Georges Bank Scallop Stock Assessment - 1984

By

R.K. Mohn, G. Robert and D.L. Roddick
Invertebrates and Marine Plants Division
Fisheries Research Branch
Halifax Fisheries Research Laboratory
Department of Fisheries and Oceans
Scotia-Fundy Region
P.O. Box 550
Halifax, N.S.
B3J 2S7

ABSTRACT

The 1984 fishery reflected another year of depletion of a resource which has not experienced good recruitment since the 1977 year class. The Canadian catch was 1,945 t, which is the lowest catch for the Canadian fleet since 1959. This was taken from a biomass that is estimated to be the lowest since research surveys were initiated. Yield per recruit and stock projections show that the stock is seriously overfished. The effects of the currently used catch restriction of an average of 35 meats/pound and proposed alternatives of 45 and 30/pound are compared to assess their conservation impact. None of these management measures is adequate by itself to significantly aid stock reconstruction.

RÉSUMÉ

La pêcherie de 1984 reflète une autre année de diminution d'une ressource qui n'a pas été l'object d'un bon recrutement depuis 1977. Les prises Canadiennes sont de l'ordre de 1,945 t, valeur la plus basse pour la flottille Canadienne depuis 1959. Ces prises ont originé d'une biomasse qu'on estime être la plus basse depuis qu'on a commencé à faire des inventaires de stocks. Le rendement par recrue et des projections de stock établissent que le stock est sérieusement surexploité. On compare l'effet du compte de chairs (35) en vigueur et des alternatives proposées de 45 et 30 compte par livre afin d'évaluer l'impact sur la conservation. Aucune de ces mesures de gestion n'est adéquate par elle-même pour contribuer, d'une façon significative, à la reconstruction du stock.

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 to 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. In 1981, the Georges Bank scallop fishery relied on age 4 scallops for 60% of its catch, older scallops having become scarcer through the year. In 1982, the fishery relied mainly on the 1977 year class, and landings by the Canadian fleet decreased by 50% in comparison to 1981. 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. Effort in 1984 was slightly lower than 1983, and the Canadian catch fell to 1,945 t, its lowest level since 1959.

For this document, the standard assessment techniques (research survey abundance, yield per recruit analysis, cohort analysis, and stock projections) are applied to the Georges Bank scallops. It is shown that the stock is depleted and that the currently discussed management options are inadequate for stock reconstruction.

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 3 which contains weight distribution in 2 g intervals for the last 6 years. Month-by-month port sampling data are given in Table 4.

Catch in numbers at age (Table 5) for the cohort analysis are derived from these port sampling data and the sum of U.S. and Canadian catches in the new 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 research cruise data. The values expressing meat weight as a function of shell height use the parameters 1.027E-5 for the constant and 3.090 for the exponent of height. The 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) having the values of 145.5, 1.5, and 0.38 respectively for L_∞, T_0, and k.

Traditionally, catch statistics are compiled on an annual basis and recruitment to a fishery is discussed in terms of year class strengths. It is generally accepted that Georges Bank scallops are born in October and the first annual ring is laid down the following March. This ring 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 mark the first birthday and the approximately 25 mm annulus will mark the second birthday. The date 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 below 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 occur 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.

The values for the columns of meat and ovary weights as a function of size, given in Table 6, are derived from data published in Serchuck et al. (1982). An allometric equation was fitted from the log of shell height and ovary weight giving 3.875E-7 for the constant and 3.617 for the exponent. This value is used as an index of reproductive potential. It is not known what the relationship is between pre-spawning ovary weight and viable gamete production; therefore, this simple index is presented. It is realized that there are many factors which would influence subsequent recruitment even if gamete production could be estimated.

As was done last year (Mohn et al. 1984), the standard cohort analysis was augmented by the separable VPA of Pope and Shepherd (1982). The results are presented in Tables 7a and b.

A research survey was carried out on Georges Bank during August 1984. The design of the survey was based on a stratification by commercial effort. The logbooks of the commercial fleet in the preceeding 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. 1982).

A Thompson-Bell yield per recruit analysis was not carried out again this year as the same growth and selectivity are appropriate as for last year. The values of 0.56 for $F_{0.1}$ and 0.89 for F_{max} would still be applicable.

The regulations operant on the offshore fleet are that the average weight of samples taken from the catch cannot be less than 13 g, which corresponds to 35 meats/pound. 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 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 young scallops. The annual growth is divided into quarterly components of 10, 35, 35 and 20%. The annual effort is also partitioned into quarters at the rates of 15, 40, 30 and 15%. Selectivity for the projections follows the pattern of the fishery as revealed from the cohort analysis instead of that of the gear (Caddy 1972).

RESULTS

The catch-at-age matrix (Table 5) does not extend back beyond 1972 because of the lack of reliable data. There are very few animals caught above the age of 9. Therefore, the catch at age is truncated at this age which is not a plus group. The results of the cohort analysis are given in Table 7 and show that the stock was in a very depressed state in 1984. The last apparent good recruitment was the 1977 year class; and subsequent recruitment, as defined by the 3 year olds (see Table 7), has been very poor. The fishing mortality has been highest on the 5 year olds in recent years, and the high mortality of 4 year olds in 1981 reflects the relaxation of regulations in the fishery for that year. Again one notes the difference between the selectivity of the gear (Caddy 1972) and fishing mortality as a function of age as determined by the cohort analysis. The difference in patterns is a result of the behaviour of the fishermen who direct their effort against the younger animals because they occur in higher densities. In tuning the VPA, F was regressed against effort as defined in terms of hours and crew-hours-meters (crhm) as given in Table 2. The F was unweighted and the fit was poor ($r < 0.57$) for both indices. The estimated biomass was also used in tuning against the CPUE. The regression coefficient between biomass of ages 4 to 9 and CPUE as defined by hours fished was 0.90 and 0.86 for crhm. The last point fell just beneath the regression line and the penultimate fell just above it (see Fig. 2). A range of starting F's was tried; but the regression coefficients were virtually unaffected, falling with decreasing F; and further reduction would have taken the last point further from the regression line. Also the effort decreased from 1983 to 1984 but the weighted F did not. Taking these observations into account led us to adopt the value of 0.8 for the fully recruited F which is slightly lower than last year's estimate. The numbers at age estimated from the research survey (Tables 8 and 9) for 3+ drop approximately 4% while the cohort 3+ numbers fall about 20%. Lower starting F's would increase this discrepancy. The 4+ biomass (Table 10) from the cohort analysis and the recruitment from that stock are plotted in Figure 3 to display what appears to be a compensatory stock-recruit relationship.

The research survey data (Table 9) show the depletion of the stock which has taken place in recent years. The survey results are not considered to be reliable for age 2 animals because of their low partial recruitment to the research gear and should not be considered as always an accurate predictor of the following year's recruitment. Nonetheless, the five-fold increase in 2 year olds estimated from 1983 to 1984 is an unmistakable sign of a significant improvement in recruitment which will be better estimated this fall. The biomass estimates from the research data are not corrected for efficiency of the gear. The 3+ biomass from the research surveys and the cohort analysis follow:

3+ biomass estimates (10^6 t).

	1978	1979	1980	1981	1982	1983	1984
Research	14.2	5.7	1.4	3.8	2.6	1.6	1.2
Cohort	41.0	35.6	33.7	33.9	24.2	17.7	12.2

The simulations for the three meat count levels are given in Table 11. The program is the same as last year. Table 11a contains the results for the 45 meat count (45 MC). As is seen in the first row of this table the fishing intensity on small animals is not restricted compared to even the 1981 mortality which was used as a basis pattern for this run. As would be expected, by mid 1986 the standing stock biomass is much smaller than for the other runs. These are not meant to predict actual catches but are only used as relative indices to compare the three meat counts. One sees a slight disruption in pressure on small animals with a 35 MC and severe restriction (up to 18% of full rate) for 30 MC. If proper discounting rates and market values as a function of meat size were known a net present value calculation would be useful in comparing strategies. Figure 4 shows the meat size distribution for 45 MC and 30 MC.

Last year's yield per recruit analysis had an $F_{0.1}$ at 0.56 and F_{max} at 0.89 (Mohn et al. 1984). The fully recruited F levels are just below the F_{max} value, and in the face of poor recruitments the biomass has not been able to support this intensity of fishing. These target F levels are based on the selectivity from the cohort analysis. It was argued last year that such selectivities are more appropriate than those based on the gear. Also one should recall that significant improvements in yield per recruit are obtained if the fishing pressure is applied to older animals than is now the practice. Last year the relative amounts of ovary pre-spawning biomass in a stable age distribution at various fishing levels were incorrectly estimated. The revised values are less sensitive to F and are:

F	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
B(%)	100	79	64	51	42	35	30	25	22	19	17

CONCLUSIONS

All indices show that the 5Ze stock is at or near an all-time low level. Fishing mortality on young animals approaches unity and has been at this level for years, resulting in a depleted stock. All relevant indices show that fishing mortality is at too intense a level for this stock. This is

compounded by the failure of a strong year class to appear in the last few years. However, the abundance of 2 yr olds in the 1984 research survey predicts a strong recruitment to the fishery in the fall of 1985. The value that this recruitment gives to the fishery will depend on whether this year class is fished while still young or allowed to grow. The fishing mortalities on young animals in 1981 should not be repeated. Because of the depletion of the standing stock, the data available suggest that 1985 will be bleak until the recruitment is felt. The actual time of recruitment will depend on growth rates and the legal size limit.

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Table 1 .- Catch statistics (t of meats) for 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	U.S.A.	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	3000*	1945	4945

*estimate

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			C.P.U.E.
		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	96	13016	0.401
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

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

	YEAR					
GRAM	1979	1980	1981	1982	1983	1984
1	0	0	0	0	0	0
3	2	15	16	2	12	7
5	31	99	84	26	66	96
7	96	172	204	99	110	205
9	137	169	253	146	118	169
11	140	128	177	159	125	108
13	112	92	96	132	111	69
15	86	67	52	103	90	55
17	66	51	31	73	70	46
19	50	38	20	55	53	41
21	42	32	15	45	44	37
23	38	24	11	33	36	30
25	30	20	8	27	27	25
27	25	17	6	21	23	20
29	23	13	5	17	18	18
31	20	11	4	13	15	15
33	17	9	3	11	13	12
35	15	7	3	8	10	11
37	13	6	2	6	8	8
39	10	5	2	5	8	6
41	9	4	1	4	6	5
43	7	3	1	3	6	4
45	7	3	1	2	5	3
47	5	3	1	2	4	2
49	4	2	1	1	4	2
51	3	2	1	1	2	2
53	3	2	1	1	3	1
55	2	1	1	1	3	1
57	1	1	0	0	1	1
59	1	1	0	1	2	0
61	1	1	0	0	2	0
63	1	1	0	0	1	0
65	1	0	0	0	2	0
67	0	0	0	0	1	0
69	0	0	0	0	1	0
71	0	0	0	0	0	0
73	0	0	0	0	1	0
75	0	0	0	0	0	0
77	0	0	0	1	0	0

Table 4. Frequencies of numbers at weight in 2 gram intervals (normalized to 1000) by month for 1984. Last row is sample size.

	MONTH										
GRAMS	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0	0	0
3	5	3	9	4	3	2	6	7	32	5	19
5	84	41	126	77	62	61	85	158	234	120	172
7	132	117	187	184	181	189	225	309	211	257	283
9	100	97	106	181	184	187	169	225	115	161	154
11	42	98	66	118	123	143	91	91	76	100	73
13	63	77	73	63	84	82	65	45	60	48	57
15	60	100	75	51	56	56	56	36	56	49	42
17	67	50	68	46	46	46	48	18	42	45	32
19	97	53	43	48	49	38	37	20	28	33	33
21	67	64	45	46	38	38	32	14	20	34	26
23	74	47	25	35	35	28	30	12	24	30	15
25	42	44	30	28	25	25	23	12	17	23	18
27	30	36	26	24	22	19	20	11	10	19	14
29	9	38	21	23	21	18	11	12	8	16	14
31	28	21	24	13	17	16	17	7	6	13	8
33	14	18	12	13	12	15	16	10	5	11	5
35	28	14	11	10	10	10	14	8	8	11	10
37	16	15	12	9	7	5	10	1	8	10	4
39	14	11	10	6	5	7	10	1	8	4	4
41	9	14	5	5	5	5	6	1	4	3	2
43	2	8	7	5	1	2	6	1	3	2	4
45	5	3	4	2	2	3	6	2	4	1	3
47	2	6	5	3	2	2	4	0	3	1	1
49	2	6	1	2	3	2	3	0	3	2	5
51	0	3	2	1	3	0	3	0	3	0	1
53	0	6	2	1	1	1	2	0	2	0	1
55	0	3	1	1	1	1	1	0	2	0	0
57	2	3	0	1	1	0	1	0	1	0	0
59	0	0	0	0	1	0	0	0	2	0	0
61	0	2	0	0	1	0	1	0	2	0	0
63	0	3	0	0	0	0	1	0	1	0	0
65	5	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	1	0	1
69	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	1	0	0	0	0
SAMP	431	660	2006	6515	5271	6270	3467	1538	1860	2154	1889

Table 5. Catch-at-age matrix for Georges Bank landings on the Canadian side of the ICJ line.

AGE	YEAR												
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
3	84	45	19	56	8	5	12	4	12	26	3	4	6
4	183	142	260	445	335	448	201	111	157	467	113	55	68
5	58	41	117	147	199	355	334	146	107	230	143	72	51
6	21	10	23	32	43	45	123	73	52	38	63	32	26
7	9	5	8	10	21	16	40	55	31	27	19	24	18
8	4	3	4	5	14	9	20	35	26	23	18	12	18
9	3	2	3	3	16	6	17	37	24	29	24	28	11
	362	248	433	698	637	884	746	462	408	841	383	228	198

Table 6. Smoothed growth characteristics. Height is in mm., weight of meat and ovary is in grams and count is per 500 g.

AGE	HEIGHT	WEIGHT	COUNT	PRE-SP*
2.25	25.2	0.2	2281.8	0.0
2.50	41.2	1.0	499.9	0.3
2.75	52.2	2.1	240.0	0.6
3.00	57.1	2.8	181.4	0.9
3.25	63.2	3.8	132.7	1.3
3.50	74.1	6.2	81.1	2.3
3.75	81.7	8.3	60.1	3.2
4.00	85.1	9.4	53.0	3.7
4.25	89.2	10.9	45.7	4.4
4.50	96.7	14.0	35.7	5.9
4.75	101.9	16.5	30.4	7.1
5.00	104.2	17.6	28.3	7.7
5.25	107.0	19.2	26.1	8.5
5.50	112.1	22.1	22.6	10.0
5.75	115.7	24.4	20.5	11.2
6.00	117.2	25.4	19.7	11.8
6.25	119.2	26.7	18.7	12.5
6.50	122.7	29.2	17.1	13.9
6.75	125.1	31.0	16.1	14.9
7.00	126.2	31.9	15.7	15.4
7.25	127.5	32.9	15.2	16.0
7.50	129.9	34.9	14.3	17.1
7.75	131.5	36.3	13.8	17.9
8.00	132.3	36.9	13.6	18.3
8.25	133.2	37.7	13.3	18.7
8.50	134.8	39.1	12.8	19.6
8.75	136.0	40.2	12.5	20.2
9.00	136.5	40.6	12.3	20.4
9.25	137.1	41.2	12.1	20.8

* Pre-spawning ovary weight as a function of height

Table 7. Results from cohort analysis.

A. Population numbers ($\times 10^6$)

AGE	YEAR												
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
3	594	832	1142	1378	1307	787	466	727	875	342	185	219	197
4	350	458	711	1015	1194	1175	707	411	654	781	285	165	195
5	193	142	279	396	495	762	637	449	266	443	262	150	96
6	54	119	89	141	219	259	351	258	267	139	181	101	67
7	29	29	99	59	97	157	191	201	164	192	89	104	61
8	16	17	21	82	44	67	127	135	129	119	148	62	72
9	8	10	13	15	69	27	52	96	88	93	86	117	45
	1243	1608	2353	3087	3425	3233	2532	2277	2445	2108	1236	918	732

B. Fishing mortality

AGE	YEAR												
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
3	0.160	0.058	0.018	0.043	0.006	0.006	0.027	0.006	0.015	0.084	0.015	0.021	0.032
4	0.802	0.396	0.484	0.618	0.350	0.513	0.354	0.335	0.291	0.993	0.542	0.435	0.456
5	0.378	0.365	0.582	0.494	0.549	0.674	0.802	0.419	0.550	0.792	0.852	0.706	0.800
6	0.529	0.092	0.309	0.277	0.234	0.203	0.458	0.353	0.229	0.341	0.454	0.406	0.530
7	0.403	0.199	0.088	0.195	0.263	0.111	0.247	0.340	0.222	0.161	0.259	0.274	0.381
8	0.349	0.204	0.239	0.063	0.404	0.152	0.182	0.323	0.232	0.224	0.138	0.236	0.297
9	0.416	0.256	0.283	0.226	0.286	0.266	0.409	0.520	0.328	0.399	0.348	0.293	0.300
	0.434	0.224	0.286	0.274	0.299	0.275	0.354	0.328	0.267	0.428	0.373	0.339	0.399

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
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
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
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

(con't)

Table 8.- Total weighted average number of scallops per tow at age.

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

Table 9. Indices of abundance of scallop age-classes by contour analysis; number 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		

Table 10. Cumulative biomass (t)

AGE	YEAR												
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
3+	11537	14133	21499	29470	36681	41785	40981	35648	33679	33909	24219	17734	12176
4+	9874	11802	18302	25610	33022	39582	39675	33611	31228	32951	23701	17120	11625
5+	6589	7500	11622	16068	21795	28537	33025	29751	25077	25614	21026	15572	9796
6+	3197	5004	6715	9095	13082	15128	21821	21845	20399	17824	16419	12935	8099
7+	1829	1969	4453	5516	7526	8555	12897	15284	13608	14300	11810	10368	6400
8+	911	1054	1308	3629	4442	3560	6801	8868	8371	8162	8964	7042	4457
9+	325	411	522	616	2817	1080	2121	3883	3593	3771	3493	4742	1808

Table 11a. Simulations for three meat count levels – 45 meat count.

	YEAR							
	1985	1985	1985	1985	1986	1986	1986	1986
RATE ON SMALLS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEAN WT. CATCH	11.64	11.34	12.12	11.67	11.63	12.74	15.75	17.47
CATCH (MILL.)	25.29	86.58	93.49	126.49	84.00	236.52	172.31	91.49
CATCH (T)	294.33	981.48	1132.81	1475.55	976.84	3012.15	2714.11	1598.55
CUM. CATCH (T)	294.33	1275.81	2408.62	3884.17	976.84	3988.99	6703.10	8301.65
BIOMASS (T)	8785.40	11113.50	12086.00	12116.20	12075.20	11283.00	9733.90	9195.30

	1987	1987	1987	1987	1988	1988	1988	1988
RATE ON SMALLS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEAN WT. CATCH	16.69	17.54	19.91	20.19	15.99	16.84	19.04	19.74
CATCH (MILL.)	44.31	125.21	92.90	58.28	24.16	71.28	57.47	45.48
CATCH (T)	739.58	2195.99	1849.24	1176.52	386.28	1200.45	1094.22	897.78
CUM. CATCH (T)	739.58	2935.57	4784.81	5961.33	386.28	1586.73	2680.95	3578.73
BIOMASS (T)	8936.90	8015.10	6850.10	6560.40	6536.10	6331.20	5804.90	5735.90

	1989	1989	1989	1989
RATE ON SMALLS	1.00	1.00	1.00	1.00
MEAN WT. CATCH	14.81	15.65	17.85	24.94
CATCH (MILL.)	21.15	62.29	50.39	63.20
CATCH (T)	313.19	974.98	899.31	1576.46
CUM. CATCH (T)	313.19	1288.17	2187.48	3763.94
BIOMASS (T)	5762.10	5707.80	5335.10	4198.20

Table 11b. Simulations for three meat count levels - 35 meat count.

	YEAR							
	1985	1985	1985	1985	1986	1986	1986	1986
RATE ON SMALLS	0.86	0.73	1.00	0.77	0.50	1.00	1.00	1.00
MEAN WT. CATCH	12.89	12.87	13.03	12.89	12.87	12.96	16.01	17.99
CATCH (MILL.)	18.93	58.67	77.35	80.50	45.22	234.28	177.41	92.32
CATCH (T)	243.96	755.09	1007.82	1037.64	582.05	3035.36	2839.82	1661.10
CUM. CATCH (T)	243.96	999.05	2006.87	3044.51	582.05	3617.41	6457.23	8118.33
BIOMASS (T)	8842.50	11496.60	12693.10	13255.10	13729.70	13295.30	11870.20	11372.30

	1987	1987	1987	1987	1988	1988	1988	1988
RATE ON SMALLS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEAN WT. CATCH	17.48	18.35	20.92	21.73	17.75	18.56	20.88	22.14
CATCH (MILL.)	52.64	148.57	108.64	60.80	26.43	78.44	62.56	45.00
CATCH (T)	919.91	2726.57	2272.29	1321.02	469.23	1456.21	1305.86	996.45
CUM. CATCH (T)	919.91	3646.48	5918.77	7239.79	469.23	1925.44	3231.30	4227.75
BIOMASS (T)	10998.70	9751.50	8271.50	7894.80	7810.50	7454.60	6780.40	6647.40

	1989	1989	1989	1989
RATE ON SMALLS	1.00	1.00	1.00	1.00
MEAN WT. CATCH	16.50	17.33	19.67	27.45
CATCH (MILL.)	21.97	65.35	52.53	66.46
CATCH (T)	362.55	1132.66	1033.25	1824.19
CUM. CATCH (T)	362.55	1495.21	2528.46	4352.65
BIOMASS (T)	6640.50	6506.90	6051.20	4728.60

Table 11c. Simulations for three meat count levels - 30 meat count.

	YEAR							
	1985	1985	1985	1985	1986	1986	1986	1986
RATE ON SMALLS	0.39	0.33	0.45	0.35	0.18	0.25	1.00	1.00
MEAN WT. CATCH	15.03	15.03	15.01	15.03	14.97	14.90	15.86	17.92
CATCH (MILL.)	12.14	37.08	66.98	52.21	24.89	93.25	228.32	115.15
CATCH (T)	182.50	557.32	1005.37	784.77	372.49	1389.95	3621.97	2063.78
CUM. CATCH (T)	182.50	739.82	1745.19	2529.96	372.49	1762.44	5384.41	7448.19
BIOMASS (T)	8911.10	11846.90	13120.40	13995.40	14758.20	16648.70	14779.70	13980.40

	1987	1987	1987	1987	1988	1988	1988	1988
RATE ON SMALLS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEAN WT. CATCH	17.77	18.69	21.33	22.17	18.54	19.37	21.70	22.80
CATCH (MILL.)	65.58	184.06	133.05	70.62	29.06	86.31	68.79	48.15
CATCH (T)	1165.70	3439.21	2837.95	1565.65	538.86	1671.88	1492.65	1097.99
CUM. CATCH (T)	1165.70	4604.91	7442.86	9008.51	538.86	2210.74	3703.39	4801.38
BIOMASS (T)	13434.10	11683.90	9730.80	9134.10	8989.20	8476.40	7643.70	7407.50

	1989	1989	1989	1989
RATE ON SMALLS	1.00	1.00	1.00	1.00
MEAN WT. CATCH	17.10	17.95	20.31	28.87
CATCH (MILL.)	22.80	67.98	54.78	78.27
CATCH (T)	389.91	1220.45	1112.70	2259.98
CUM. CATCH (T)	389.91	1610.36	2723.06	4983.04
BIOMASS (MT)	7370.00	7167.30	6639.50	4733.50

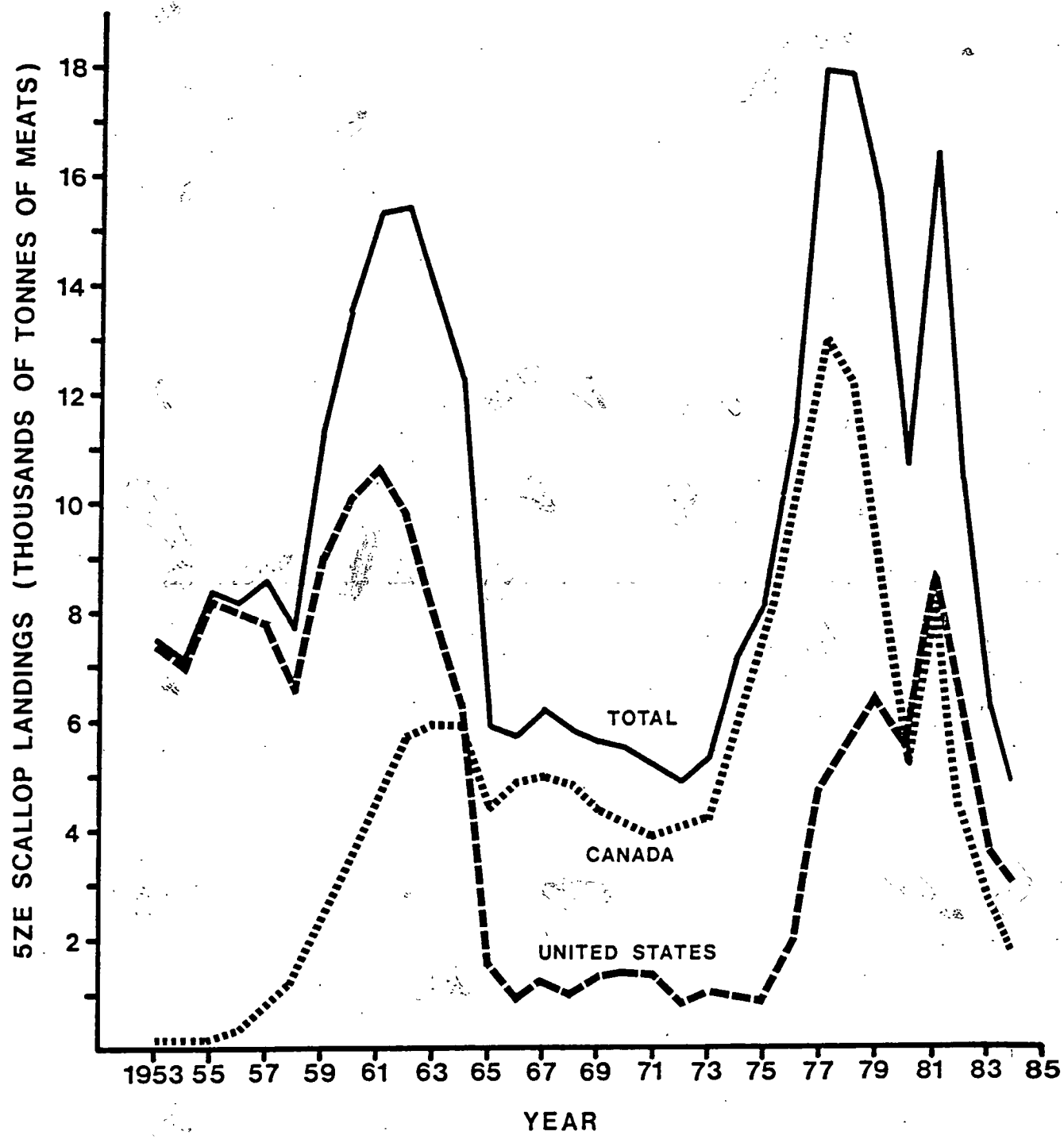


Fig. 1. Scallop landings from 5Ze by Canada and the United States, 1953 to 1984.

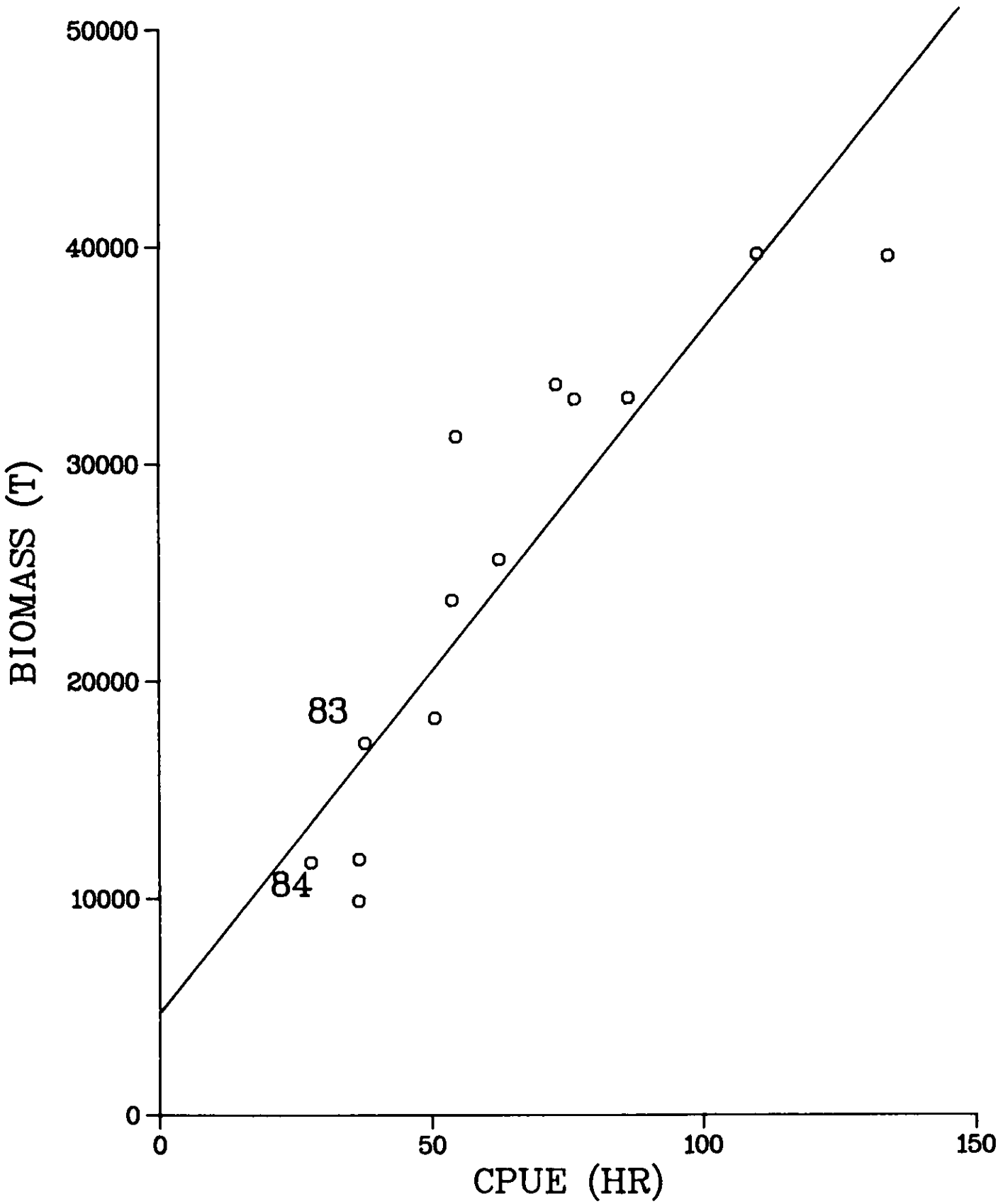
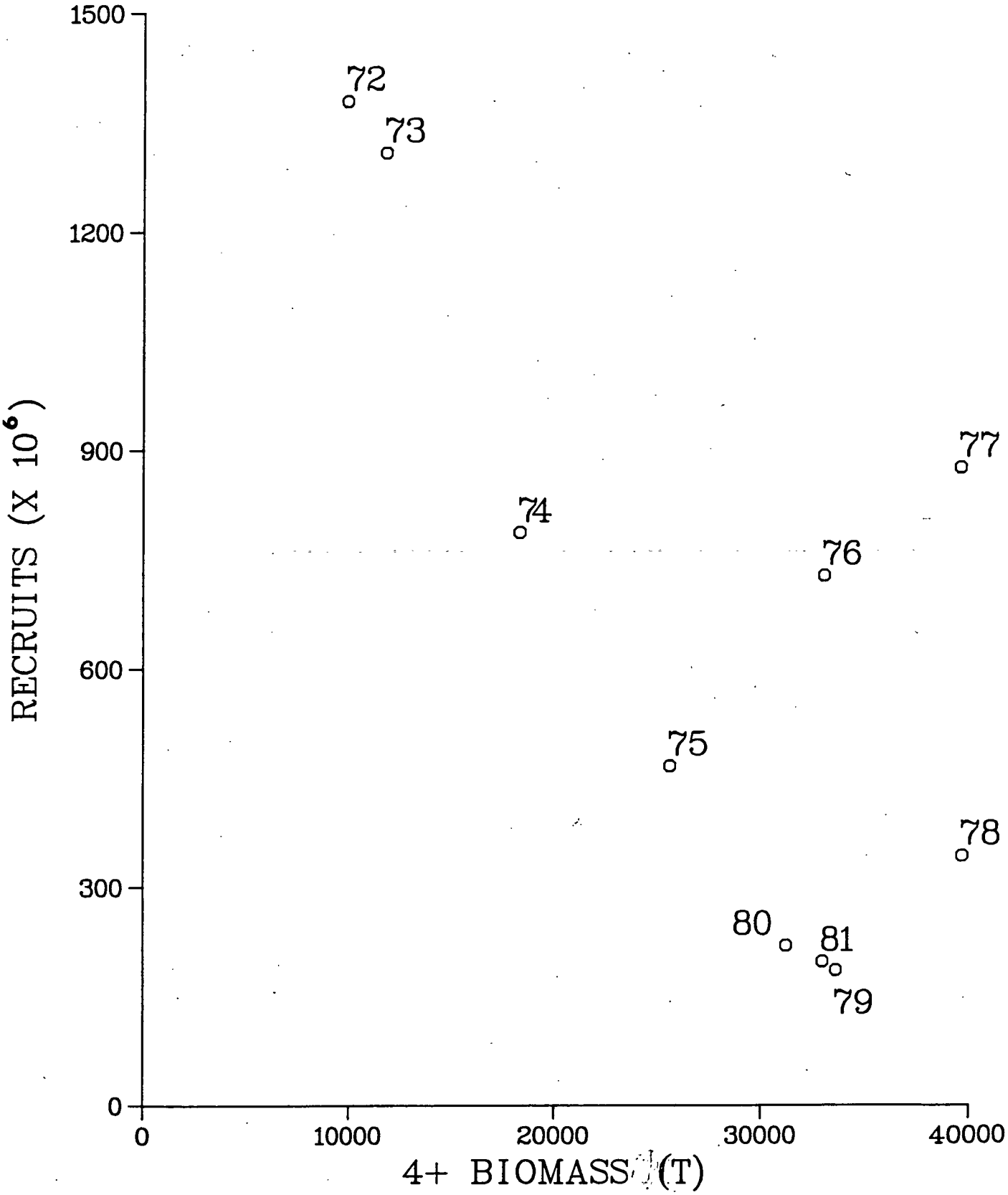


Figure 2 - Regression of biomass (Ages 4 to 9) versus CPUE (hr).



Fiuure 3. 4+ Biomass versus Recruits.

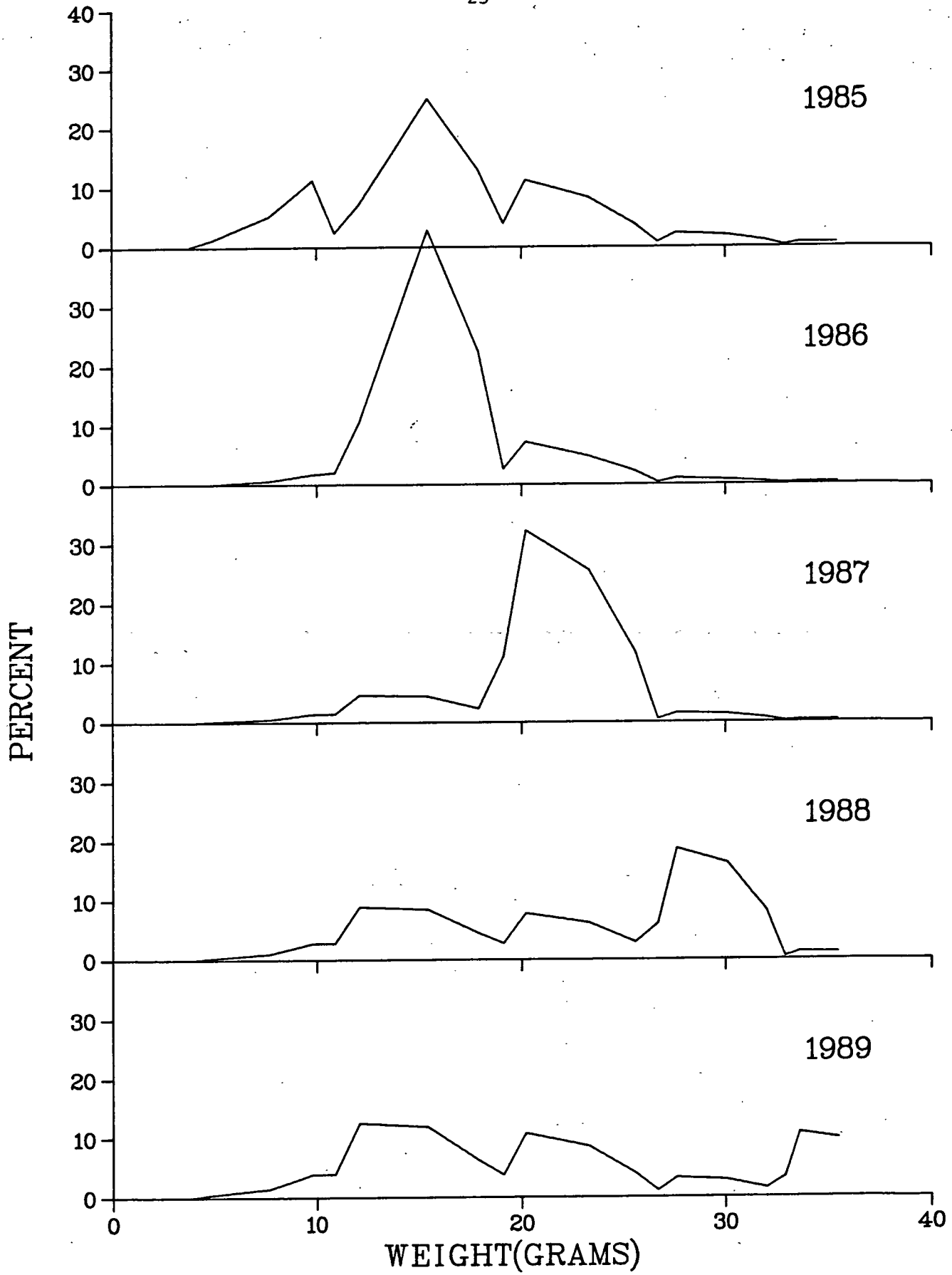


Figure 4a. Simulated Meat Size Distribution, 30MC.

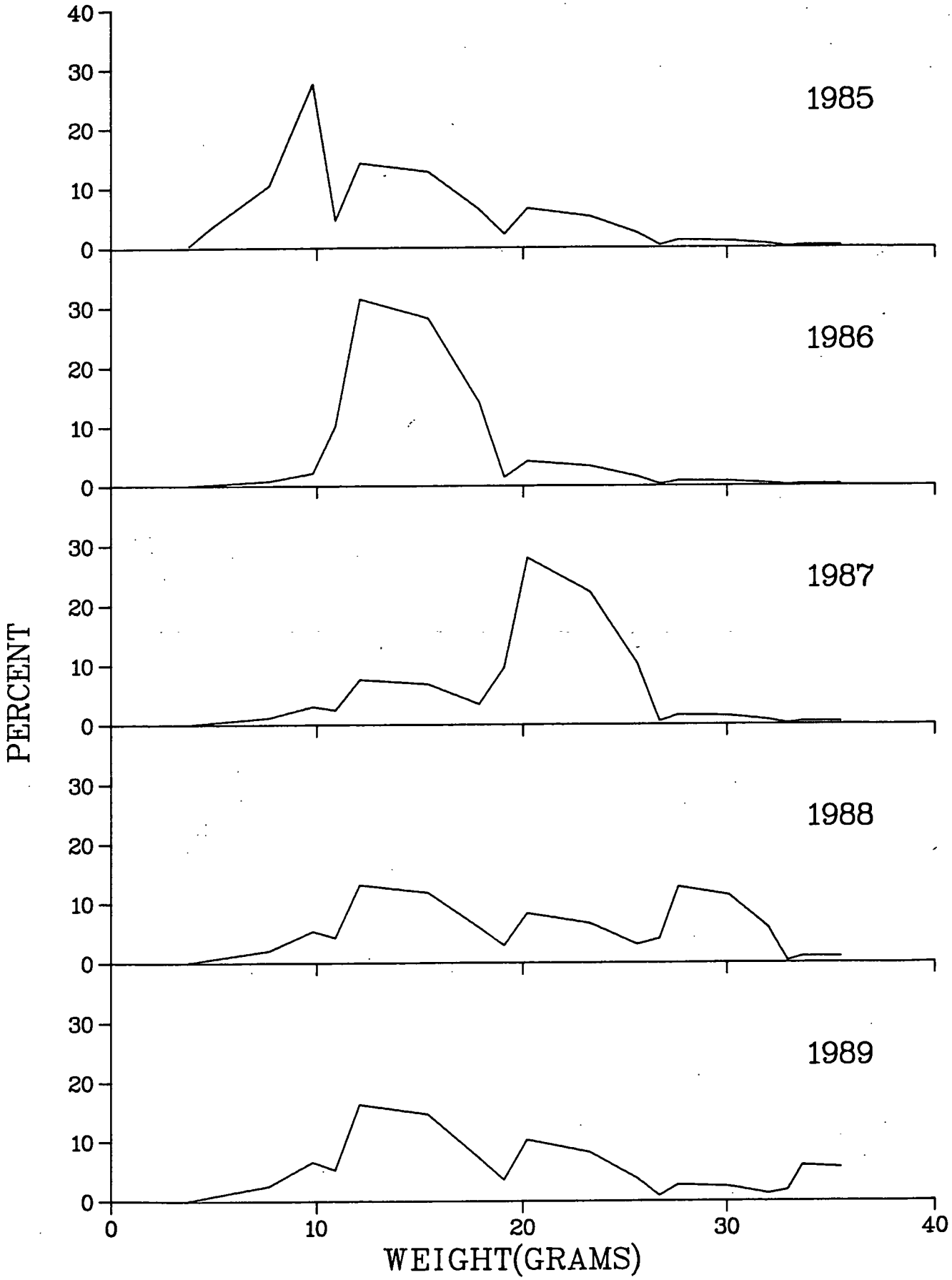


Figure 4b. Simulated Meat Size Distribution, 45 MC.