean weight at age

The matrix of mean weight at age (Table 3) was constructed by applying the following length-weight relationship to the mean lengths at age as estimated by the modal analyses:

$$W = 0.000758 \times L^{2.92}$$

The relationship was obtained for the West Greenland area (D.M. Carlsson, unpublished data). The weight at age matrix was used to estimate the catch and population biomasses.

ESTIMATION OF PARAMETERS

Natural mortality rate

A value of 0.5 was assumed for the instantaneous natural mortality rate (M) in the present analysis. This value is considered to be appropriate for a shrimp population (Fréchette and Parsons, 1983).

Fishing mortality for the oldest ages

The vector of fishing mortalities for the oldest ages was estimated as described in McQuinn (1986). This method assumes that the F for age 7 is equal to the F for age 8+ and requires only a F value for age group 8+ in the last year as input. The resulting vector was used to start the cohort analysis.

AGE BY AGE CALIBRATION OF THE COHORT ANALYSIS

The cohort analysis was calibrated age by age using the adaptive framework (Gavaris, 1988). The formulation involved estimating population numbers (N) at age 4 through 8 in 1990 and the age-specific coefficients (q) by predicting the number at age caught per hour using the minimization of the residuals sums of squares in the ln scale as the objective criteria. An initial calibration showed the intercepts to be non significant. A summary of the formulation used in the calibration is as follows:

Parameters:
- year-class estimates: N, 1990; ages 4 to 8+;
- calibration constants: q; ages 4 to 8+;
- number of parameters: 10.

Structure:
- F for oldest age-group (8+) = F at age 7;
- model did not include an intercept term.

Input:
- catch at age: 1981 to 1990, ages 4 to 8+;
- commercial catch rate:
  number caught per hour, 1981 to 1990, ages 4 to 8+;
- number of observations: 50.

Objective function:
- log transformation.

RESULTS AND DISCUSSION

The mean square residuals of the analysis from the adaptive framework were 0.420. The estimated population numbers in 1990 for ages 4 through 8+ and the age-specific regression coefficients are presented in table 4. The coefficients of variation were low for all age-specific coefficients and for age 7 and 8+ numbers:

	Age 4	Age 5	Age 6	Age 7	Age 8+
Number	68%	45%	38%	20%	14%
Coefficient	23%	22%	21%	22%	23%

The correlations between parameters are presented in table 5. The correlations were all below 0.3 except for two values of 0.33 and 0.41.

The standardized residuals of the regressions between the expected and observed number caught per hour are shown in table 6 and the corresponding plots on an age by age basis are presented in figures 1 to 5. A pattern is apparent:

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
4	.	.	-	+	-	-	+	+	.	.
5	-	+	.	+	-	.	.	.	.	.
6	+	.	+	.	.	.	.	.	.	-
7	-	-	.	.	+	+	+	-	.	.
8	-	-	.	.	+	+	+	-	.	.

Expected numbers caught per hour were higher for age 7 and 8+ in 1981 and 1982 than those observed. However, they were lower than those observed in 1985, 1986 and 1987.

The cohort analysis indicated that the age 5+ biomass and numbers declined from 1981 to 1984, increased from 1984 to 1987, declined again from 1987 to 1989 and then increased in 1990 (Tables 7 and 8, Figure 6). The mean population number (age 5+) in the most recent years, 1986 to 1990, was 75% higher than the mean population number in the first half of the 80's. The mean biomass of the same age groups in 1986-1990 showed an increase of 67% over the mean population biomass in 1982-1985 but was at about the same level as in 1981. The difference in the amplitude of the biomass and number increases can be explained by the decrease of the mean age of the individuals in the catch from 1981 to 1990:

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Age	7.3	7.0	6.9	6.2	6.7	6.3	6.4	6.2	6.5	5.9

The fishing mortality matrix estimated from the analysis indicates that the values for ages 4 through 6 were below 0.5 and could be variable over the years (Table 9). However, the values increased substantially between age 6 and 7 when shrimp transition from male to female occurs. The F for ages 7 and 8+ were over 1.1 in 1983, 1985, 1986 and 1987, and, 1989 and 1990. The variation in the fishing mortalities was similar from 1983 to 1990 with low F for ages 4, 5 and 6 and a sudden increase in estimates for ages 7 and 8+. The fishing mortalities for age 5+ were:

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
F	0.26	0.12	0.42	1.49	1.45	1.35	1.55	1.62	1.82	-

There is about a 6 fold increase in the estimate of F for the 1984-1989 period compared to the 1981-1983 period.

This analysis indicated the 1990 partial recruitment as shown below:

	Age 4	Age 5	Age 6	Age 7	Age 8+
PR	.227	.093	.138	.745	1.000

Only age 8 shrimp were fully recruited to the fishery. The pattern of the partial recruitment is somewhat similar to the F pattern: there is a substantial increase of the values between ages 6 and 7. This would be expected since sex inversion occurs between ages 6 and 7 and the females (ages 7 and 8) are primarily targeted by the fishery.

The results obtained with the adaptive framework show that analysis can be applied successfully to shrimp data. The diagnotics presented here indicate that the model fits the data well. Although more analyses should be done in order to explore further the reliability of the method, it has already shown some potential. The perception of the status of the resource is similar to that described by Parsons and Veitch (1991) using standardized CPUE and catch at age data. Even with high fishing mortalities on females since 1983, there are no indications that recruitment failures have occured over the decade. Population numbers and biomass have not decreased since 1981 and there is a sign of good recruitment to the fishery for the next few years as indicated by the number of animals at age 5 in 1990 which are the highest in the series.

However, the data used in the cohort analysis represent less than 15% of the total annual landings in Subarea 0+1. It is not known if the results presented here are representative of the whole stock. Also, the results of the cohort analysis are only as reliable as the input catch at age data. The modal analysis is leats accurate for the female ages, those which are targeted by the fishery.

REFERENCES

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Gavaris, S. 1988. An adaptive framework for the estimation of population size. CAFSAC Res.Doc. 88/29, 12 p.

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Table 1. Catch ($X10^3$) at age by year

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
4	10029	5829	5308	29577	6961	12161	29154	68331	54783	89980
5	25161	31378	65585	67121	47909	87653	108033	117932	153294	302049
6	67722	31510	137599	48697	67505	87099	219202	164757	187215	150325
7	129558	23710	165609	75913	163886	145791	368698	330174	391994	176289
8+	303564	119689	206657	50636	65857	33802	39910	46083	149491	129023

Table 2. Number caught per hour -- standardized

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
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

Table 3. Mean weight (g) at age

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
4	3.7	3.8	3.2	4.1	4.1	3.7	3.3	3.5	3.3	4.0
5	4.6	5.6	4.9	5.7	5.4	5.0	4.7	4.8	4.6	5.3
6	6.3	7.3	6.7	7.1	6.7	7.1	6.6	6.6	6.7	7.3
7	8.2	9.3	9.7	9.2	9.1	9.3	9.4	9.8	9.4	9.7
8+	10.5	11.2	11.8	11.7	12.0	12.2	12.1	12.5	11.7	11.5

Table 4.

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.004666
MEAN SQUARE RESIDUALS 0.420097

PARAMETER	PARAMETER EST.	STD. ERR.	T-STATISTIC
1.Age 4 number	7.76321E0006	5.27441E0006	1.47186E0000
2.Age 5 number	2.89177E0006	1.30219E0006	2.22071E0000
3.Age 6 number	1.00538E0006	3.77848E0005	2.66080E0000
4.Age 7 number	3.31187E0005	6.47132E0004	5.11776E0000
5.Age 8 number	2.10603E0005	2.98708E0004	7.05045E0000
6.Age 4 coeff.	1.10817E-003	2.52371E-004	4.39105E0000
7.Age 5 coeff.	9.38655E-003	2.04323E-003	4.59399E0000
8.Age 6 coeff.	2.86945E-002	6.10756E-003	4.69819E0000
9.Age 7 coeff.	1.92107E-001	4.17363E-002	4.60288E0000
10.Age 8 coeff.	2.02961E-001	4.58871E-002	4.42305E0000

Table 5. Parameter Correlation Matrix

	1	2	3	4	5	6	7	8	9	10
1	1.000	.079	.062	.027	.016	-.330	-.032	-.017	-.010	-.007
2	.079	1.000	.088	.038	.023	-.239	-.259	-.024	-.014	-.009
3	.062	.088	1.000	.052	.028	-.189	-.200	-.226	-.018	-.012
4	.027	.038	.052	1.000	.050	-.082	-.086	-.113	-.294	-.021
5	.016	.023	.028	.050	1.000	-.049	-.050	-.055	-.135	-.412
6	-.330	-.239	-.189	-.082	-.049	1.000	.098	.052	.029	.020
7	-.032	-.259	-.200	-.086	-.050	.098	1.000	.055	.031	.021
8	-.017	-.024	-.226	-.113	-.055	.052	.055	1.000	.039	.023
9	-.010	-.014	-.018	-.294	-.135	.029	.031	.039	1.000	.055
10	-.007	-.009	-.012	-.021	-.412	.020	.021	.023	.055	1.000

Table 6. Standardized Residuals for CPUE at age

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
4	-.06	.47	-.89	1.00	-1.29	-.48	.48	.99	-.23	.00
5	-.77	.62	.12	.97	-.59	-.22	-.31	.27	-.27	.20
6	.51	.04	.68	.20	.07	-.38	-.16	-.43	-.04	-.49
7	-1.12	-.55	.23	.20	.92	.72	.59	-.50	-.36	-.15
8	-1.18	-.60	.18	.15	.87	.67	.54	-.55	-.42	.35

Table 7. POPULATION NUMBERS (000)

	1981	1982	1983	1984	1985	1986	1987	1988
4	1431996	1495708	1542287	3109414	4438838	3943365	2343317	3093161
5	889287	860739	902653	931310	1862921	2686870	2382301	1398589
6	295672	519784	497627	496409	512594	1092607	1561405	1360802
7	468295	126592	290725	194664	263162	258331	594867	776325
8	1097251	639042	362785	129846	105751	59895	64392	108353
4+	4182501	3641866	3596077	4861644	7183265	8041068	6946281	6737230
5+	2750505	2146157	2053790	1752230	2744428	4097703	4602964	3644069
6+	1861218	1285418	1151137	820919	881507	1410833	2220663	2245481
7+	1565546	765634	653510	324510	368913	318226	659259	884678

	1989	1990
4	4760717	381684
5	1822881	2844856
6	756441	986248
7	697055	313002
8	265829	196170
4+	8302924	4721959
5+	3542207	4340275
6+	1719326	1495419
7+	962885	509172

Table 8. SECOND QUARTER POPULATION BIOMASS

	1981	1982	1983	1984	1985	1986	1987
4	4650534	5015840	4328181	11278040	15864905	13015228	6803622
5	3586503	4238565	3911251	4717582	8795516	11808348	9881153
6	1643856	3334807	2955510	3105985	3044402	6836335	9039252
7	3401205	1034501	2488671	1571882	2101770	2111063	4918951
8	11096951	6327547	3790649	1341835	1116164	645911	687021
4+	24379050	19951261	17474263	22015324	30922757	34416886	31330000
5+	19728516	14935421	13146082	10737284	15057852	21401658	24526378
6+	16142013	10696856	9234831	6019702	6262337	9593309	14645225
7+	14498157	7362048	6279320	2913717	3217934	2756974	5605972

	1988	1989	1990
4	9417483	13822336	1340604
5	5973770	7448219	13255844
6	7877929	4379175	6327521
7	6720875	5763949	2679363
8	1193354	2747091	1983947
4+	31183412	34160770	25587279
5+	21765929	20338434	24246675
6+	15792158	12890214	10990831
7+	7914229	8511039	4663311

Table 9.

F (WEIGHTED AND UNWEIGHTED MEANS)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
4	.009	.005	.004	.012	.002	.004	.016	.029	.015	.350
5	.037	.048	.098	.097	.034	.043	.060	.115	.114	.144
6	.348	.081	.439	.135	.185	.108	.199	.169	.382	.213
7	.424	.268	1.173	.659	1.383	1.154	1.370	.743	1.147	1.150
8	.424	.268	1.173	.659	1.383	1.154	1.370	.743	1.147	1.545
7+	.424	.268	1.173	.659	1.383	1.154	1.370	.743	1.147	1.302
8+	.424	.268	1.173	.659	1.383	1.154	1.370	.743	1.147	1.545

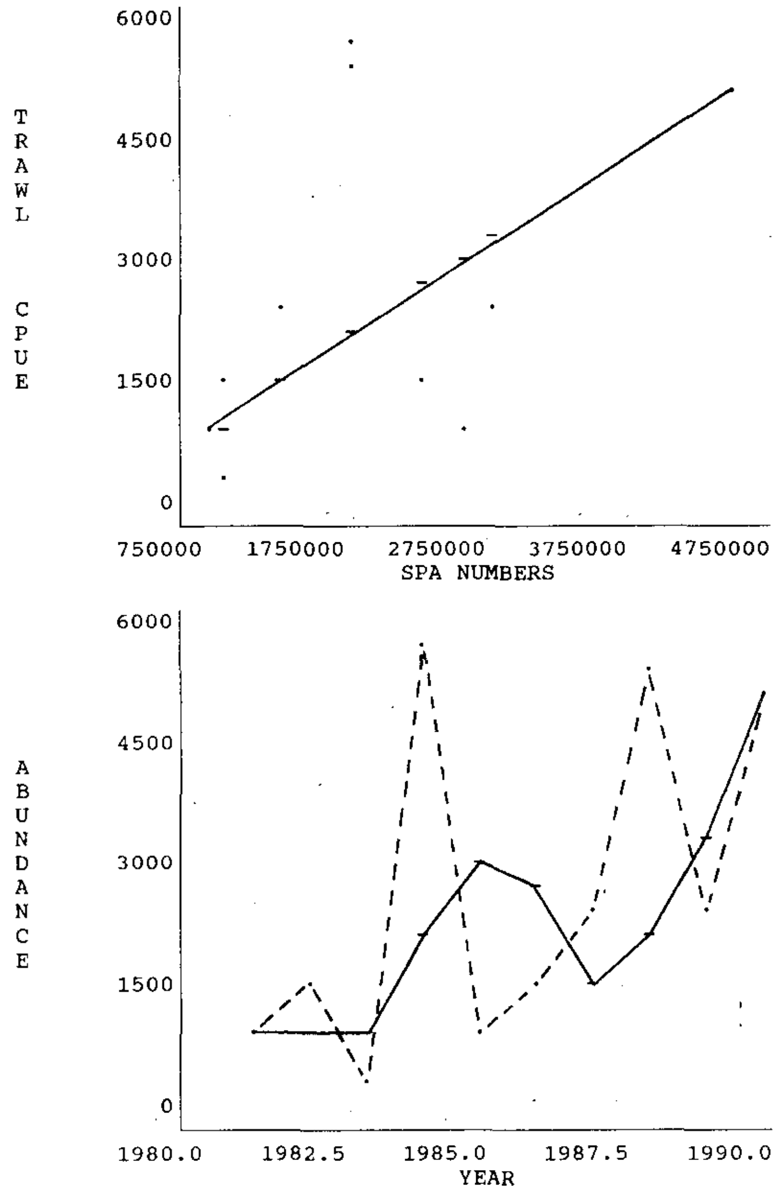

FIGURE 1. Age 4 plots.
A: trawl CPUE vs SPA numbers;
B: trend in population abundance over time
_ _ _ _ : observed _______ : expected

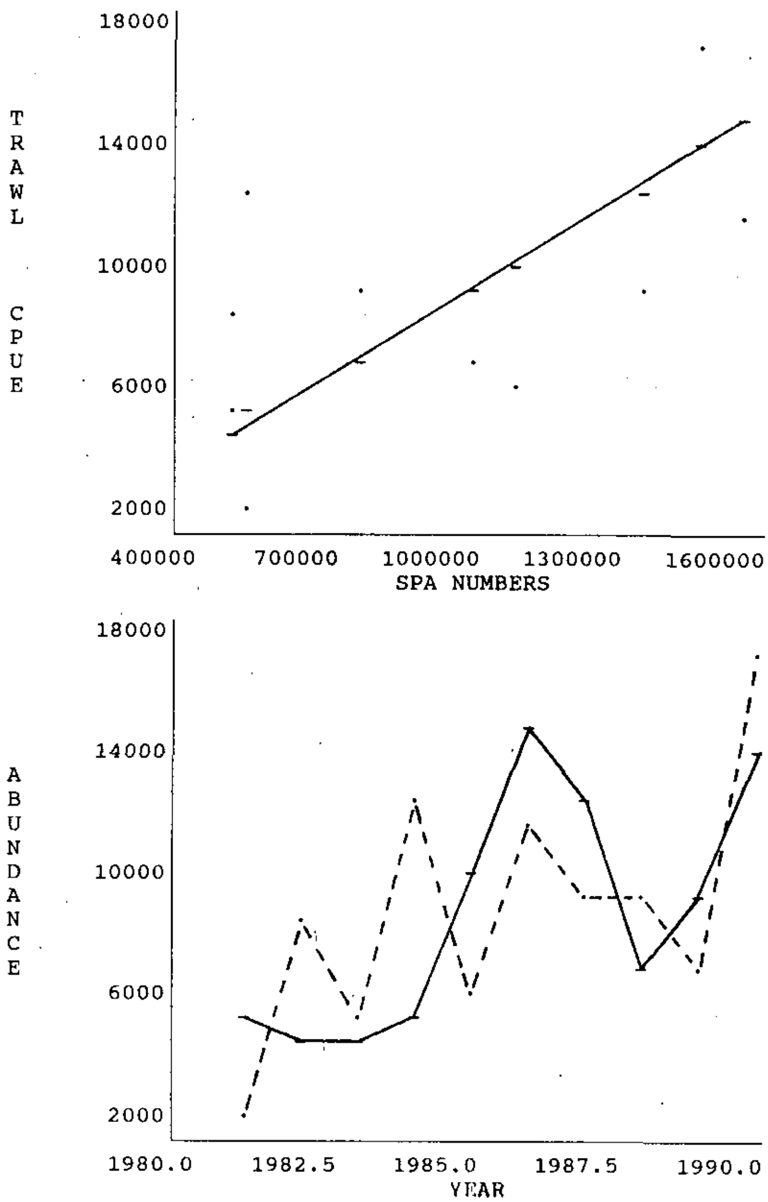

FIGURE 2. Age 5 plots.
A: trawl CPUE vs SPA numbers;
B: trend in population abundance over time
_ _ _ _ : observed ______ : expected

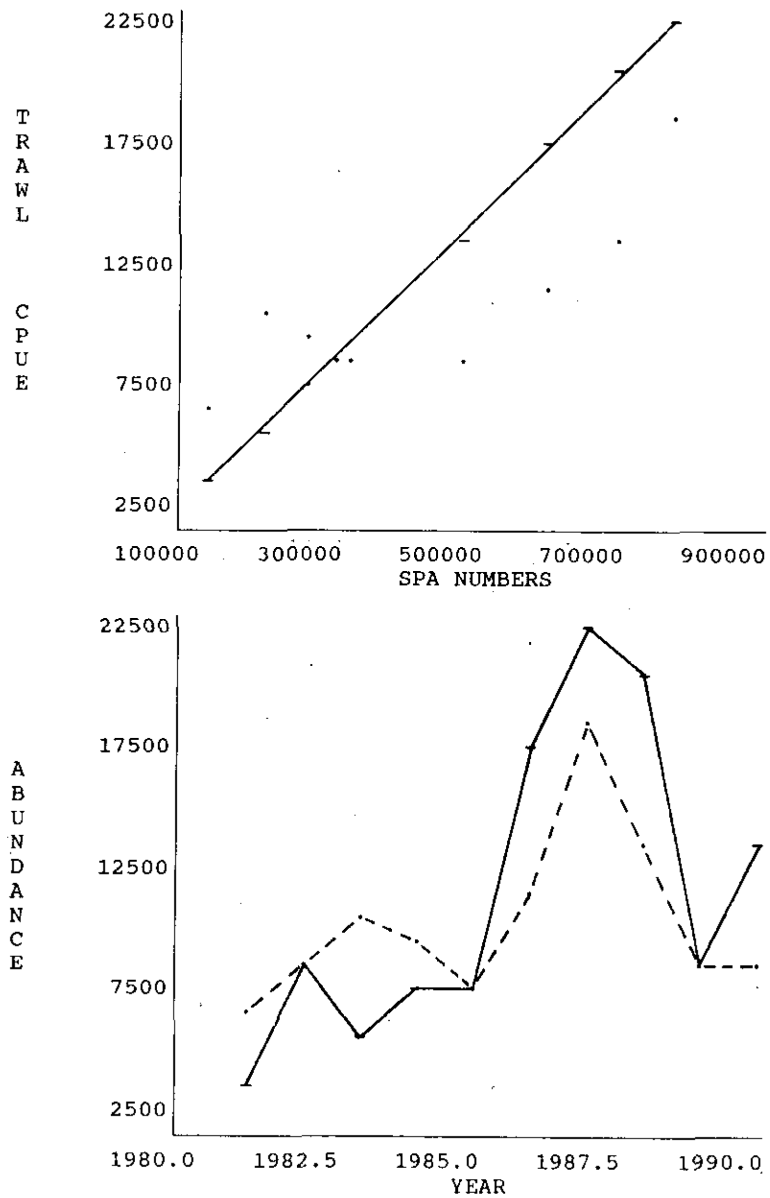

FIGURE 3. Age 6 plots.
A: trawl CPUE vs SPA numbers;
B: trend in population abundance over time
_ _ _ _ : observed _______ : expected

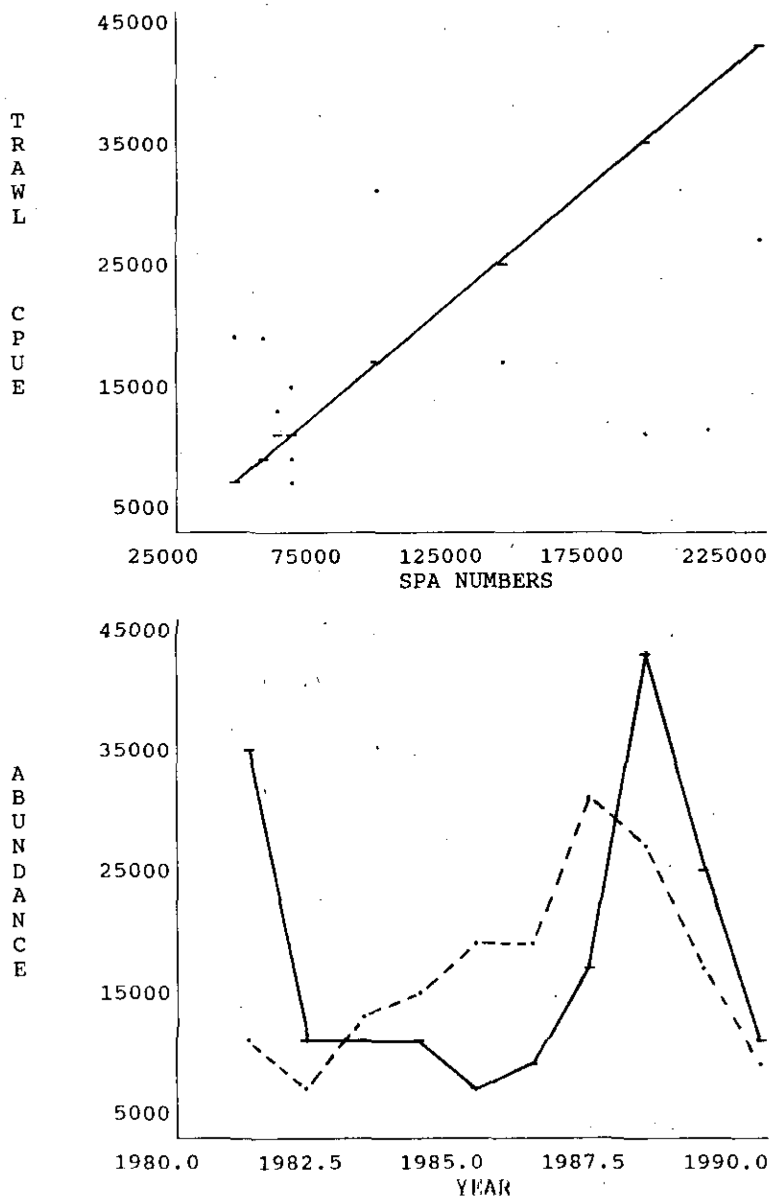

FIGURE 4. Age 7 plots.
A: trawl CPUE vs SPA numbers;
B: trend in population abundance over time
_ _ _ _ : observed _______ : expected

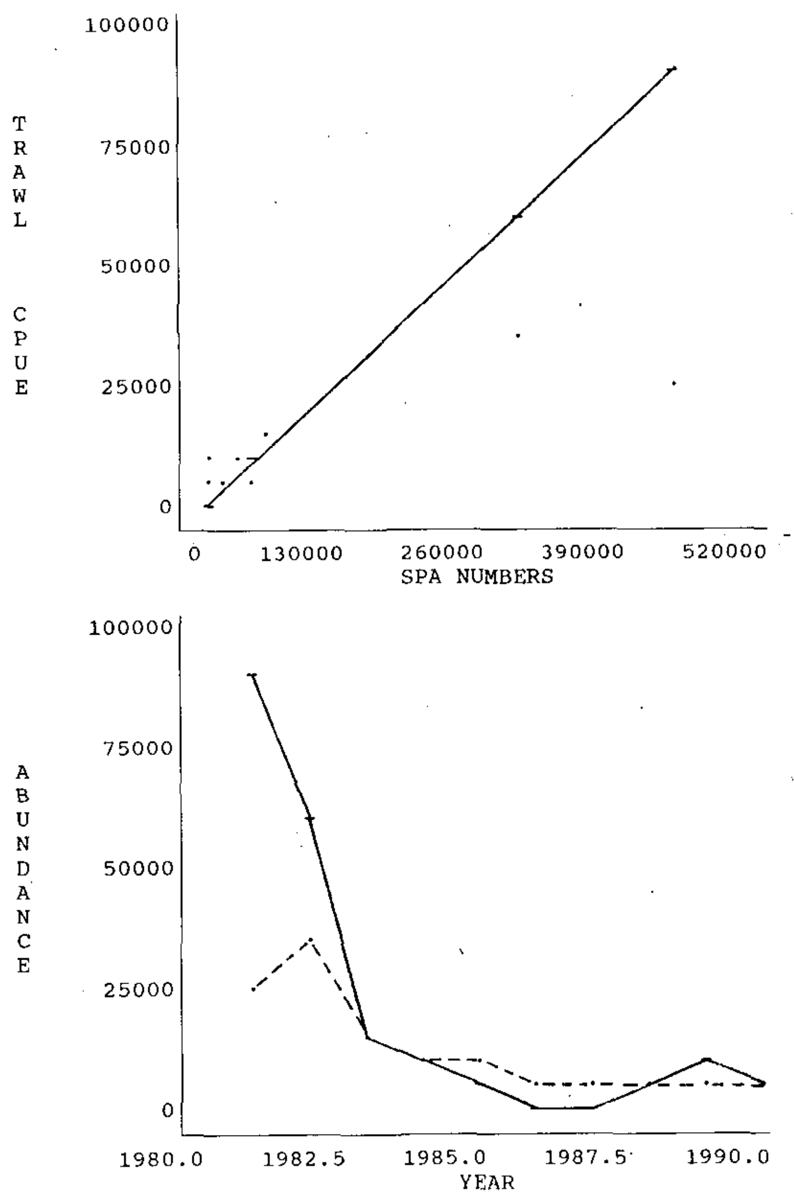

FIGURE 5. Age 8 plots.
A: trawl CPUE vs SPA numbers;
B: trend in population abundance over time
_ _ _ _ : observed ________ : expected

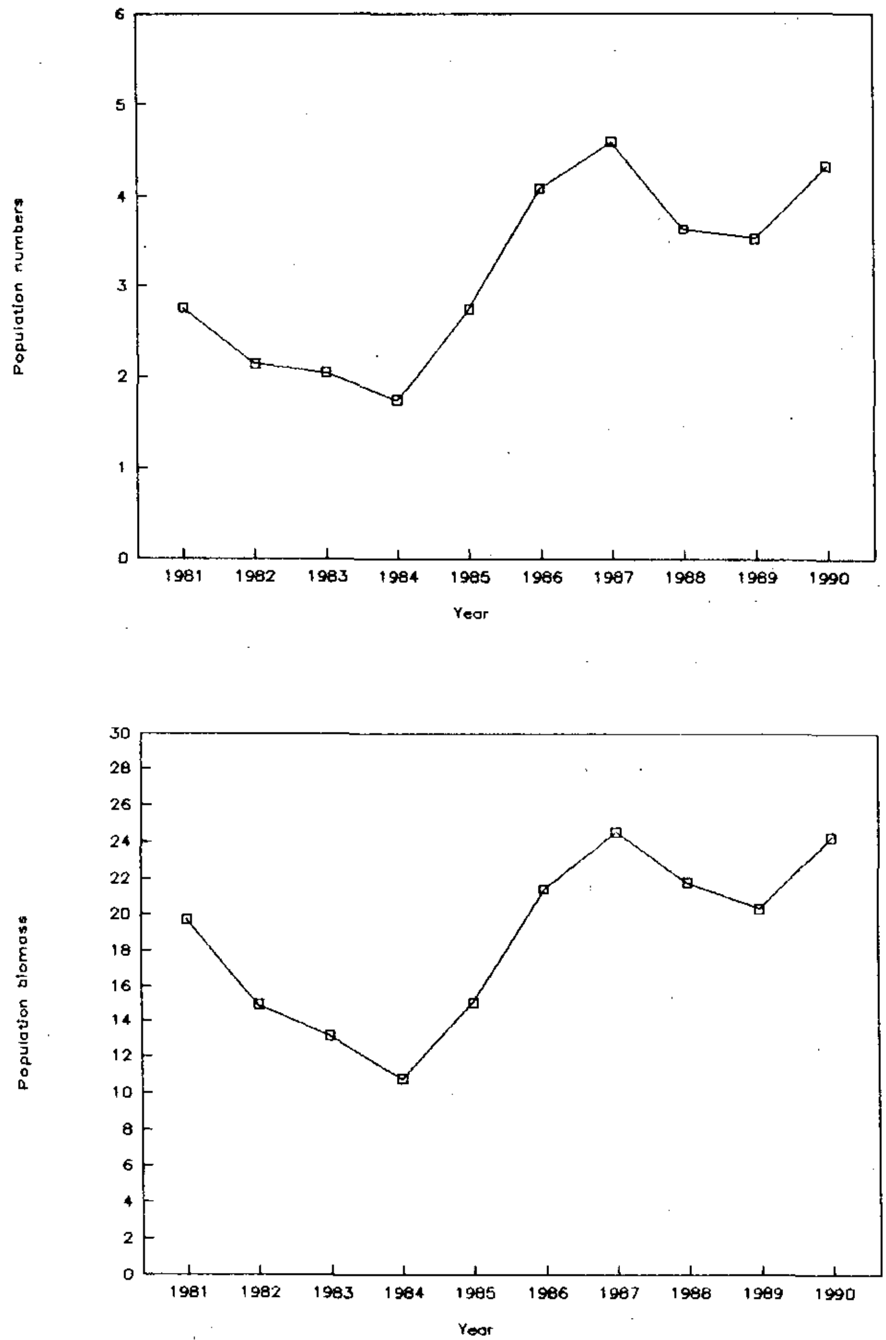

Figure 6. Population numbers and biomass by year for ages 5+.