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Georges Bank Scallop Stock Assessment - 1986

By

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ABSTRACT

The Canadian Georges Bank scallop catch for 1986 was 4,900 t., a 29% increase over last year and the highest of the last five years. This continues the recovery from 1984 landings, which were the worst since 1959. This is due to the strong 1982 and good 1981 and 1983 year-classes. The biomass at the end of 1986 is the highest it has been since the peak of 1977-1978. Research data indicate that the 1984 year-class is also good, and therefore catches should continue at this level or higher in 1987.

In 1986, with a TAC divided into enterprise allocations and the 1981 year-class reaching a size that required little or no blending by the middle of the year, effort focussed on this abundant year-class and CPUE more than doubled over last year.

Yield per recruit and stock projections show that the stock is still fished at a level higher than F_{max}.

For the stock projections the starting numbers are from the cohort analysis, aged forward to January 1987.

RÉSUMÉ

Les prises canadiennes de pétoncles sur le banc Georges sont estimées à 4,900 t en 1986, une augmentation de 29% comparée à l'année précédente et les prises les plus élevées durant les cinq dernières années. Les débarquements continuent de s'améliorer depuis 1984 losqu'ils avaient atteint le niveau le plus bas jamais enregistré (1959). Cette performance est attribuable à la forte classe d'âge de 1982 et aux bonnes années de 1981 et de 1983. La biomasse établie à la fin de 1986 est la plus élevée qu'elle a été depuis le plateau de 1977-78.Les données de recherche indiquent que la classe d'âge de 1984 est prometteuse; par conséquent, les prises devraient continuer à ce niveau ou augmenter pour 1987.

En 1986, la pêche opéra sous un système d'allocations par entreprises. Vers le milieu de l'année, la classe d'âge de 1981 atteignait une grosseur de viandes telle qu'il n'était presque plus nécessaire de mélanger pour obtenir le compte de viandes en vigueur. Cette abondante classe d'âge devint le point focal de l'effort et les PUE plus que doublèrent celles de l'année précédente.

L'analyse de rendement par recrue et les projections de stock montrent que le stock est encore exploité à un niveau plus élevé que F_{max}.

Pour les projections de stock, les nombres de départ provenant de l'analyse de cohortes sont âgés d'avance à Janvier 1987.

INTRODUCTION

Two strong year-classes, those of 1957 and 1972, produced major peaks in landings in the last 30 years of the Georges Bank scallop fishery (Fig. 1 and Table 1). The more recent peak occurred in 1977 and 1978 with landings of over 17,000 t. Landings fell to about 10,000 t in 1980 but increased by almost 6,000 t to 16,000 t in 1981 as a result of increased Canadian and U.S. fishing effort and a relaxation of the enforcement of the meat count regulation on the Canadian fleet. U.S. catch levels have shown an upward trend since the early 1970's to over 8,000 t in 1981, representing an increase of 400% from 1976 to 1981 and a parallel increase in effort. From 1982 on, landings by the Canadian fleet decreased steadily to 1,945 t in 1984, its lowest level since 1959. Marked improvement in catches and catch-rates characterize the fishery in the last two years, however, as landings reached 4,900 t in 1986, a 250% increase over 1984. As another moderately good year-class is about to recruit to the fishery, and the biomass is the highest it has been since 1978, this fishery should continue to improve.

In 1986 the deep-sea fleet (vessels over 19.8m L.O.A.) fished under a meat count of 33 per 500g, which had been implemented on January 1st, 1986, and other management measures as per 1985. In addition, an arbitrary upper catch limit of 4,300 t had been agreed to for 1986. This competitive fishery landed trips over 13,608 kg. With the agreement from industry, the fishery closed on May 20th to provoke negotiations toward the implementation of enterprise allocations. Much discussion took place and the fishery resumed on June 9th; every component of the deep-sea fleet having ratified the allocation plan.

The Bay of Fundy fleet was entitled to fish 111 t on Georges Bank in 1986 (2.9% of the previous year's catch of 3,812 t). Depleted stock conditions in the Bay of Fundy waters shifted a great deal of effort from this fleet to Georges Bank stocks. Preliminary figures establish that this fleet's take was well over their allotment.

METHODS

Catch and effort data are compiled from logbooks. Those logs with complete effort data are called Class 1 and are used to determine catch rates (see Table 2). Also, data on size distribution of meats from the commercial fleet are derived from port samples. Canadian port sampling data were applied to the Canadian and U.S. total catch east of the ICJ line. This assumes similar fishing practices for both fleets. The annual changes in fishing practice can be seen in Table 3a, which contains weight distribution in 2 gram intervals for the last seven years. Changes within 1986 are shown in the same manner in Table 3b, which has the monthly distributions.

Catch in numbers at age (Table 4) for the cohort analysis are derived from the port sampling data and the sum of U.S. and Canadian catches in the Canadian zone. For more details on the method used to derive catch at age see Roddick and Mohn (1985). The total catch (U.S. and Canadian) from the Canadian zone is decomposed into weight frequencies. The weights were converted to shell heights using the allometric relationship derived from 1982 -1985 research and commercial data (Robert et al., 1987). The values expressing meat weight as a function of shell height use the parameters 9.012E-6 for the constant and 3.097 for the exponent of height. These values agree closely with those of Serchuck et al. (1982) for the same stock. Von Bertalanffy growth coefficients relating shell height and age were taken from Brown et al. (1972) as had been done previously.

Traditionally, catch statistics are compiled on an annual basis and recruitment to a fishery is discussed in terms of year-class strength. It is generally accepted that Georges Bank scallops are born in October and the first annual ring is laid down the following spring. This is typically less than 10 mm and becomes difficult to discern as the animal grows. For this reason the ring, which is approximately 25 mm from the umbo is often referred to as the first annulus (see, for example, Naidu 1970). The convention which we shall adopt is that animals born in the fall of a year will be of that year-class and it will be further assumed that they were born on January 1 of that year. The deposition of the ring less than 10 mm will take place during the first year of life. The data of the deposition will be assumed to take place on April 1. A back calculation is then made to estimate the shell height for January 1. The annual growth rates for weights, given in Table 5, are converted into rates for heights and this results in a 16% reduction of the ring size being used for the January 1 size. For example, an animal born in the fall of 1978 is of the 1978 year-class and will be approximately 25 mm on its second birthday (January 1, 1980) although the ring would not be deposited for a few months. Table 5, as well as all other age data, uses this convention, with correction of ring sizes back to January 1. For use in age/weight programs and projections the actual weights used are mid quarter values.

A research survey was carried out on Georges Bank during August 1986. The design of the survey was based on a stratification by commercial effort. The logbooks of the commercial fleet in the preceding 9 months were analyzed to determine areas of high and low fishing intensity. The areas of high intensity were sampled more heavily as they represent the area most important to the fleet (and presumably the areas of greatest abundance). The estimate of abundance was formed by contouring the catch rates at age of the survey tows and expanding the mean by the area enclosed by a given contour (Robert et al. 1986). The average number of animals at age per tow is given in Table 6. The numbers per tow are converted into indices of abundance by weighting them by the appropriate contour areas. The indices are shown in Table 7.

A Thompson-Bell type yield per recruit analysis was carried out breaking growth down into quarters and using 1986 selectivity values, corrected to reflect the meat count of 33 meats/500 grams. This was done in order to take into account the dynamic growth of the younger age-classes of scallops. This method also takes into account the average quarterly distribution of effort. However, this method cannot include the effects of blending.

A more detailed study of yield per recruit as it applies to the Georges Bank scallop stock was carried out, but as it is detailed in a separate paper (Mohn et al., 1987) it will not be repeated here.

The regulations operant on the offshore fleet are that the catch should average no more than 33 meats per 500 grams which corresponds to an average weight of 15 grams per meat. Placing a limitation on the average instead of stipulating a minimum means that the fishermen may take small animals and then balance them with larger ones. Such a practice, called blending, renders the use of most yield models inappropriate. If there are not enough larger animals to blend in, then the mortality on the small ones will have to be reduced. Thus, the partial recruitment is a function of abundance at age. In order to take this practice into account, a stock projection program was written in 1984 (Mohn et al 1984) in which the mortality on the animals beneath the stipulated average is adjusted until the mean weight of the catch is within 1% of the required average. The only other way in which this program differs from the normal stock projection is that the variables are updated quarterly because of the very rapid growth of the young scallops. The annual growth is divided into quarterly components of 10, 35, 35 and 20% and annual effort is partitioned into quarters by the rates of 10, 55, 25 and 10%. Selectivity for the projections follows the pattern of the fishery as revealed from the cohort analysis instead of that of the gear (Caddy 1972). Starting numbers at age for the projections were derived by aging ahead the 1986 cohort estimates to Jan. 1987.

Because cohort analyses deal only with the removals from a cohort and not the growth of the animals it is not appropriate to use this method for a dynamic species like scallops. In the first year of recruitment the animals experience approximately a 300% increase in weight. In order to reduce the magnitude of the errors caused by ignoring growth effects, the cohort analysis was carried out on a quarterly basis. This required that catch at age be determined on a quarterly basis. Also, the above mentioned quarterly distribution of effort had to be taken into account. Selectivity had to be determined on a quarterly basis also. This was done by adjusting last year's selectivity pattern to reflect the port sampling data for the last quarter of 1986. This pattern, multiplied by the F determined from tuning for the last quarter year, was used as a starting vector for the quarterly cohort analysis. Natural mortality was set at .025 per quarter and no attempt was made to include a seasonal or age dependent effect.

RESULTS

Survey catch-rates (Tables 6,7 and 8) indicate that while year-classes older than 5 are depleted, the strength of the stock is improving with relatively abundant age 5 scallops. The 1982 year-class (age 4) which is sizable, has practically not been exploited yet. A lowering of the meat count to 33 per 500g and reduced fishing pressure are starting to show positive results. The prerecruits (1983 year-class) seem more important than the 1985 survey results had shown; the next incoming year-class also appears to be strong. Stock rebuilding is noticed in contour analysis results (Table 7) to follow the trends outlined in survey catch-rates. Recruited abundance, number-wise, has not been that high since the recent survey series started in 1978.

The cohort analysis was tuned by regressing commercial CPUE versus 4+ biomass (Figure 2.) The regression coefficient was 0.94 and it was encouraging to see a good relationship between these variables. The CPUE was from Canadian vessels inside the Canadian Zone. Table 9 contains the population estimates for Jan. 1 of each year. Table 10 is the fishing mortalities. The quarterly estimated mortalities for 1986 are lower than 1985's, especially on older animals, as the strong year-class of 1982 has reached a size that no longer requires the blending of large animals to make the meat count (Table 11). These results suggest that the fishing mortality is of the order of 1.07 for the fully recruited 5-yr olds, which were required for blending at the start of the year. It is still very low on the larger four year old year-class in spite of its making up more than half the catch by numbers, this is due to its magnitude. Although effort focussed on this group, the fact that it is three times the size of its neighbors resulted in a low fishing mortality by the last quarter of 1986.

A comparison of the research survey contouring and cohort biomass can be seen here and in Figure 3.

3+ Biomass Estimates From Research Survey And Cohort Analysis.

	1978	1979	1980	1981	1982	1983	1984	1985	1986
Research	25342	10013	2597	7135	4968	2940	2266	6706	8625
Cohort	19860	12806	12544	13461	8903	6484	7188	13793	18356

The quarterly based yield per recruit analysis used mid-quarter meat weights and the expanded selectivity used both in the cohort analysis and in the projections. (See Figure 4.) The F_{max} was at an F of 0.630 and $F_{0.1}$ at 0.402. These values differ from previous assessments as the selectivity pattern has changed with the meat count.

Figure 5 shows the apparent lack of a stock recruit relationship as described by traditional models. This may indicate that environmental factors, or dynamics not accounted for in conventional models, determine year-class strength.

Two projections were run for a three year period, one at F_{max}, and the other at $F_{0.1}$, using an estimated recruitment of 400 ($x10^6$) for 1987 and 300 ($x10^6$)for the following two years (Table 11). As expected F_{max} shows a more rapid removal of the incoming age-classes. The $F_{0.1}$ shows a sustainment of the pulse at a biomass approximately 25% higher after three years. The recommended catch level from this projection, based on $F_{0.1}$, is 6,500 t for 1987. For more details on the setting of catch levels for this stock see Mohn et al 1987.

Figures 6a and 6b show some of the results of a contour analysis of the survey data. These figures show the aggregated nature of the scallop resource, and they are seen to be concentrated on the Northern Edge and NE Peak for 1986. The total number of scallops is shown in the upper left hand contour map of Figure 6a. Figure 6b follows the 1982 and 1983 year-classes from 1984 to 1986, the concentrations along the Northern Edge appear to be less persistent than the concentrations on the Peak. By age five (Figure 6a), the aggregations are well scattered (no change of scale).

CONCLUSIONS

A relatively strong recruitment was seen in the 1986 fishery. This is evidenced by the change in the monthly CPUE of 1986 compared to 1985 (Figure 7). Fishing early in the year means a loss of yield, and may affect the cohort analysis. The fishery required less blending as the season progressed and the CPUE doubled over last year. The 1986 research survey indicates that the strong recruiting year-class of this year will be followed by an above average one which should further bolster the fishery. At $F_{0.1}$ the recommended catch level for 1987 is 6,500 t, at F_{max} the catch level is 9,000 t.

There is a problem relating the research abundance indices and those derived from cohort analysis as is shown in Figure 3; although the most recent 5 years have tracked each other fairly well (Figure 3). The relative magnitude of the recent trends from the cohort and the contouring analysis suggests that the research figures could be corrected by a factor of two.

REFERENCES

Bourne, N. 1964. Scallops and the offshore fishery of the Maritimes. Bull. Fish. Res. Board Can. No. 145: 60 p.

Brown, B.E., M. Parrack, and D.D. Flesher. 1972. Review of the current status of the scallop fishery in ICNAF Division 5Z. Int. Comm. Northw. Atl. Fish. Res. Doc. 72/113: 13 p.

Caddy, J.F. 1972. Size selectivity of the Georges Bank offshore dredge and mortality estimate for scallops from the northern edge of Georges in the period June 1970 to 1971. Int. Comm. Northw. Atl. Fish. Res. Doc. 72/5: 10p.

Mohn, R.K., G. Robert and D.L. Roddick. 1984. Georges Bank scallop stock assessment - 1983. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 84/12: 28 p.

Mohn, R.K., D.L. Roddick and G. Robert. 1987. Biological considerations in the definition of fishing strategies for Georges Bank scallops. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. in preparation.

Naidu, K.S. 1970. Reproduction and breeding cycle of the giant scallop *Placopecten magellanicus* (Gmelin) in Port au Port Bay, Newfoundland. Can. J. Zool. 48: 1003-1012.

Robert, G., and G.S. Jamieson. 1986. Commercial fishery data isopleths and their use in offshore sea scallop (*Placopecten magellanicus*) stock evaluations. Can. Spec. Publ. Fish. Aquat. Sci. 92:76-82.

Robert, G. and M.J. Lundy. 1987. Shell height-meat weight allometry for Georges Bank scallop (*Placopecten magellanicus*) stocks. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 87/xx xp. (in press)

Roddick, D.L. and R.K. Mohn. 1985. A method for the generation of catch-at-age data. Int. Cons. Explor. Mer C.M. 1985/D14: 21 p.

Serchuck, F.M., P.W. Wood, Jr., and R.S. Rak. 1982. Review and assessment of the Georges Bank, mid-Atlantic and Gulf of Maine Atlantic sea scallop (*Placopecten magellanicus*) resources. Woods Hole Lab. Ref. Doc. 82-06: 132 p.

Table 1.- Catch statistics (t of meats) from Georges Bank, NAFO subdivision 5Ze. For Canada: Statistics from SA 5Z not separated into 5Ze and 5Zw prior to 1967. Source: Pre-1961, Bourne (1964); 1961 on, ICNAF and NAFO Statistical Bulletins.

YEAR	USA	CANADA	TOTAL
1953	7392	148	7540
1954	7029	103	7132
1955	8299	120	8419
1956	7937	318	8255
1957	7846	766	8612
1958	6531	1179	7710
1959	8910	1950	10860
1960	10039	3402	13441
1961	10698	4565	15263
1962	9725	5715	15440
1963	7938	5898	13836
1964	6322	5922	12244
1965	1515	4434	5949
1966	905	4878	5783
1967	1234	5011	6245
1968	998	4820	5818
1969	1329	4318	5647
1970	1420	4097	5517
1971	1334	3908	5242
1972	824	4161	4985
1973	1084	4223	5307
1974	929	6137	7066
1975	860	7414	8274
1976	1777	9675	11452
1977	4823	13089	17912
1978	5589	12189	17778
1979	6412	9207	15619
1980	5477	5221	10698
1981	8443	8013	16456
1982	6523	4307	10830
1983	4328	2748	7076
1984	3071	1945	5016
1985	2949	3812	6761
1986	4438*	4900**	9338*

* Preliminary
** Estimated

Table 2.- Catch and effort data. Canadian catches (t of meats) in NAFO subdivision 5Ze. Total effort is derived from effort from Class 1 data.

YEAR	CATCH	EFFORT			CPUE
		days	hours 10^3	crhm 10^3	kg/crhm
1972	4161	8188	114	13971	0.298
1973	4223	7946	115	13541	0.312
1974	6137	8205	121	14610	0.420
1975	7414	8221	119	15216	0.487
1976	9675	7593	112	15142	0.639
1977	13089	8689	97	13001	1.007
1978	12189	8547	111	15207	0.802
1979	9207	8827	126	17315	0.532
1980	5221	6848	95	12951	0.403
1981	8013	8443	105	15247	0.526
1982	4307	6116	80	10968	0.393
1983	2748	5483	76	9876	0.278
1984	1945	5716	70	8598	0.226
1985	3812	7376	105	12644	0.301
1986	4900	3915	52	6957	0.704

Table 3a.- Frequencies of numbers at weight in 2 gram intervals (normalized to 1000) by year.

	YEAR							
GRAMS	1979	1980	1981	1982	1983	1984	1985	1986
1	0	0	0	0	0	0	0	0
3	2	15	16	2	12	7	1	0
5	32	99	84	26	66	96	20	0
7	97	172	204	99	110	205	112	6
9	136	169	253	146	118	169	211	41
11	137	128	177	159	125	108	197	125
13	110	92	96	132	111	69	136	209
15	85	67	52	103	90	55	87	225
17	65	51	31	73	70	46	57	160
19	50	38	20	55	53	41	42	96
21	43	32	15	45	44	37	30	55
23	38	24	11	33	36	30	21	28
25	31	20	8	27	27	25	17	17
27	25	17	6	21	23	20	13	11
29	24	13	5	17	18	18	11	8
31	21	11	4	13	15	15	9	3
33	17	9	3	11	13	12	7	3
35	16	7	3	8	10	11	6	3
37	13	6	2	6	8	8	5	2
39	11	5	2	5	8	6	4	1
41	9	4	1	4	6	5	3	2
43	7	3	1	3	6	4	3	1
45	7	3	1	2	5	3	2	0
47	5	3	1	2	4	2	2	0
49	4	2	1	1	4	2	1	0
51	3	2	1	1	2	2	1	1
53	3	2	1	1	3	1	1	0
55	2	1	1	1	3	1	1	0
57	1	1	0	0	1	1	0	0
59	1	1	0	1	2	0	0	0
61	1	1	0	0	2	0	0	0
63	1	1	0	0	1	0	0	0
65	1	0	0	0	2	0	0	0
67	0	0	0	0	1	0	0	0
69	0	0	0	0	1	0	0	0
71	0	0	0	0	0	0	0	0
73	0	0	0	0	1	0	0	0
75	0	0	0	0	0	0	0	0
77	0	0	0	1	0	0	0	0
79	0	0	0	0	0	0	0	0

Table 3b.- 1986 meat weight port sampling data. Numbers at weight in 2 gram intervals normalized to 1000. Sample sizes are given in last row.

Grams	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
5	2	0	0	1	0	0	0	0	0	0	0	0
7	9	18	11	2	1	0	3	0	3	6	11	3
9	89	79	64	21	10	14	19	21	32	45	57	39
11	197	135	165	119	85	30	70	94	144	135	148	95
13	196	175	228	263	226	101	141	158	201	173	164	137
15	168	169	181	271	317	260	208	218	210	159	150	166
17	119	122	123	168	207	233	253	201	153	146	100	159
19	68	88	74	79	92	216	165	107	118	100	128	143
21	48	70	53	36	31	74	75	111	58	86	92	107
23	32	35	32	18	12	34	29	56	33	58	43	56
25	13	27	19	9	7	14	15	13	15	32	52	35
27	12	21	12	3	4	3	4	13	9	32	24	24
29	14	13	9	4	3	14	8	0	10	13	20	12
31	3	6	5	2	2	0	2	4	3	5	5	8
33	9	6	4	0	2	7	3	0	2	2	4	6
35	3	8	4	1	0	0	3	4	4	3	3	5
37	3	8	2	0	2	0	0	0	2	2	1	5
39	2	2	4	0	1	0	1	0	1	2	0	1
41	6	6	2	0	0	0	0	0	3	0	0	0
43	2	2	2	0	0	0	0	0	0	0	0	0
45	1	1	2	0	0	0	0	0	0	0	0	0
47	1	2	1	0	0	0	0	0	0	0	0	0
49	1	1	1	0	0	0	0	0	0	0	0	0
51	1	4	1	0	0	0	0	0	0	0	0	0
53	1	2	1	0	0	0	0	0	0	0	0	0
55	0	0	1	0	0	0	0	0	0	0	0	0
57	1	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0	0	0	0	0
N	1220	2143	2789	4256	3093	296	917	234	1171	617	752	881

Table 4.- Catch at age.

Catch in numbers (10^6) east of ICJ line

AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	231	151	194	381	148	179	115	61	113	296	48	38	60	61	2
4	102	83	198	273	370	567	318	200	185	465	202	106	67	145	184
5	33	17	45	51	96	142	199	116	74	70	113	78	32	38	110
6	4	4	6	8	16	14	68	44	21	16	15	17	20	11	9
7	2	1	3	2	6	4	25	22	13	8	7	4	8	10	3
8	1	0	1	1	3	2	13	8	6	5	4	3	2	4	2
9	0	0	0	0	3	1	9	6	3	4	4	3	1	1	1
10	0	0	0	0	1	1	8	5	2	2	3	4	1	1	0
11	0	0	0	0	1	1	13	5	2	2	2	3	2	1	0
Total	371	256	447	717	645	911	768	466	421	869	398	255	195	274	311

Table 5.- Shell height (mm), meat weight (g) and meat count per 500 grams at age as used by projection and age/weight programs. Height and weight as of first day of quarter.

Biological age	Cohort age	Shell Height	Meat Weight	Count /500g
2.25	3.00	61.23	3.11	161
2.50	3.25	63.22	3.44	145
2.75	3.50	74.57	5.73	87
3.00	3.75	83.13	8.03	62
3.25	4.00	87.30	9.34	54
3.50	4.25	89.23	10.00	50
3.75	4.50	96.26	12.64	40
4.00	4.75	102.35	15.29	33
4.25	5.00	105.51	16.80	30
4.50	5.25	107.02	17.55	28
4.75	5.50	111.60	19.99	25
5.00	5.75	115.81	22.42	22
5.25	6.00	118.08	23.81	21
5.50	6.25	119.18	24.50	20
5.75	6.50	122.23	26.49	19
6.00	6.75	125.13	28.49	18
6.25	7.00	126.72	29.63	17
6.50	7.25	127.50	30.20	17
6.75	7.50	129.55	31.73	16
7.00	7.75	131.54	33.26	15
7.25	8.00	132.65	34.13	15
7.50	8.25	133.19	34.57	14
7.75	8.50	134.58	35.69	14
8.00	8.75	135.94	36.82	14
8.25	9.00	136.70	37.47	13
8.50	9.25	137.08	37.79	13
8.75	9.50	138.03	38.60	13
9.00	9.75	138.96	39.41	13
9.25	10.00	139.48	39.88	13
9.50	10.25	139.74	40.11	12
9.75	10.50	140.39	40.68	12
10.00	10.75	141.02	41.26	12
10.25	11.00	141.38	41.58	12
10.50	11.25	141.56	41.75	12
10.75	11.50	142.00	42.15	12
11.00	11.75	142.44	42.55	12

Table 6.- Total weighted average number of scallops at age per tow.

Sampling dates	Age (years)								
	2	3	4	5	6	7	8	9	10+
1979	26	108	31	20	9	4	2	1	4
1980	432	56	34	6	2	1	0	0	1
1981	166	179	24	5	2	1	0	0	0
1982	22	41	20	5	1	0	0	0	0
1983	41	26	15	4	2	1	0	0	0
1984	175	25	9	2	1	0	0	0	0
1985	82	165	15	2	0	0	0	0	0
1986	198	136	145	12	1	0	0	0	0

Table 7.- Indices of abundance of scallop age-classes by contour analysis; Numbers at age (10^6).

Sampling dates	Age (years)						
	2	3	4	5	6	7	8
1978	781.15	370.39	834.23	326.25	95.21	36.39	11.74
1979	106.18	327.06	184.39	137.46	44.97	22.71	8.25
1980	350.50	181.55	38.58	19.54	14.37		
1981	548.31	551.89	137.31	66.98			
1982	241.77	430.42	98.11	23.43	5.09		
1983	204.16	115.75	97.88	24.27	9.52		
1984	1166.26	183.36	48.08	11.06	3.59		
1985	737.04	779.10	83.09	8.74			
1986	574.29	710.64	221.56	30.26			

Table 8.- Stratified average number of scallops at age per tow and stratified total number of scallops per tow, N.

Stratum	Sampling dates	Age (years)									N	s.d.
		2	3	4	5	6	7	8	9	10^+		
Very Low	1979	3	18	6	9	8	4	2	1	5	39	40
	1980	39	5	6	4	2	2	1	1	2	62	92
	1981	71	92	48	6	1	1	0	0	0	239	325
	1982	6	6	20	10	1	0	0	0	0	64	200
	1983	26	19	8	3	2	1	0	0	0	69	175
	1984	74	14	8	2	1	0	0	0	0	125	295
	1985	32	79	6	1	0	0	0	0	0	170	375
	1986	42	154	50	5	1	0	0	0	0	292	582
Low	1979	17	36	26	26	9	4	3	2	7	130	229
	1980	65	28	18	8	3	1	1	0	1	125	256
	1981	24	26	9	2	1	1	0	0	0	78	102
	1982	14	18	20	5	1	0	0	0	0	86	138
	1983	81	59	19	5	2	1	0	0	0	172	230
	1984	151	27	11	2	1	0	0	0	0	253	445
	1985	74	64	11	2	0	0	0	0	0	188	324
	1986	165	143	49	14	2	0	0	0	0	376	769
Medium	1979	41	117	39	21	9	5	2	1	3	238	234
	1980	550	74	36	10	2	1	0	0	0	674	1725
	1981	377	279	24	7	2	1	0	0	0	712	1025
	1982	24	37	18	4	1	0	0	0	0	90	143
	1983	16	28	15	4	2	1	0	0	0	69	88
	1984	449	35	12	2	0	0	0	0	0	636	931
	1985	173	511	22	2	0	0	0	0	0	710	1164
	1986	70	35	63	14	2	0	0	0	0	185	139
High	1979	27	147	42	19	9	3	1	0	1	249	231
	1980	727	104	66	6	2	1	0	0	1	908	1256
	1981	133	285	32	5	2	1	0	0	0	458	674
	1982	30	68	21	4	1	0	0	0	0	129	143
	1983	60	24	20	5	1	0	0	0	0	112	113
	1984	215	52	8	1	1	0	0	0	0	277	400
	1985	110	255	22	2	0	0	0	0	0	392	481
	1986	309	144	232	14	1	0	0	0	0	702	854

Table 9.- Population numbers east of ICJ line from cohort analysis.

Age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	474	532	741	1196	1219	782	505	402	848	707	243	193	448	1228	436
4	185	208	336	482	714	960	532	346	305	659	352	173	139	347	1052
5	135	72	110	116	178	295	327	179	124	101	157	127	57	62	176
6	13	91	49	57	57	71	133	107	52	42	25	36	42	21	20
7	11	8	79	38	44	36	51	55	55	27	23	9	16	19	8
8	2	9	7	69	32	34	29	22	29	37	17	14	4	7	7
9	1	1	7	5	61	27	29	14	12	21	29	12	10	2	3
10	1	1	1	6	5	52	23	17	7	8	15	22	8	8	1
11	1	0	1	1	6	3	47	14	11	4	5	10	16	6	6
Σ	824	923	1332	1972	2316	2260	1676	1156	1443	1607	866	596	740	1700	1709

Table 10 - Fishing mortality east of ICJ line from cohort analysis

Age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
3	.72	.36	.33	.42	.14	.29	.28	.17	.15	.60	.24	.23	.16	.06	.01
4	.85	.53	.96	.90	.78	.98	.99	.93	1.00	1.34	.92	1.01	.71	.58	.20
5	.29	.29	.55	.62	.83	.70	1.02	1.13	.98	1.29	1.38	1.02	.90	1.04	1.07
6	.35	.04	.15	.16	.35	.23	.77	.57	.55	.50	.99	.68	.70	.85	.62
7	.16	.11	.04	.07	.16	.13	.74	.54	.28	.36	.40	.64	.70	.83	.40
8	.35	.04	.09	.02	.09	.06	.63	.49	.25	.16	.30	.21	.57	.86	.30
9	.24	.19	.05	.06	.05	.04	.42	.54	.29	.22	.16	.27	.16	.93	.33
10	.29	.13	.23	.03	.35	.02	.43	.34	.42	.37	.26	.20	.21	.16	.35
11	.31	.33	.33	.32	.32	.27	.37	.44	.24	.60	.45	.39	.15	.30	.06
A	.40	.23	.30	.29	.34	.30	.63	.57	.46	.60	.57	.52	.47	.62	.37

Table 11.- Stock projections at current F_{MAX} (.630) and at $F_{0.1}$ (.402)

F=.630	1987	1987	1987	1987	1988	1988
Rate on smalls	1.00	1.00	1.00	1.00	1.00	1.00
Mean Wgt. Catch	16.13	16.85	18.37	19.73	18.92	18.92
Catch (Mill.)	60.79	302.45	123.69	45.62	41.22	214.43
Catch (t)	980.80	5095.48	2272.69	900.22	770.39	4057.70
Cum. Catch (t)	980.80	6076.28	8348.97	9249.19	770.39	4828.09
Biomass (t)	21366.60	18724.30	18013.40	18659.70	19187.50	16931.60
	1988	1988	1989	1989	1989	1989
Rate on smalls	1.00	1.00	1.00	1.00	1.00	1.00
Mean Wgt. Catch	19.71	20.97	19.47	19.57	20.50	21.53
Catch (Mill.)	89.53	33.43	31.16	164.53	70.80	26.88
Catch (t)	1764.23	701.13	606.83	3219.77	1451.08	578.80
Cum. Catch (t)	6592.32	7293.45	606.83	3826.60	5277.68	5856.48
Biomass (t)	16312.40	16942.60	17359.00	15620.00	15108.60	15733.80

F=.402	1987	1987	1987	1987	1988	1988
Rate on smalls	1.00	1.00	1.00	1.00	1.00	1.00
Mean Wgt. Catch	16.14	16.92	18.52	19.97	19.13	19.51
Catch (Mill.)	39.17	206.92	91.27	34.71	31.16	168.02
Catch (t)	632.31	3500.64	1690.50	693.07	596.04	3278.48
Cum. Catch (t)	632.31	4132.95	5823.45	6516.52	596.04	3874.52
Biomass (t)	21744.30	20947.30	21034.40	21968.10	22809.20	21668.00
	1988	1988	1989	1989	1989	1989
Rate on smalls	1.00	1.00	1.00	1.00	1.00	1.00
Mean Wgt. Catch	20.36	21.72	20.49	20.75	21.69	22.84
Catch (Mill.)	73.31	28.01	25.39	137.50	61.22	23.64
Catch (t)	1492.55	608.22	520.32	2852.83	1328.06	539.84
Cum. Catch (t)	5367.07	5975.29	520.32	3373.15	4701.21	5241.05
Biomass (t)	21564.90	22349.60	22979.30	21909.30	21725.00	22399.10

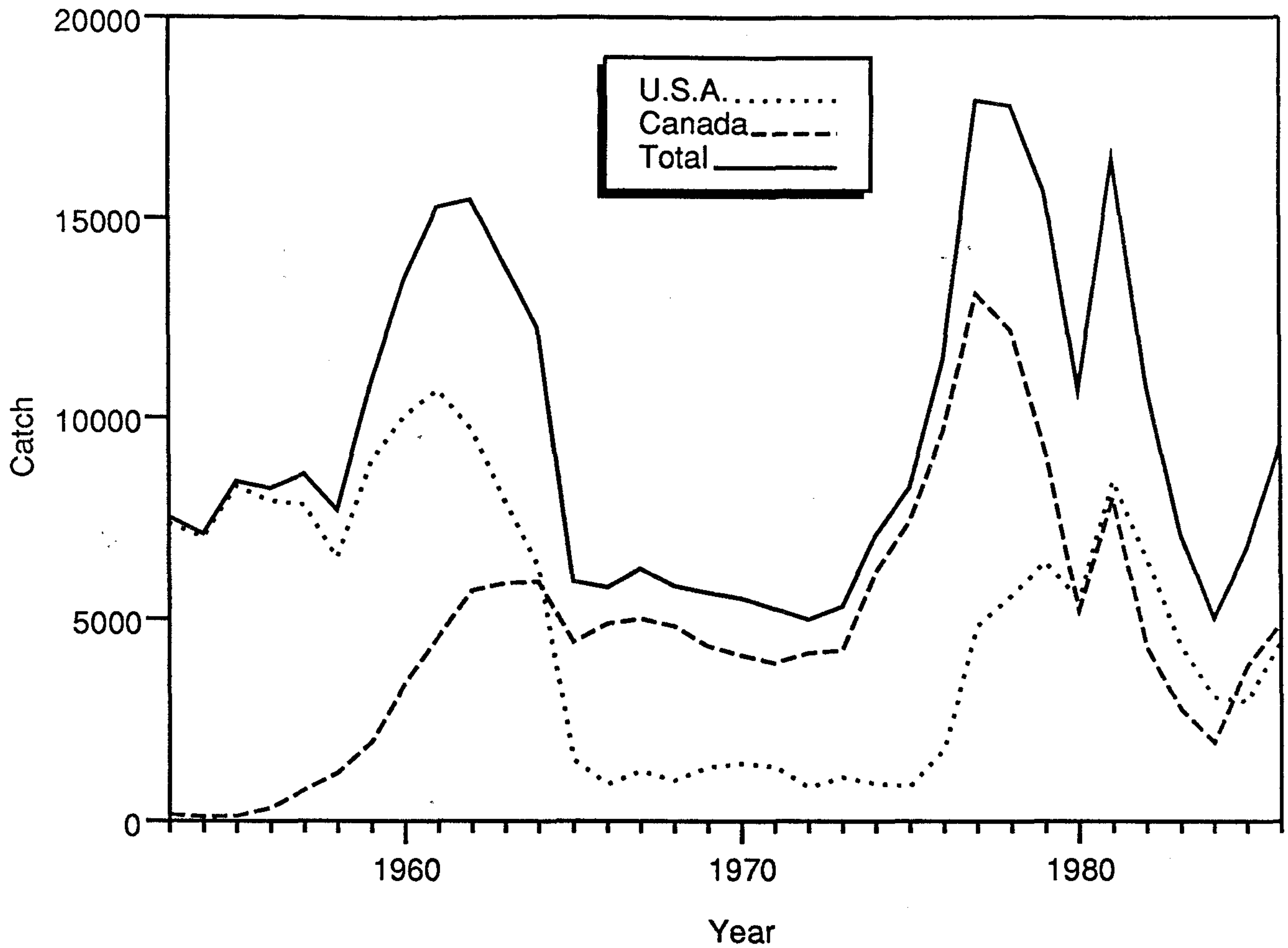

Figure 1. - Landings (t of meats) from NAFO subdivision 5ze.

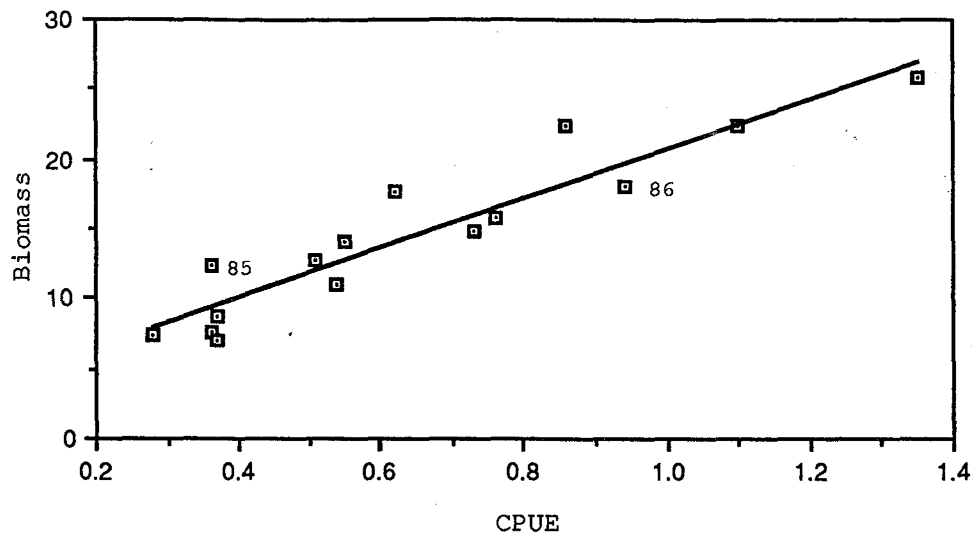

Figure 2. - Cohort biomass (t of meats x 1000) vs CPUE (kg/hr).

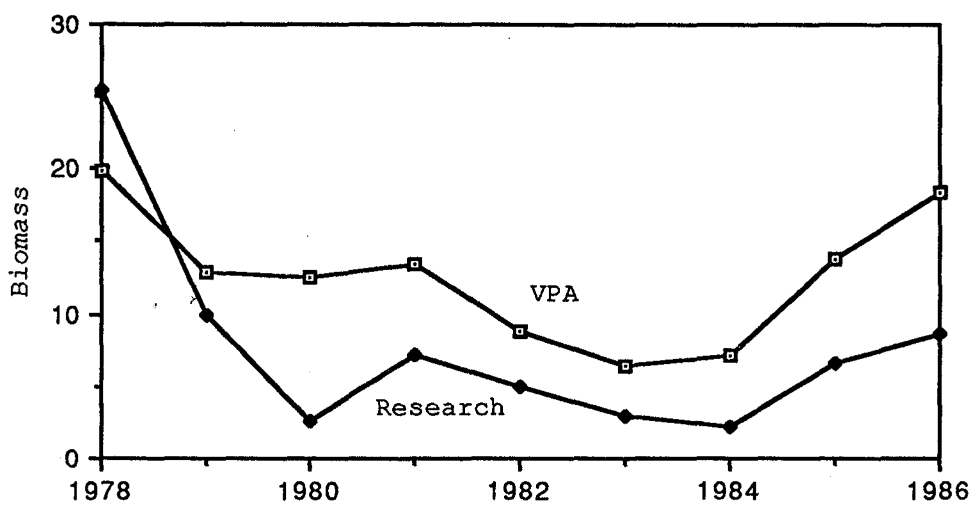

Figure 3. - Research survey and VPA biomass estimates for ages three plus.

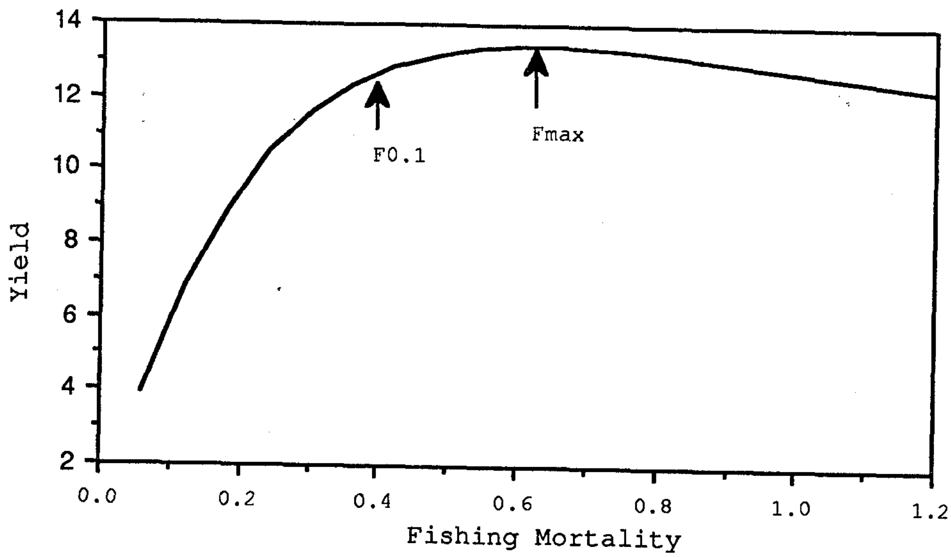

Figure 4. - Yield per recruit, F_{MAX} = .630, $F_{0.1}$ = .402.

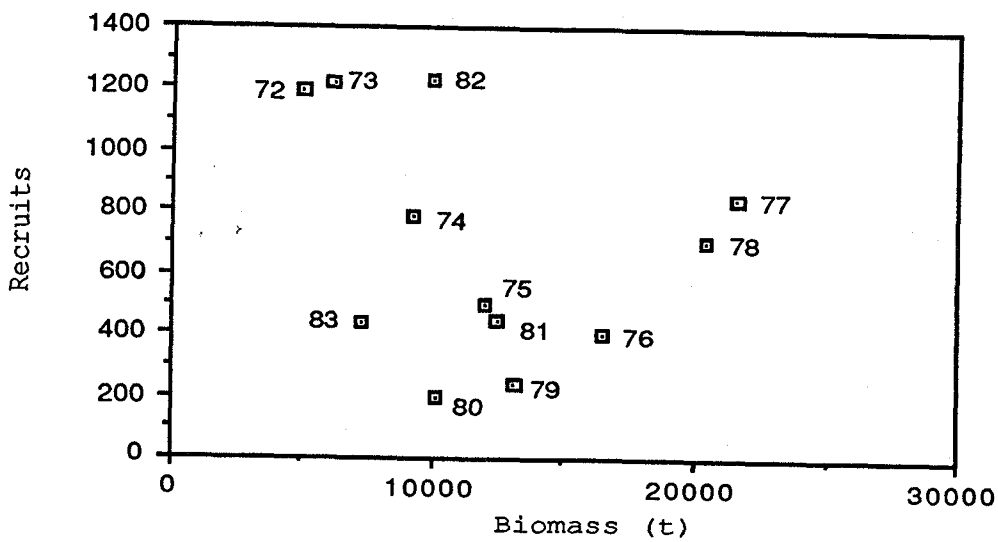

Figure 5. - Age 4+ biomass versus recruits (lagged three years).

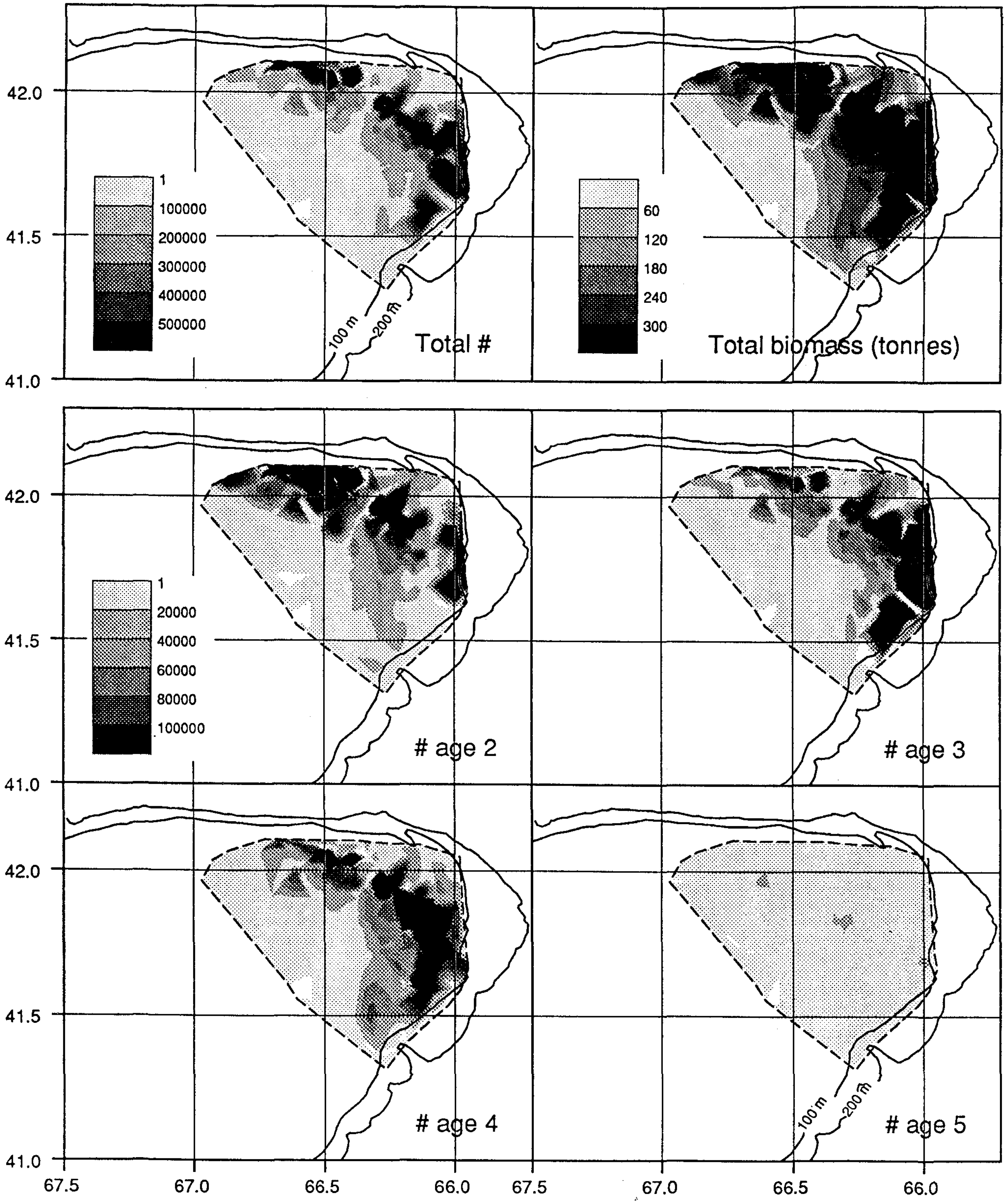

Figure 6a. - Contour analysis of 1986 research survey results (per sq. km.)

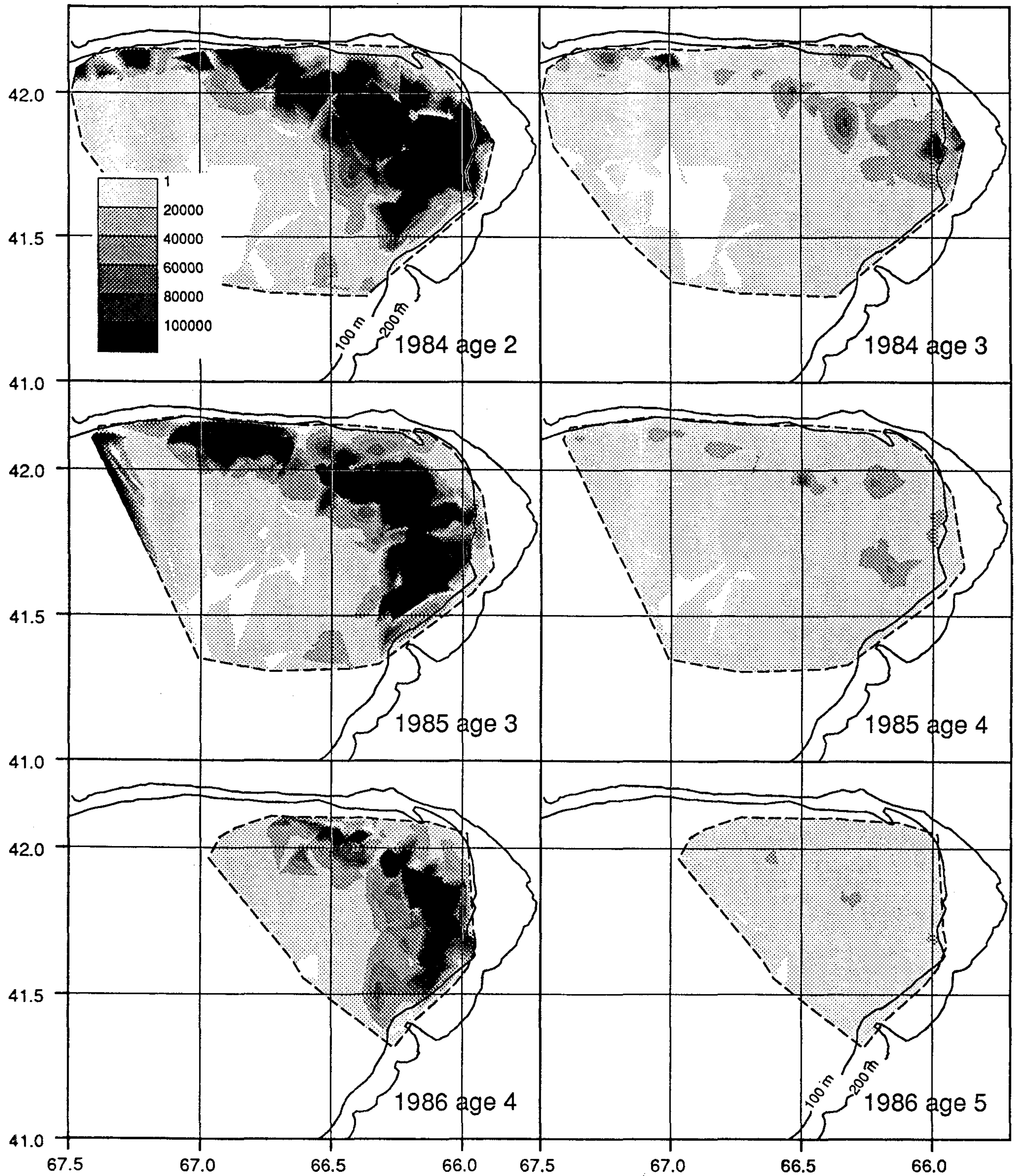

Figure 6b. - Contour analysis of research survey results.

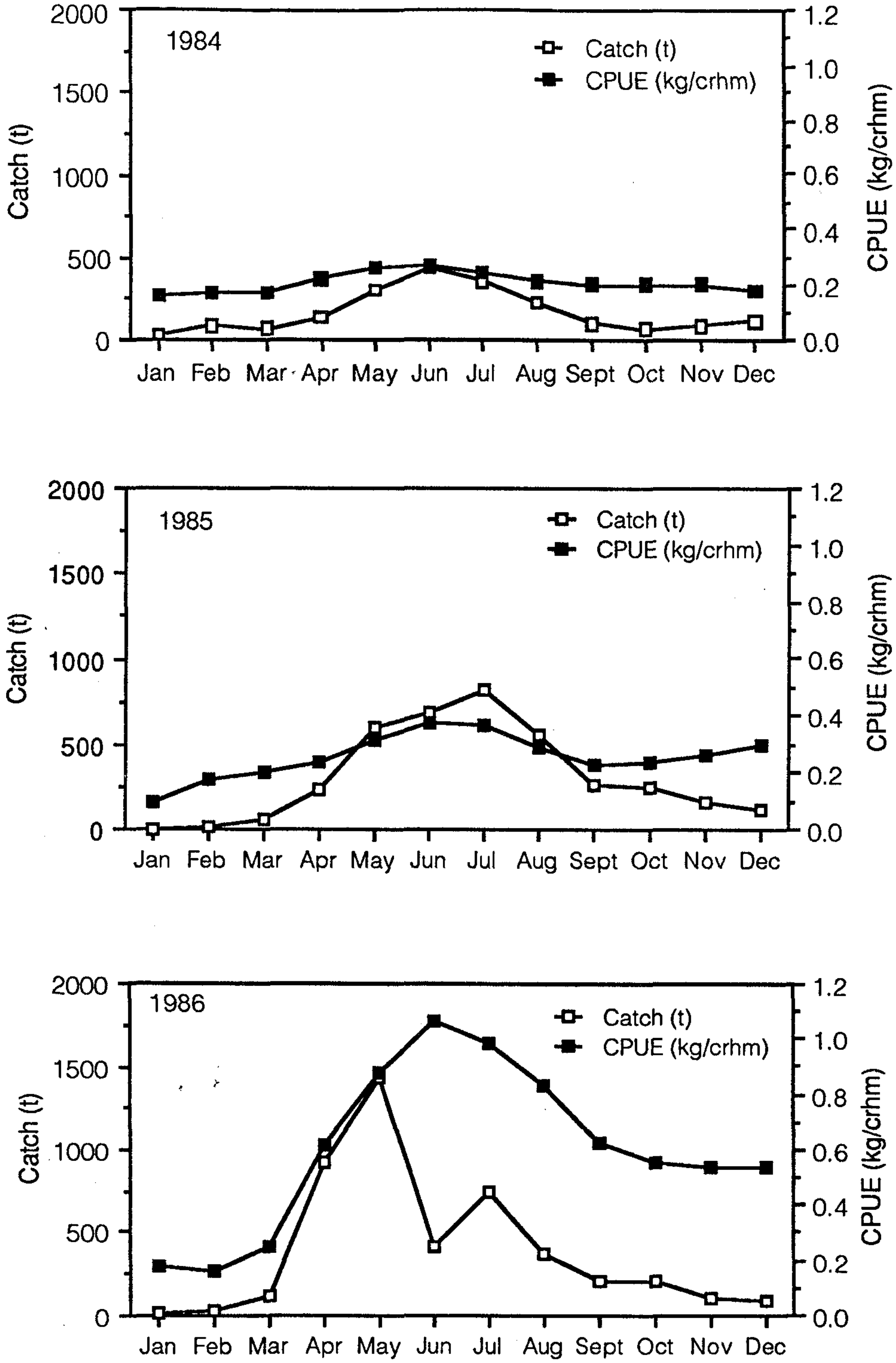

Figure 7. - Monthly CPUE and catch for the last three years for vessels over 19.8m L.O.A. fishing Georges Bank.