CAFSAC
RES. DOC. 79/19

1978 4WX HERRING ASSESSMENT

by

M. Sinclair, K. Metuzals and W. Stobo

Marine Fish Division

Fisheries and Oceans Canada

Dartmouth, Nova Scotia

INTRODUCTION

Principally as a result of tagging studies, it has been concluded that there is overwintering migration of herring from S. W. Nova Scotia to the Chedabucto Bay area. For management purposes, the catches in the two areas are considered to belong to a unit stock. Thus, herring caught by all gear types in ICNAF statistical areas 465 and 466 within 4Xa, and by the purse seine fleet only in area 451 of 4Wa, have been included in the 4WX assessment (fig. 1). Catches by fixed gears in statistical districts 8 to 30 in 4WX are considered to belong to "local" stocks and are not included. Catches by both the purse-seine fleet and weirs, predominantly of juvenile herring, in 4Xb have also not been included in the assessment of this stock although a significant portion of this catch may well belong to the 4WX stock. Approximately 30% of the long distance returns of the juveniles tagged in the N. B. weirs are from 4WaXa, the larger proportion being found in ICNAF area 5. The winter purse seine fishery in 4Xb is directed on one (before January) and just-turned two-year-old fish (after January). It is probable that these fish come from the S. W. Nova Scotia spawning stock since there is no evidence of one-year-old fish moving up the coast of Maine from the areas of high larval abundance in area 5. In this document, only the traditional stock definition (i.e., exclusion of 4Xb catch) is considered in the analytical assessment.

CATCH DESCRIPTION

The seasonal catch distribution by gear type is shown in table 1 and fig. 2. Except for two situations, the seasonal distribution in the catch during 1978 was similar to previous years. There was an unusual purse seine fishery off Liverpool in February, almost uniquely on two-year olds and the drift gillnet fishery on spawning fish off S. W. Nova Scotia was anomalous. The very low catch in this area and gear type associated with the lack of a normal distribution in catch around the time of peak spawning suggests poor 1978 spawning (fig. 3).

The annual catch trends for the various gears are shown in figures 4 and 5. The major components of the fishery, the mobile gears, are in decline. The N. S. weir catches have been declining gradually to 1977, but there was a sharp increase in 1978 due to a large catch of two-year olds especially in the autumn. The N. B. weir catch trend shows a different distribution with high levels for the past several gears. The dramatic 1977 increase in catch by the N. S. gill nets due to increased effort was not maintained even though the effort was again high. The total annual catch distribution (4Xb excluded) is shown in fig. 6. The TAC of 109,000t in 1978 was undercaught by 20,000t.

The overall age composition of the catch of the various components of the fishery are shown in table 2. In 1976 and 1977 an ageing problem had been noted in distinguishing between the 1970 and 1971 year-classes. The size of these two year-classes are apparently well defined with the 1970 year-class being about six times the size of the 1971 (Stobo et al. 1978). This convention has been followed again in this assessment. Two observations support the adjustment. The 4Wa winter purse-seine fishery 1970/71 age class ratio approximates the 6/1 assumption. Perhaps the annulus is more clearly defined by the end of the growing season. Secondly, the mean weight-at-age estimates from uncorrected ages suggest an anomously high weight for age seven fish in 1978 (fig. 7). This could be due to a proportion of the 1970 year-class being incorrectly aged as seven-year-olds. The low weight for eight-year-old fish may be a density dependent effect associated with the extremely large 1970 year-class. The overall % age composition of the various components of the 1978 catch, after correction of the 1970/71 age classes, are shown in fig. 8.

The adult fisheries are dominated by the 1970 and 1973 year-classes; the juvenile fisheries, of course, by two-year-olds. The age composition by month within each gear type was very similar except for the N. S. weirs. The summer catches are composed of a full range of ages, whereas the autumn catch is predominantly one and two-year-olds. In figure 9, the age composition for the total catch is shown.

EFFORT

Catch per unit effort indices in pelagic schooling species have been shown to be subject to bias because of changes in catchability (q), due to both learning by the fleet and reduced distributional range during stock depletion (Pope, 1978). Several additional problems associated with effort and CPUE measures are perhaps specific to the 4WX purse seine fishery. Since many fishermen do not report number of sets, "skunk" sets, or nights searched without sets, the CPUE index for purse seine components in previous assessments has been catch per successful night. The small range in values (30 to 50 t/night) over a 12 year period in 4Xa is disturbing, given the strong population biomass fluctuations. All the biases are in the direction of masking a decrease in CPUE. When the stock is low, more sets per night may be made and more nights searching may be done, which would not necessarily be reflected in CPUE (catch per successful night). A further complication with an opposite bias has been the implementation in 1977 of individual nightly boat quotas in the summer 4Xa purse seine fishery. This effectively reduces the power of a night's fishing. To investigate possible changes in efficiency of individual boats, as well as the fleet, a questionnaire concerning fishing effort was mailed to each member of the Atlantic Herring Fishermen's Co-op. In addition, the log records of several fishermen who have consistently reported detailed information (searching time, individual set information) were re-analyzed.

The responses to the questionnaire were quantified in Table 3. Several points suggest increasing efficiency of the fleet as a whole: more searching over a broader geographical area with some increase in fleet co-operation, and improved technological searching aids. Nightly boat quotas are reported by half the captains to decrease the fishing power of a night. Analysis of individual captain's log records permitted the searching time and number of sets to be included in the CPUE indices. The results are summarized in fig. 10. There is some concurrence between the captains, which is marginally improved when catch per set is the index, and good agreement between 4Wa and 4Xa. The results parallel the regular CPUE analysis of previous assessments but tend to accentuate the trends caused by the strong 1970 year-class. The questionnaire suggests that learning should be superimposed on the CPUE trends. Changes in fishing mortality per unit of effort (q) on the 4Xa purse seine fleet were estimated by using the catch equation. Population numbers (1969 to 1976) were taken from cohort analysis, purse seine catch at age numbers were extracted from the overall catch matrix and, subsequently, fishing mortality (F) calculated. Weighted F estimates were then divided by purse seine effort (1969 to 1976) to give trends in q (fig. 11). The trend supports use of a learning coefficient on a year-to-year basis.

Taking into consideration the questionnaire responses and the q trend, two CPUE series - an unadjusted index and an index with a year-to-year learning factor - were calculated. The effective value of a night's effort was increased by 10% from 1967 to 1976 and by 7.5% in 1977 and 1978. The reduction in efficiency increase for the last two years was included to compensate for the opposite trend - reduction on the power of a night's fishing - imposed by nightly boat quotas. The overall result is that a 1978 night is equal to two 1967 nights (a not unreasonable increase). The definition of the index and the source data are shown in table 4. The fixed gear catch per unit effort indices were not included in the overall index since market demand rather than population abundance is thought to influence the catch per weir. The CPUE trends for the adult purse seine fishery are shown in Figure 12. The 1977 4Wa CPUE is interpolated since the calculated value (117 t/night) appears spurious (no evidence of an increase by captains A - D in fig. 10). The adjusted 4Xa purse seine CPUE distribution is similar to the trend in catch per Nova Scotia weir, which should be an accurate reflection of population size if the above-mentioned market demand influence is minimal. The observed increase in the 1978 CPUE for the N. S. weirs should precede the purse seine CPUE by a year or two (due to the different partial requirements for the gears) if the 1976 year-class is strong. The two weir CPUE trends are shown in table 5 and figure 13. The N. B. weir CPUE recent trend (steep rise since 1974 in N. B. weirs while the N. S. catch/weir and the purse seine CPUE's declined) suggests that the 4Xb weir fishery involves, at least partially, a separate stock. The effort series, both adjusted and unadjusted, are shown in tabel 6.

POPULATION SIZE

Partial recruitment was calculated from the average fishing mortality at age from 1970 to 1976, as generated by cohort analysis using a starting F estimated from the ratio of CPUE values of individual cohorts (age 5 and older) between 1978 and 1977. The results are:

AGE	2	3	4	5	6	7	8	9	10	11+
PR	0.33	0.49	1	1	1	1	1	1	1	1

This partial recruitment vector was used in calculating weighted F, but was not used in projections or in estimating two-year-old population numbers in 1978 since there is some evidence that young fish were avoided by the purse seine fleet. F's for older ages in years 1965 to 1976 were the average values for the fully recruited ages (ages 5 to 8). Several iterations were made to adjust the F's for older ages. Starting F's for 1978 were set by optimizing the regression of F, weighted by the fishable populations, on effort. Two analyses were carried out, with the effort adjusted and unadjusted by "learning". The population and F matrices for the best runs and the corresponding G.M. regressions are shown in table 7 and figures 14 and 15. A marginally better relationship between weighted F and effort was found using the adjusted series.

The fishable biomass generated using the adjusted effort series is a somewhat better fit with the CPUE index trend than is that derived using unadjusted effort series (fig. 16). Total larval abundance during the autumn survey agrees well with cohort analysis derived recruited biomass. The good fit suggests that larval abundance estimates may provide useful estimates of spawning stock size. Both VPA analyses indicate that the stock is at a low point in the history of the fishery. The fishable biomass estimates made with the effort adjusted indicate that the 1978 level is considerably lower than the previous minimum in 1972, whereas the estimates made with unadjusted effort put the 1972 and 1978 recruited biomasses at about the same level. The range in possible weighted fishing mortality (0.35 to 0.47), depending on which effort series is the most realistic, is considerable.

Total population biomass (2+) estimates for 1978 are dependent on the selection of an appropriate partial recruitment for two-year-olds in 1978 (recall that the purse seine fleet avoided to a large degree small fish). The total biomass trends are shown in fig. 17. Using a 1978 partial recruitment for age two fish of 0.1 (rather than 0.33), a minimum age 2+ biomass of 340,000 t is estimated. The estimate using the unadjusted effort series would be about 80,000 t higher.

RECRUITMENT

Several methods of predicting age two year-class size were considered. This is particularly important during 1978 since the partial recruitment changed. By all accounts, the 1976 year-class is a large one [high 1978 catches in gears directed at two-year-olds; expansion of range of two-year-olds (Liverpool fishery) in 1978, and three-year-olds in 1979; purse seine fleet reports from sonar observation]. There has been a fair relationship between VPA (age two) and age two in purse seine catch/total P.S. catch (fig. 18). Because of the avoidance of two-year-olds during 1978, the predicated 1976 year-class is only of moderate size using this regression. The relationship between VPA (age two) and N. B. weir age one catch, N. B. weir age two catch, and N. S. weir age two all indicate that the 1976 year-class is large (fig. 19-21). An environmental regression developed with Dr. W. Sutcliffe also predicts an exceptional 1976 year-class. The regressions are summarized in table 8. Using a range of 1976 year-class at age two from 3 - 4 billion, estimates of 1978 P.R. at age two were made using the catch equation (table 9).

YIELD PER RECRUIT

Using the following mean weights-at-age (kg) (estimated from the 1978 catch) and partial recruitment vector, a,

AGE	1	2	3	4	5	6	7	8	9	10	11+
WT	0.009	0.030	0.93	0.159	0.205	0.250	0.285	0.315	0.341	0.382	0.329
PR	-	0.10	0.49	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

yield per recruit curve was derived (fig. 22). $F_{0.1}$ was 0.282. The 1978 fishing mortality was considerably higher than $F_{0.1}$ if adjusted effort is used in "fixing" the cohort analysis.

PROJECTIONS

Using the partial recruitments corresponding to the yield-per-recruit options, a 1976 year-class of 3×10^9 at age two, and future recruitment equal to the geometric mean of 1965 to 1976 age two population numbers, several ten-year projections were run:

1. $F_{0.1}$ in 1979 and onwards (both options)
2. Catch of 99,000 mt in 1979 and subsequently fishing at $F_{0.1}$.
3. Catch of 110,000 mt in 1979 and subsequently fishing at $F_{0.1}$.

In addition, two projections were made with changes in the recruitment input:

1. G.M. recruitment with log normal variability
2. Conventional year-class of 750×10^6 at age two (Stobo _et al_, 1978).

   The projections at $F_{0.1}$ and geometric mean recruitment are shown in fig. 23.

Depending upon the initial population numbers at age, the 1979 catch should be a high of 75,000 or a low of 60,000 mt. Subsequently, the $F_{0.1}$ catch would increase sharply as the 1976 year-class progressed through the fishery. The sustained catch under geometric mean recruitment (93,000 t) is low considering the catch history of this stock. If variable recruitment around the same mean is an input, the sustained catch at $F_{0.1}$ fluctuates around 140,000 mt. If the conventional year-class of 750 x 10^6 at age two (Stobo _et al_, 1978) is the recruitment input, the sustained $F_{0.1}$ yield is around 60,000 mt which is unreasonable.

A higher TAC in 1979, such as the previously established quota of 99,000 mt or an increase to 110,000 mt, would give a long-term cumulative yield higher than steady $F_{0.1}$ management (fig. 24 and table 10). The danger of optimizing yield of the large year-class is the possible error in predicting its magnitude. If the 1976 year-class is over estimated in this assessment, then taking a 1979 quota of 110,000 mt could significantly alter subsequent yields at $F_{0.1}$. In addition, the effect of maximizing the yield of the 1976 year-class (by taking a large portion of them at three and four years old) on subsequent recruitment is not known.

SUMMARY

Several factors indicate that the adult stock in 1978 is at a seriously depleted level. The quota was not taken in spite of high demand for the product. All CPUE indices of adult stock are at an historical low. Fishing effort may have been greater than $F_{0.1}$ for several years, if the adjusted effort series is accurate. Mature biomass may be lower than 40% of the maximum recorded biomass. The frequency of very poor year-classes has increased. Fortunately, there is strong evidence of a good year-class entering the fishery. Depending on the accuracy in predicting the size of this year-class, a range of short-term options have been presented.

ACKNOWLEDGEMENTS

We acknowledge the considerable work in the preparation of this assessment by J. Simon and A. Sinclair. Most of the catch statistics were provided by Dr. D. Iles' group, and the numbers at age were generated with the help of Mr. Fitzgerald at St. Andrews.

REFERENCES

Pope, J. G. (1978). Effects of Variations in Stock Size of Pelagic Species on Distribution and Availability and Vulnerability to Fishing. ICES Symposium on the Biological Basis of Pelagic Fish Stock Management.

Stobo, W. T., Gray, D. F., and Metuzals, K. (1978). Herring Assessment in 4WX, CAFSAC Res. Doc. 78/25.

Table 1 Provisional Catch (mt) during 1978 Fishery

	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Accounted[1] Total	Provisional Total
4Wa Chedabucto Bay																	
Purse Seine	274	66	16934	–	–	–	–	–	–	–	–	–	166	7528	6379	17,274[2]	17,274
non-stock																	
4Xa Southwest Nova Scotia																	
Purse Seine	-	-	-	1365	-	-	138	13666	23158	11652	4587	1289	-	-	-	55,855	57,973*
Gill Net (Stock)	-	-	-	-	-	-	63	703	1369	2695	1002		-	-	-	5,832	6,059
Weir	-	-	-	-	-	-	509	3798	3020	139	52	103	213	81	-	7,915	8,057
Miscellaneous																	
4WX Foreign																	
4WXa Stock Total	274	66	16934	1365	-	-	710	18167	27547	14486	5641	1392	213	81		86,876	
4Xb New Brunswick																	
Purse Seine	-	-	1075	1343	135	134	-	-	-	-	-	2943	806	83		6,519	6,519
Weir	-	-	-	-	-	-	353	939	5854	10383	10262	5440	-	132		33,363	38,870[3]
Miscellaneous																	
4Xb Total	-	-	1075	1343	135	134	353	939	5854	10383	10262	8383	806	215		39,882	
HERRING 4WXa + 4Xb	274	66	18009	2708	135	134	1063	19106	33401	24869	15903	9775	1019	296		126,758	

* Total as of March, 1979 from St. Andrews Statistics

1 Catch reported with location and time caught information

2 1977/78 winter only

3 including shut-offs

Table 2. Catch-at-age Table (4WX Stock) x 10^{-3}

	1	2	3	4	5	6	7	8	9	10	11+	TOTAL #	M. Tons
4Wa Chedabucto Bay Purse Seine	0	0	2952	4452	41385	14193	4178	18436	2741	477	455	89269	17274
4Xa Southwest Nova Scotia													
Purse Seine	0	13394	14318	5307	55057	39001	45860	38023	5555	1228	693	218436	57973
Gill net	0	0	69	267	4483	3578	4636	5909	1069	294	132	20437	6059
Weir	35381	100775	4706	615	6605	3659	4074	2911	473	170	219	159588	8057
4Xb New Brunswick													
Purse Seine[1]	0	232550	14132	697	97							247476	6519
Weir	213778	894372	52125	3665	810	1064	280	132					
Total (traditional stock)[2] (adjusted 1970/71 age classes)	35381	114169	22045	10641	107530	60431	58748 (27286)	65279 (96741)	9839	2169	1499	487730	89363

1 Includes both St. John area "brit" and Grand Manan, respectively winter and autumn, juvenile fisheries.

2 4Xb excluded

Table 3. Summary of responses (in %) by purse seine captains to a questionnaire concerning fishing effort.

Subject				COMMENTS
	increase	decrease	no change	
Individual searching time trend	64	14	21	
Fleet cooperation in searching trend	33	-	67	abrupt change due to co-op (1) gradual change (3)
Effect of boat quotas on number of hours fished per night	-	53	47	
	substantial	not substantial		
Initial fast learning upon entry into fishery	75	25		
Yearly Learning factor	87	13		
	linked	not linked		
Learning partially due to technological acquisitions	80	20		
	expansion	no expansion		
Expansion of nearshore area fished	20	80		
Expansion of offshore area fished	70	30		
	important	not important		
Effect of market on effort expended	69	31		
	increase	decrease	no change	
Adult school size trends	-	83	17	

Table 4. Derivation of catch per unit effort index using catch and effort data from 4WX Purse seine, Nova Scotia, weirs and gill nets, and New Brunswick weirs.

Year	4W purse-seine CPUE[1]	CPUE/ Ave.	EFFORT	EFFORT adjusted[3]	CPUE adjusted	CPUE adj/ Ave.	4X Purse-seine CPUE[1]	CPUE/ Ave.	EFFORT	EFFORT adjusted[2]	CPUE adjusted	CPUE adj/ Ave.	CPUE INDEX[5] without learning	CPUE INDEX[5] with learning
1967							55.5	1.28	2115	2115	55.5	1.82	1.28	1.82
1968							52.8	1.22	2524	2776	48.0	1.57	1.22	1.57
1969							41.7	0.96	2027	2432	34.8	1.14	0.96	1.14
1970							39.0	0.90	1817	2362	30.0	0.98	0.90	0.98
1971							32.6	0.75	1076	1506	23.3	0.76	0.75	0.76
1972	74.5	0.79	344	344	74.5	1.03	45.0	1.04	1359	2039	30.0	0.98	0.97	0.99
1973	73.6	0.78	108	119	66.6	.92	49.1	1.13	746	1194	30.7	1.01	1.07	0.99
1974	132.0	1.41	205	246	110.2	1.52	45.2	1.04	1700	2848	26.9	0.88	1.14	1.05
1975	146.5	1.56	185	241	112.2	1.55	50.9	1.17	1564	2737	29.1	0.95	1.27	1.10
1976	114.3	1.22	320	448	81.7	1.13	41.8	0.96	1397	2557	22.8	0.75	1.06	0.90
1977	85.7	0.91	210	315	57.1	0.79	33.8	0.78	2023	3853	17.8	0.58	0.81	0.62
1978	69.0	0.73	245	392	43.2	0.60	33.0	0.76	1757	3479	16.7	0.55	0.75	0.56
1979	55.4	0.59	254	432	32.6	0.45								
AVE	93.9				72.3		43.4				30.5			

1. from log records (metric tons per night)
2. 10% learning per year up to 1973, 7.5% subsequently (see text for justification)
3. 10% learning per year
4. extrapolated (See Fig.)
5. $$\text{CPUE INDEX} = \frac{\text{CPUE/AVE (4W Purse-seine)} \times \text{catch} + \text{CPUE/AVE (4X purse-seine)} \times \text{Catch}}{\text{Catch (4W + 4X purse seine)}}$$

Table 5. 4X nearshore effort and CPUE

	Nova Scotia Gill nets			New Brunswick Weirs			Nova Scotia Weirs		
Year	Effort[1]	CPUE[2]	CPUE / Ave	EFFORT [3]	CPUE	CPUE / Ave.	EFFORT[3]	CPUE	CPUE / Ave.
1967	5000	1.08	1.13	195	154	1.16	25	499	1.40
1968	5000	1.18	1.24	195	165	1.25	25	503	1.42
1969	5000	0.69	0.72	195	132	1.00	25	430	1.21
1970	5000	1.00	1.05	195	77	.58	25	468	1.32
1971	5000	0.92	0.96	195	62	.47	25	323	0.91
1972	5000	0.76	0.80	195	164	1.24	25	271	0.76
1973	5000	1.04	1.09	195	98	.74	25	500	1.41
1974	5000	0.86	0.90	195	98	.74	25	257	0.72
1975	5000	1.00	1.05	195	158	1.19	25	296	0.83
1976	5000	1.04	1.09	195	150	1.13	25	238	0.67
1977	13000	1.42	1.49	195	157	1.18	25	209	0.59
1978	13000	0.47	0.49	223	175	1.32	30	269	0.76
		0.96			132.5			355	

[1] Estimate of # of nets fished by field workers

[2] Catch (mt) per net

[3] Estimate of # of weirs actively fished.

Table 6. Derivation of standardized effort units using catch and CPUE indices from Tables 2 and 5 respectively.

	CATCH	EFFORT UNITS[1]	
		Traditional Stock	
Year	Traditional Stock Total Catch	(without learning)	(with learning)
1967	135853	106135	74644
1968	154139	126343	98178
1969	137260	142979	120404
1970	175633	195148	179217
1971	124233	165644	163464
1972	153428	158809	154234
1973	120093	112472	120819
1974	139170	122458	132940
1975	142745	112499	129522
1976	114006	107434	126975
1977	110798	137266	177590
1978	89363	118658	159157

[1] Total catch divided by appropriate CPUE index from Table 5.

Table 7. Catch, population and fishing mortality matrices.

CATCH AT AGE

Age	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	210796	43630	47948	751706	70536	106916	144167	649254	29656	118301	235590	19922	55634	114169
3	26450	270068	68430	79933	384467	58166	173662	71984	562616	45600	158941	161637	19468	22045
4	232147	58591	238394	65107	118960	285361	106170	148516	109530	616206	92356	130597	192823	10641
5	49752	308775	109814	274518	160723	201097	113561	77207	34422	53199	383646	72334	106061	107530
6	10592	45479	159203	72827	110852	120223	75593	75384	25562	15254	50599	219788	55066	60431
7	1693	13970	57948	90617	62506	111911	93620	49065	19361	8120	9357	18960	150588	27286
8	561	7722	4497	31977	22595	41257	50022	48700	17604	5313	3238	4967	12466	96741
9	54	1690	409	15441	6345	21271	36618	26055	19836	10964	3481	3556	2873	9838
10	37	215	296	5668	2693	7039	7536	13792	9661	5787	2842	1835	1253	2169
11+	1	1	148	1175	722	2674	5695	11679	11120	7359	4599	3071	3448	1499

POPULATION NUMBERS

16/ 5/79

	65	66	67	68	69	70	71	72	73	74	75	76	77	78
2	2699612	1559312	1278836	2398520	635409	794852	887836	5196187	744238	1166828	1368476	94641	205522	(2741462) with PR = 0.1
3	1054233	2019520	1237179	1003637	1283570	456405	554028	596451	3666809	582497	848275	907243	59459	117927
4	1369109	839200	1409075	950998	749382	703018	321042	296464	423199	2493053	435647	550693	596533	31066
5	368262	910877	634063	937945	719700	505903	317377	166780	108342	247379	1483573	273111	332700	313926
6	96916	256490	466372	419763	519531	443813	232238	157092	66688	57556	154401	867510	158154	176424
7	32093	69764	168845	237780	277777	325053	254581	121741	60406	31470	33321	80629	511384	79660
8	11156	24744	44478	85805	112684	170867	164869	123722	55277	31938	18418	18814	48857	282428
9	1285	8626	13271	32346	41317	71813	102563	89722	57230	29328	21341	12150	10909	28721
10	46	1003	5534	10496	12511	28087	39549	50838	49882	28907	14091	14323	6730	6332
11	9	4	627	4263	3464	7807	16626	25561	29143	32099	18431	8966	10066	4376
	5632723	5689540	5258279	6081553	4355345	3507616	2890710	6824559	5261214	4701056	4395975	2828078	1940315	3782323

FISHING MORTALITY

16/ 5/79

	65	66	67	68	69	70	71	72	73	74	75	76	77	78
2	.090	.031	.042	.425	.131	.161	.198	.149	.045	.119	.211	.265	.355	.047
3	.028	.160	.063	.092	.402	.152	.425	.143	.186	.090	.232	.219	.449	.230
4	.208	.080	.207	.079	.193	.595	.455	.807	.337	.319	.267	.304	.442	.470
5	.162	.469	.212	.391	.283	.579	.503	.717	.433	.271	.337	.346	.434	.470
6	.129	.218	.474	.213	.269	.356	.446	.756	.551	.347	.450	.329	.486	.470
7	.060	.250	.477	.547	.286	.479	.522	.590	.437	.336	.372	.301	.394	.470
8	.057	.423	.118	.531	.251	.310	.408	.571	.434	.203	.216	.345	.331	.470
9	.048	.244	.035	.750	.186	.397	.502	.387	.483	.533	.199	.391	.344	.470
10	2.160	.270	.061	.908	.272	.324	.236	.356	.241	.250	.252	.153	.230	.470
11	.130	.290	.300	.360	.260	.470	.470	.690	.540	.290	.320	.470	.470	.470
	.112	.168	.165	.305	.277	.375	.377	.227	.199	.239	.273	.287	.419	.156

Estimated using adjusted effort

Table 7 cont'd

POPULATION NUMBERS 18/ 5/79

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	2713436	1563996	1303067	2411752	642619	803394	919556	5451564	803211	1273761	1524261	107262	260726	
3	1097242	2030838	1241013	1023476	1294403	462308	561022	622421	3875893	630780	935824	1034789	69793	163124
4	1375461	874413	1418341	954138	765625	711888	325875	302190	444462	2664237	475178	622373	700958	39526
5	371456	916077	662893	945532	722271	519201	324639	170737	113029	264788	1623727	305476	391386	399422
6	98653	259105	470629	443367	525742	445917	243126	163038	69928	61394	168653	982258	184652	224472
7	33439	71186	170986	241266	297102	330138	256304	130655	65274	34123	36463	92298	605332	101354
8	12432	25845	45642	87558	115538	186689	169033	125133	62576	35923	20590	21387	58411	359346
9	1392	9671	14173	33299	42752	74150	115517	93131	58385	35304	24604	13928	13016	36543
10	47	1091	6389	11234	13291	29261	41462	61444	52673	29853	18984	16994	8186	8057
11	10	5	698	4963	4069	8445	17588	27127	37826	34384	19205	12971	12253	5568
	5703566	5752225	5333832	6156584	4423412	3571391	2974122	7147440	5583257	5064547	4847489	3209735	2304713	2490008

FISHING MORTALITY 18/ 5/79

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2	.090	.031	.042	.422	.129	.159	.190	.141	.042	.108	.187	.230	.269	.115
3	.027	.159	.063	.090	.398	.150	.419	.137	.175	.083	.208	.190	.369	.161
4	.206	.077	.205	.078	.188	.585	.446	.783	.318	.295	.242	.264	.362	.350
5	.160	.466	.202	.387	.282	.559	.489	.693	.410	.251	.303	.303	.356	.350
6	.126	.216	.468	.200	.265	.354	.421	.715	.518	.321	.403	.284	.400	.350
7	.058	.244	.469	.536	.265	.469	.517	.536	.397	.305	.334	.258	.321	.350
8	.051	.401	.115	.517	.244	.280	.396	.562	.372	.178	.191	.297	.269	.350
9	.044	.215	.032	.718	.179	.381	.431	.370	.471	.420	.170	.332	.280	.350
10	2.111	.246	.053	.816	.254	.309	.224	.285	.227	.241	.181	.127	.185	.350
11	.117	.272	.265	.301	.217	.426	.438	.635	.389	.268	.305	.301	.369	.350
	.111	.165	.162	.300	.272	.367	.364	.215	.186	.219	.244	.248	.340	.229

Estimated using unadjusted effort

Table 8 Recruitment (VPA, age 2) prediction summary.

1. NB weir, age 2 catch -
   VPA (age 2 x 10^{-6}) = -589 + 5.94 NB weir (age 2 x 10^{-6}) $R^2 = 0.47$

2. S.W. NS Purse Seine, age 2 catch
   VPA (age 2 x 10^{-6}) = 261 + 816 RATIO (age 2 catch/total catch t) $R^2 = 0.68$

3. Environmental regression
   AGE 2 (x 10^{-8}) = -8.51 - 83.1 LEVHF + 0.906 WIN 230° $R^2 = 0.86$
   where LEVHF is residual sea level at Halifax during May in feet and WIN 230° is the average of May, June and July wind vector in 230° direction at Sable Island.

Numbers at age 2

Regression	1975 year-class	1976 year-class
1	0.15×10^9	4.00×10^9
2	0.67×10^9	1.31×10^9
3		3.57×10^9

Table 9. Calculation of PR (1978) for projections

F_{1978} = 0.47 (effort adjusted)

$N_{(2\ yr)}$ estimate from recruitment regressions 3 to 4 x 10^9

Case 1 $N_{(2\ yr)}$ = 3 billion

Case 2 = 3.5 billion

Case 3 = 4.0 billion

$C_{(2\ yr)}$ if 2 year olds were fully recruited

$$= N_{2\ yr.} \frac{F \quad 1 - e^{-(F + M)}}{F + M}$$

Case 1 = 1.03 x 10^9

Case 2 = 1.20 x 10^9

Case 3 = 1.37 x 10^9

Actual catch was 1.14 x 10^8

PR Case 1 = 0.11

Case 2 = 0.10

Case 3 = 0.083

For projections					
	Age =	2,	3,	4,	5.......
	Pr =	0.10,	0.49,	1,	1.......

Table 10. Catch Projections

YEAR	POP NUMBERS	POP BIOMASS	CATCH NUMBERS	CATCH BIOMASS	MATURE F
78	4040860	339964	452349	87339.42	.4700
79	4006797	402400	426131	60136.74	.2820
80	4001568	486174	581763	93464.48	.2820
81	3854123	495086	548771	95458.55	.2820
82	3734638	485667	522035	93351.06	.2820
83	3688957	485474	511814	93307.84	.2820
84	3658568	482067	505014	92545.48	.2820
85	3638999	478788	500635	91811.88	.2820
86	3635280	481250	499803	92362.80	.2820
87	3631905	480510	499048	92197.05	.2820

YEAR	POP NUMBERS	POP BIOMASS	CATCH NUMBERS	CATCH BIOMASS	MATURE F
78	4040860	339964	452349	87339.42	.4700
79	4006797	402400	712338	99000.37	.5012
80	3745543	436715	526510	82586.84	.2820
81	3695295	457980	513232	87155.79	.2820
82	3643253	461529	501587	87949.88	.2820
83	3633690	469091	499447	89641.90	.2820
84	3626033	471642	497734	90212.81	.2820
85	3620661	472543	496532	90414.52	.2820
86	3624063	477010	497293	91414.05	.2820
87	3625297	477927	497569	91619.14	.2820

YEAR	POP NUMBERS	POP BIOMASS	CATCH NUMBERS	CATCH BIOMASS	MATURE F
78	4040860	339964	452349	87339.42	.4700
79	4006797	402400	795161	110000.13	.5700
80	3671683	422643	510613	79496.67	.2820
81	3649417	447364	502966	84780.48	.2820
82	3616740	454564	495655	86391.50	.2820
83	3617634	464350	495855	88581.15	.2820
84	3616551	468611	495612	89534.59	.2820
85	3615282	470713	495328	90005.02	.2820
86	3620770	475767	496556	91135.75	.2820
87	3623351	477166	497134	91448.91	.2820

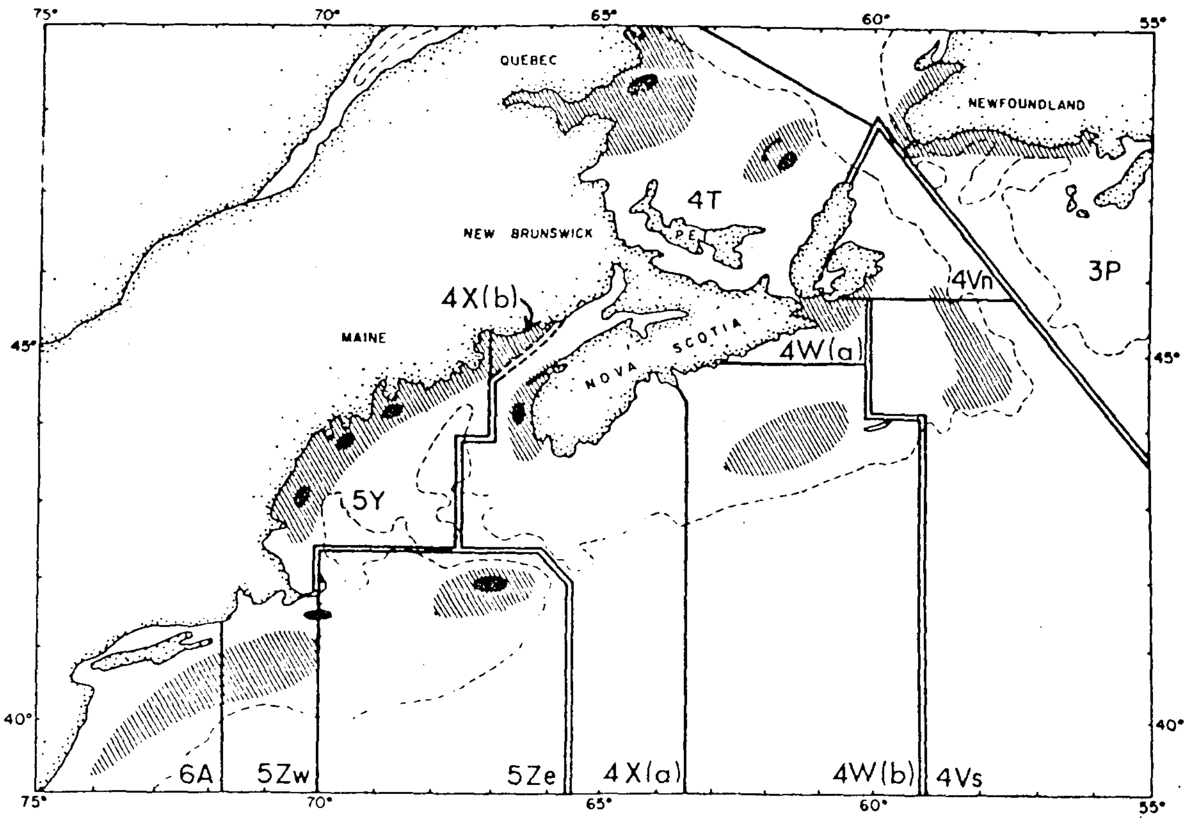

Fig. 1. Herring stock structure in Subareas 4 and 5 and Statistical Area 6. (Double lines indicate stock management areas; solid black areas indicate the general spawning grounds.)

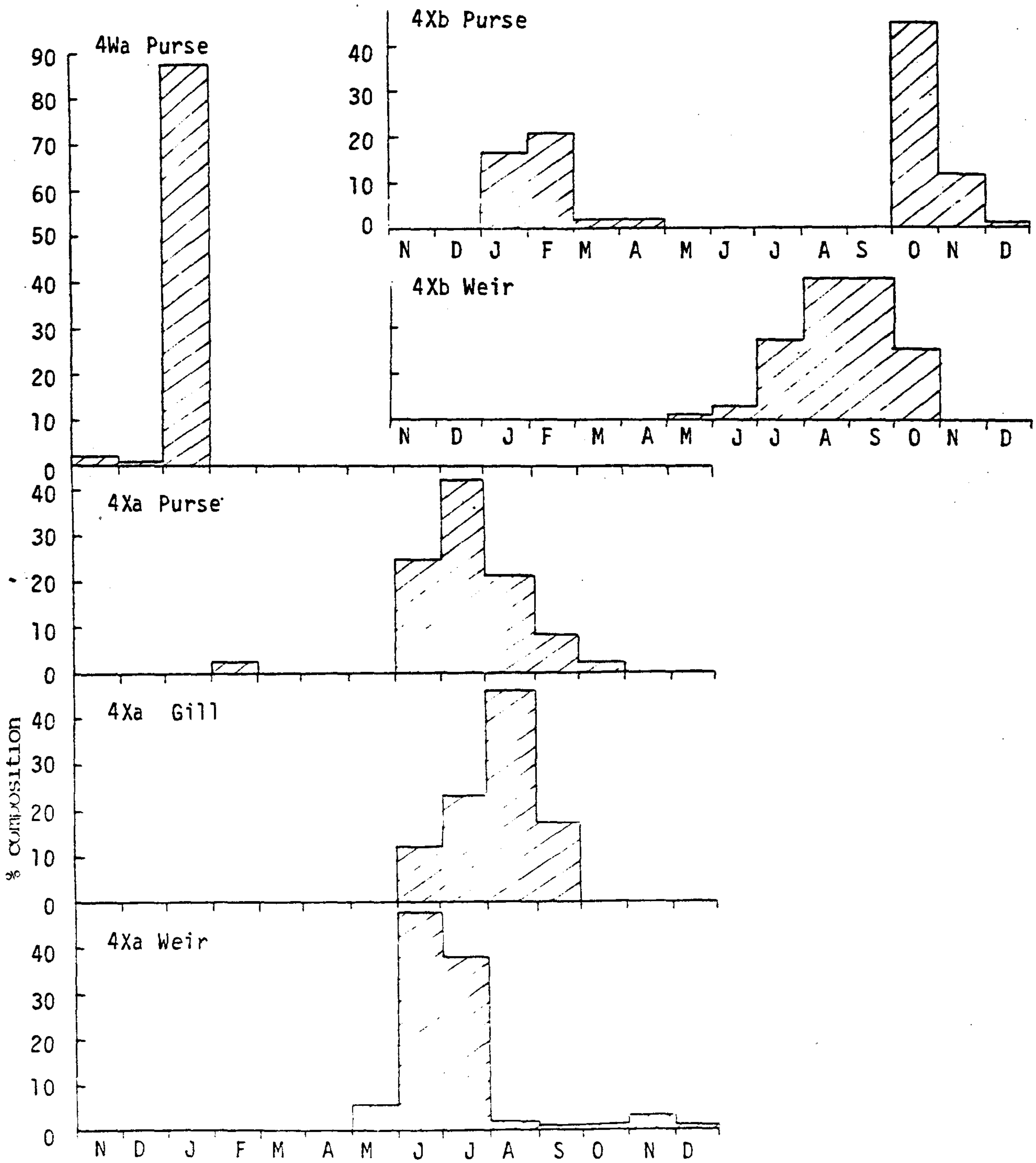

Figure 2. 1978 Seasonal catch distribution by gear

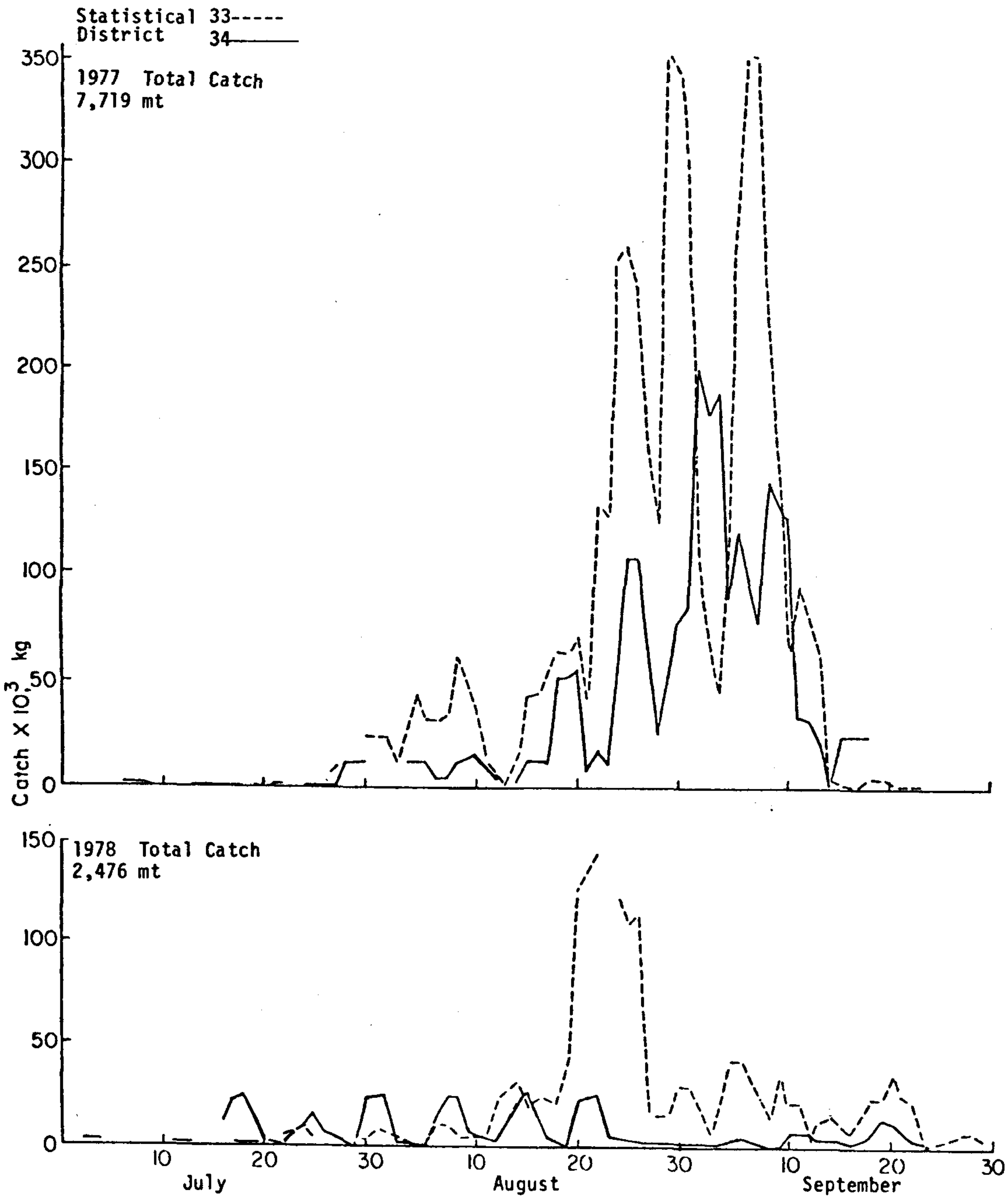

Figure 3. Daily drift gill-net catch, 1977-1978.

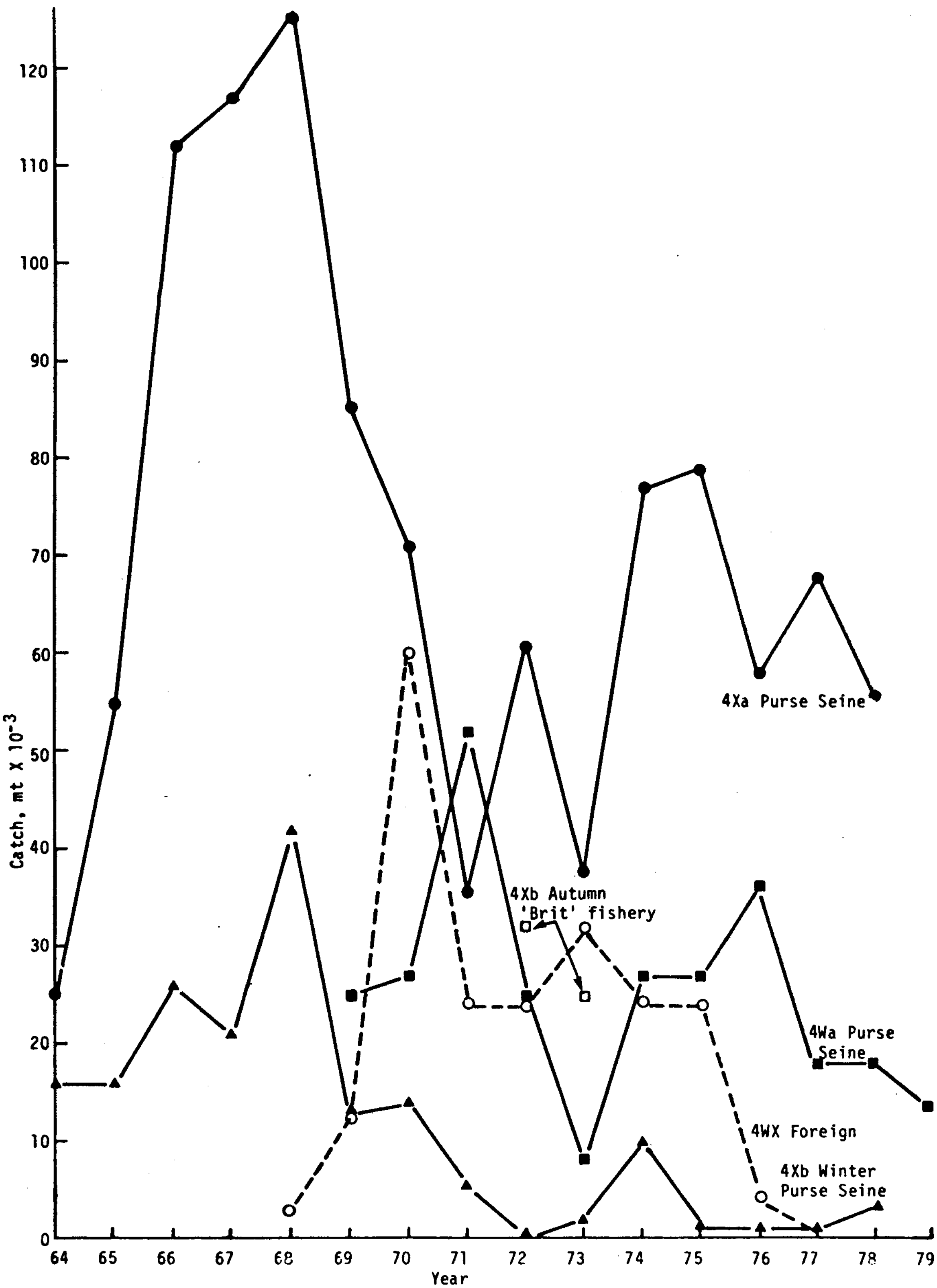

Figure 4. 4WX offshore herring catches, 1964-79.

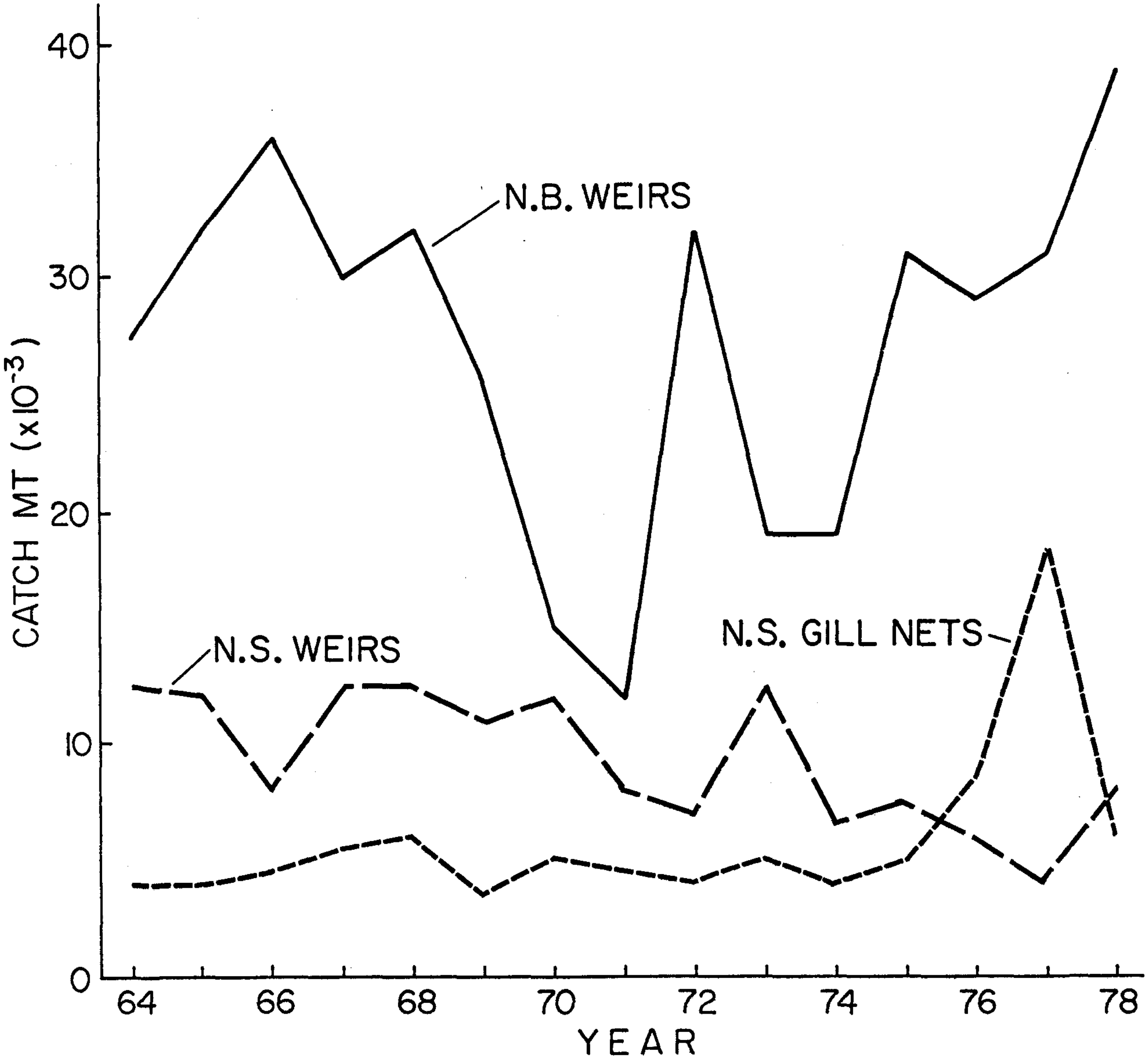

Figure 5. 4X Fixed gear catch (1964 - 1979).

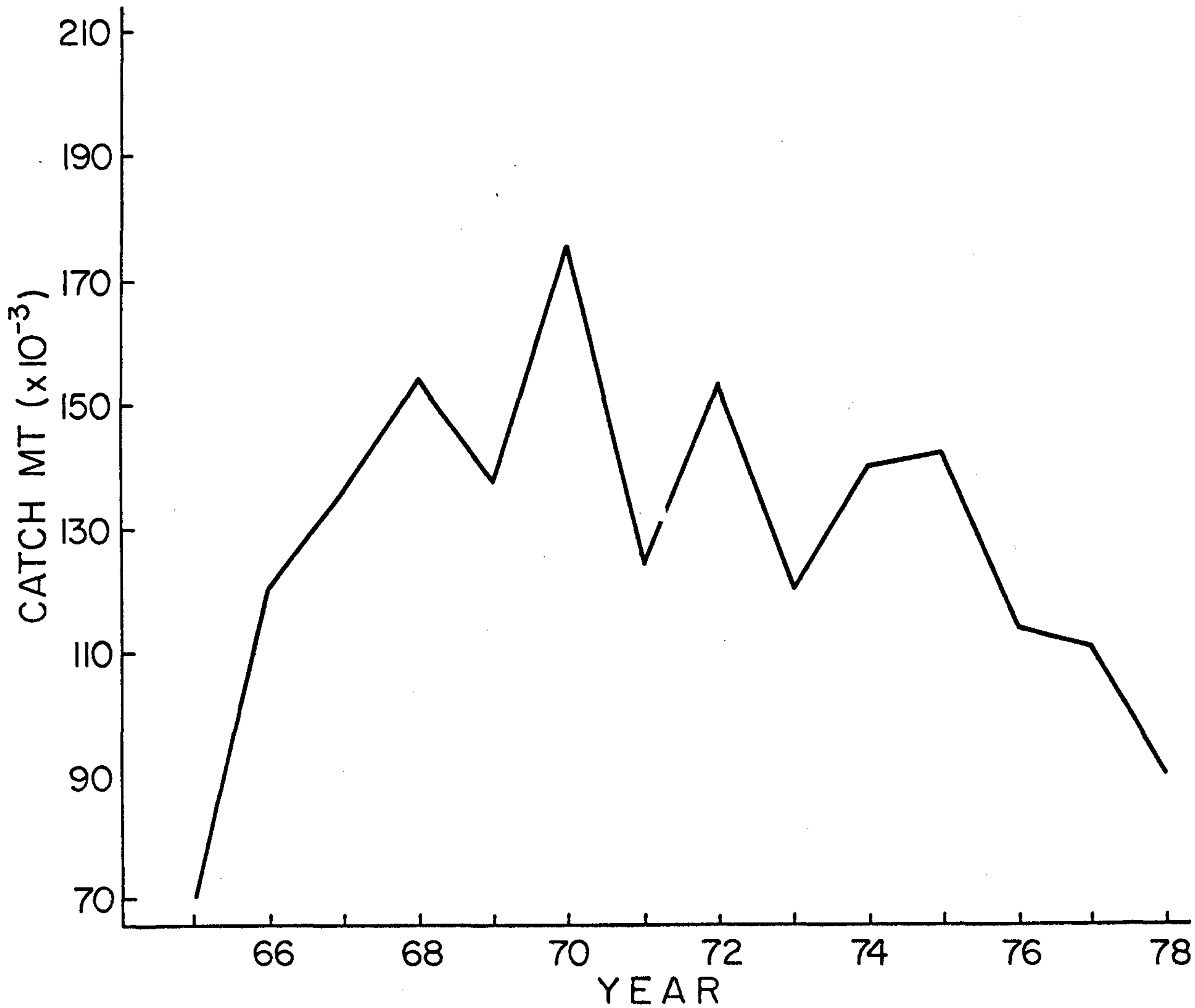

Figure 6.   4WX herring "stock" annual catch (1965 - 1978)

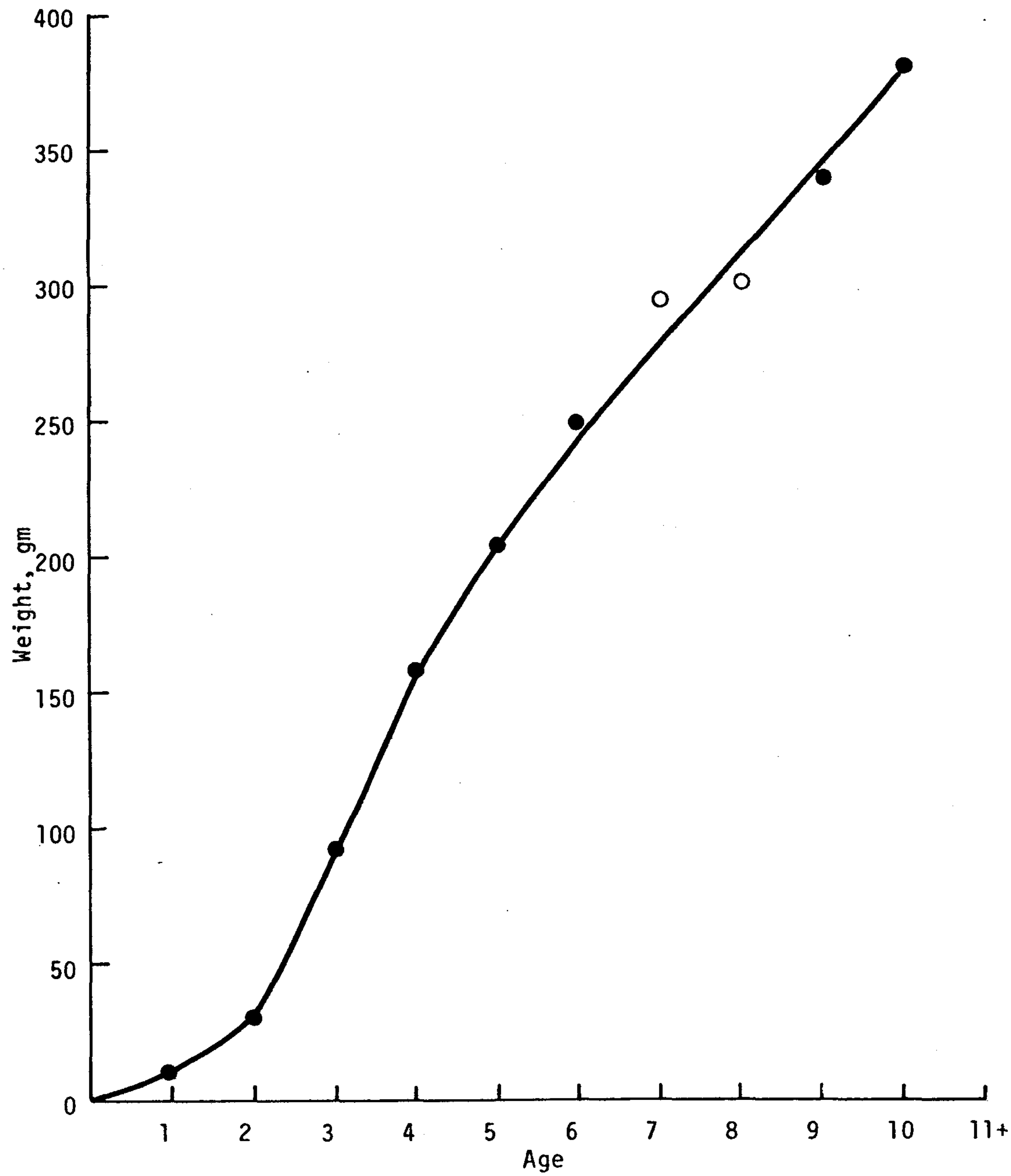

Figure 7. 1978 Weight at Age

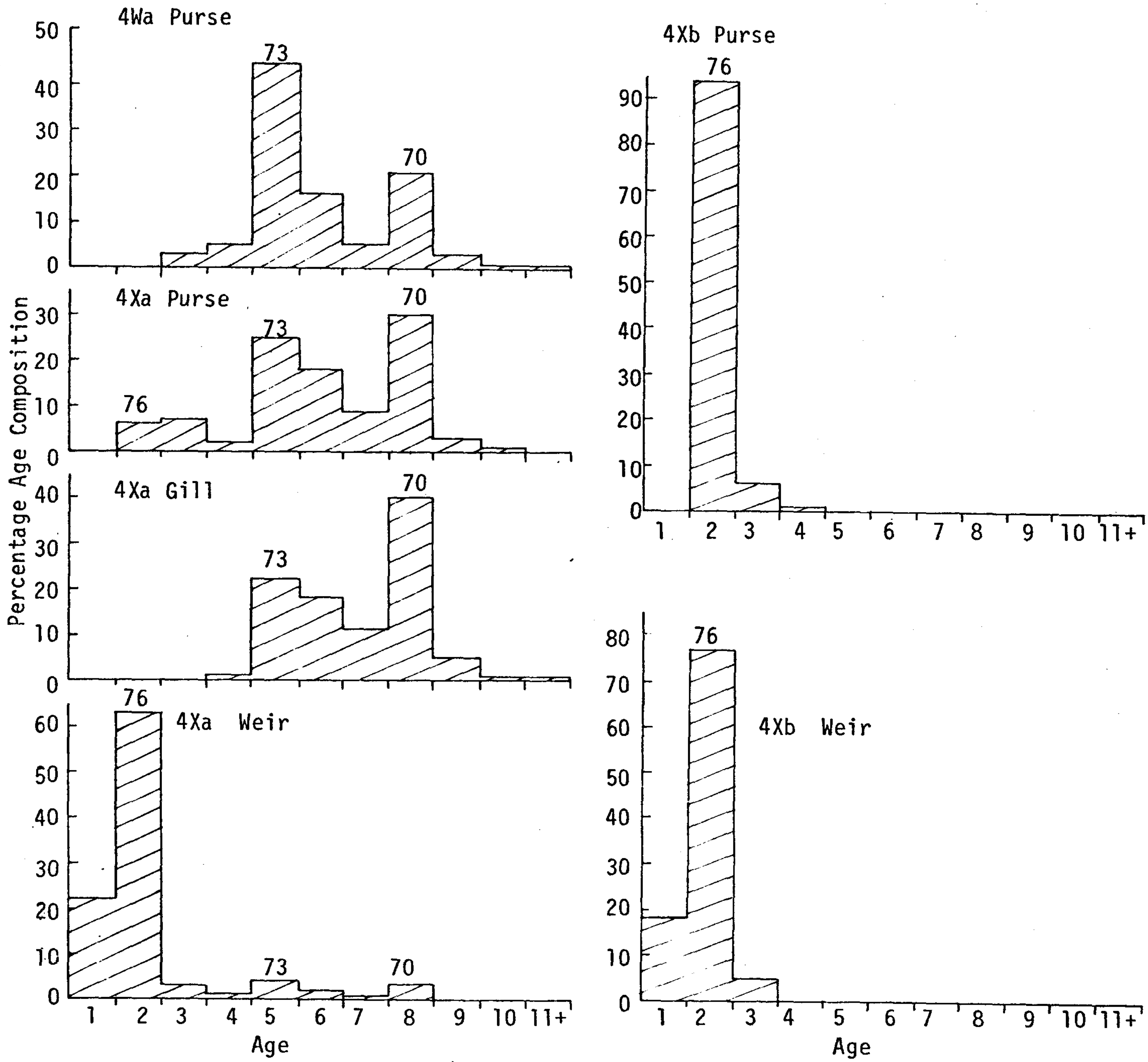

Figure 8. Percent age composition by gear of 1978 herring catch

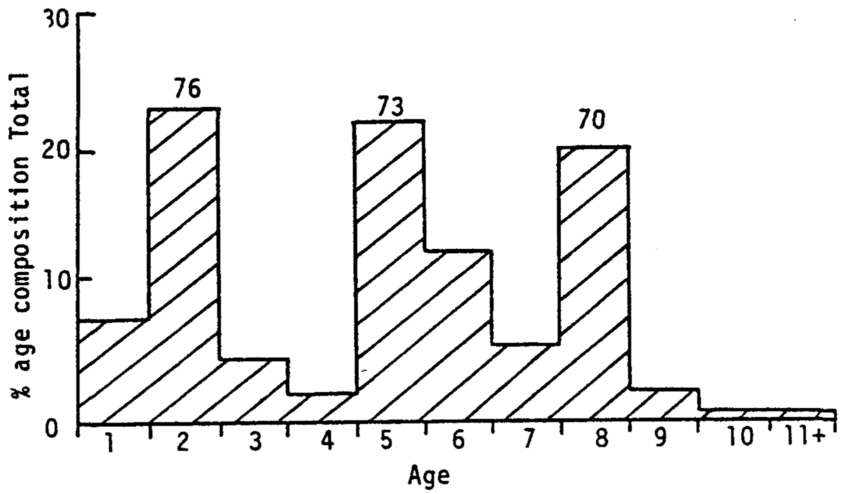

Figure 9. Percent age composition of 1978 removals from the 4WX stock.

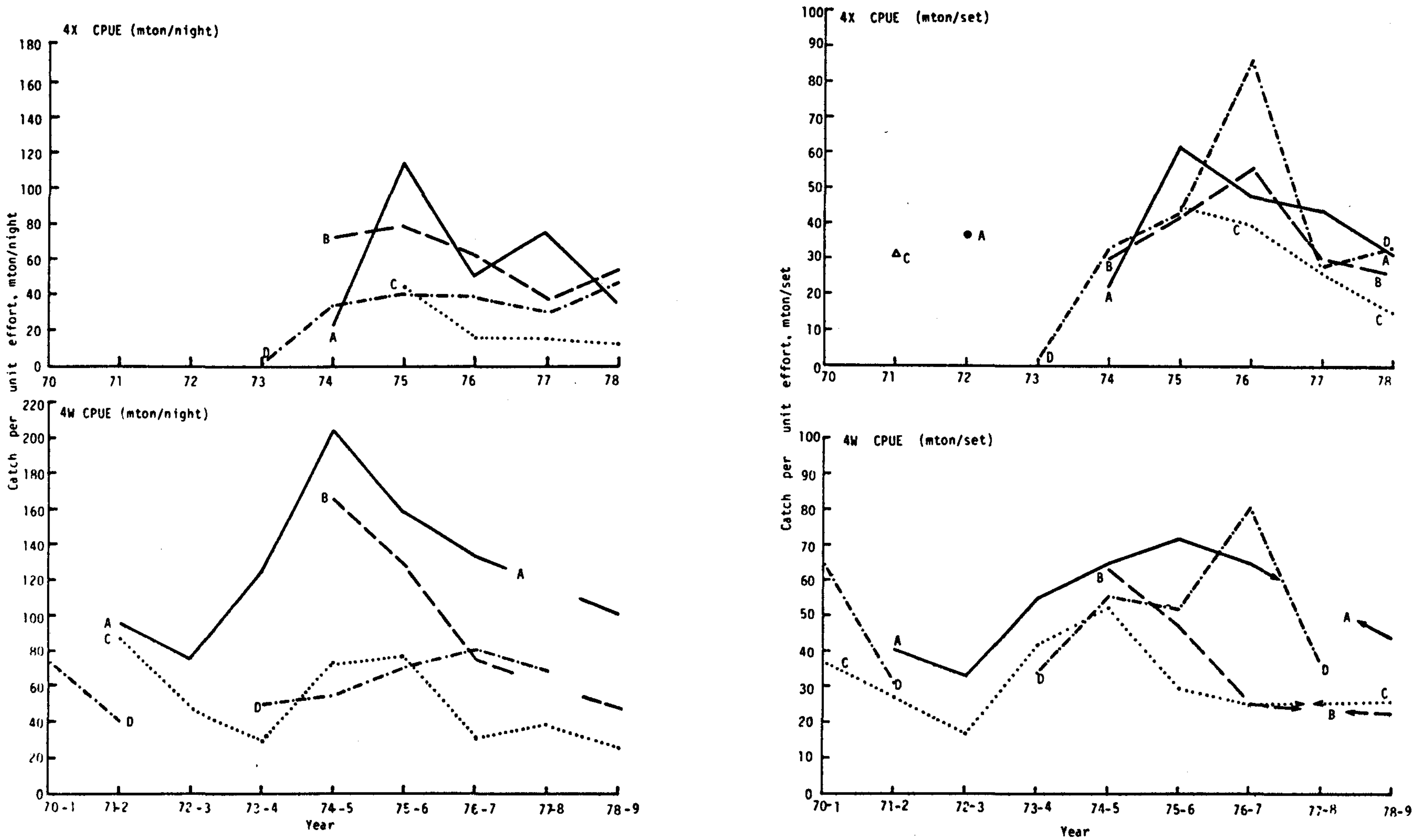

Figure 10. CPUE trends for individual purse seine captains (A, B, C and D are individual captains).

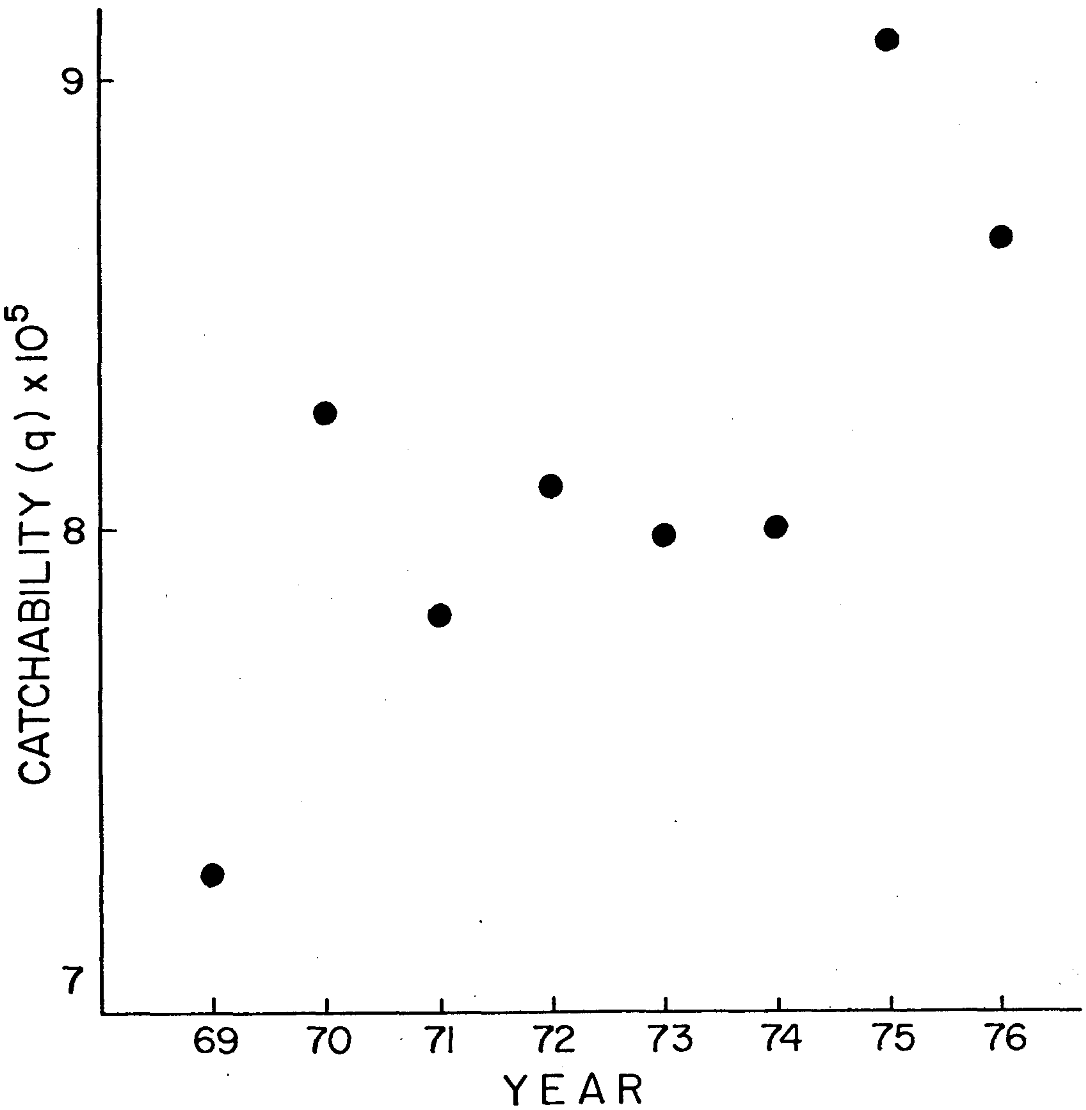

Figure 11. Catchability trend in the 4X purse seine fishery.

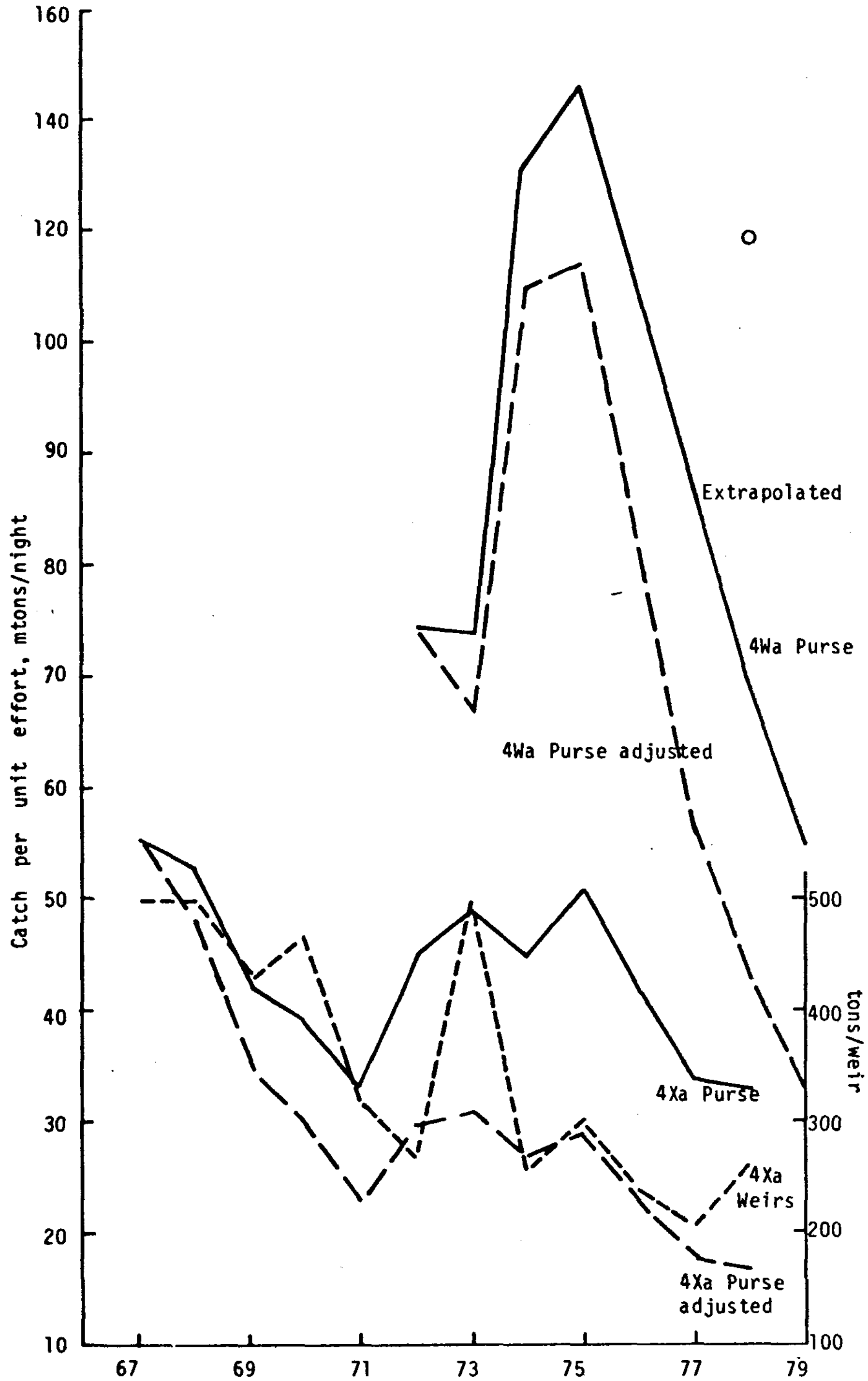

Figure 12. Catch per unit effort for 4WX purse-seine and N.S. weirs

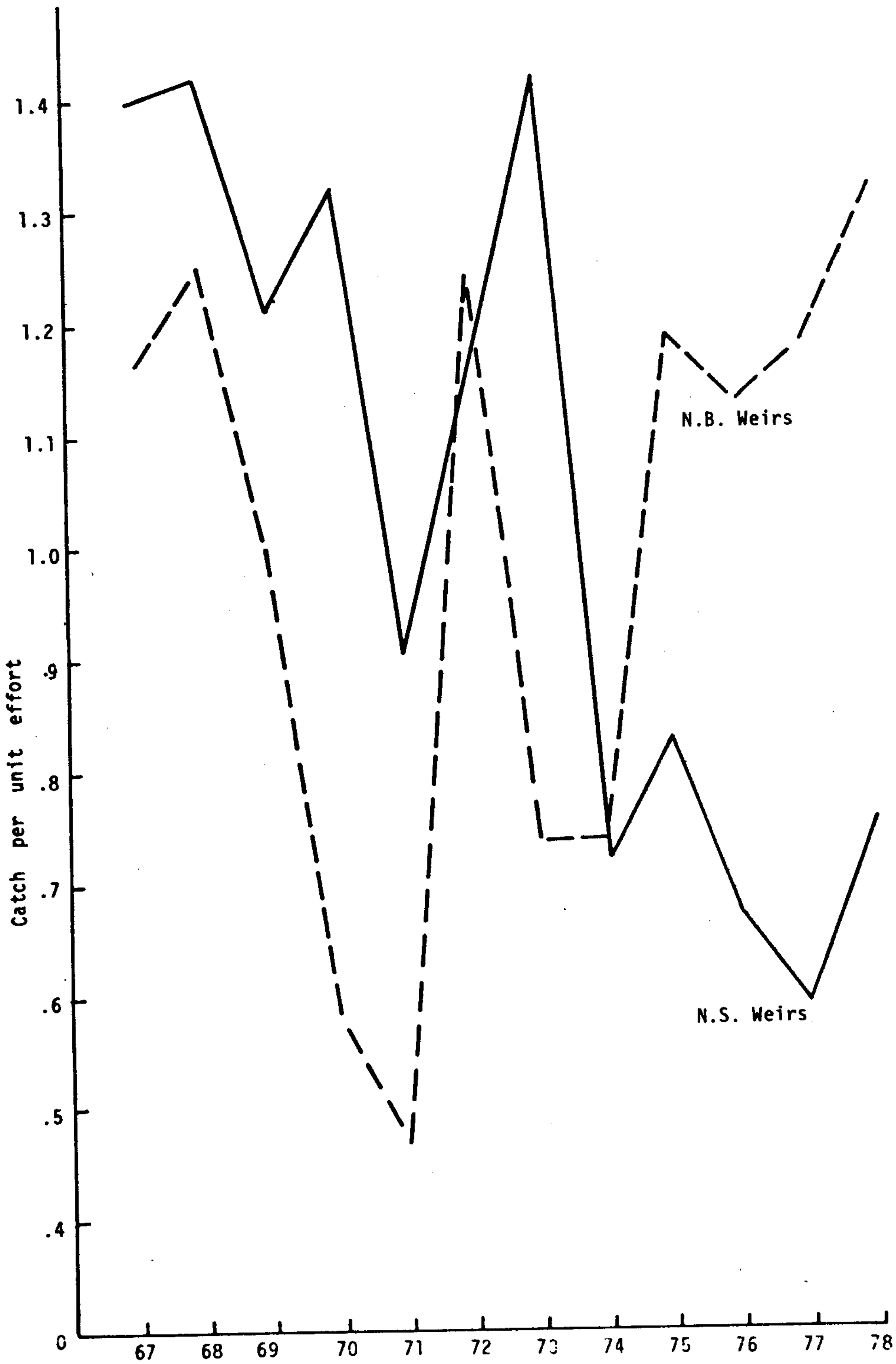

Figure 13. Normalized catch per unit effort for N.B. and N.S. weirs

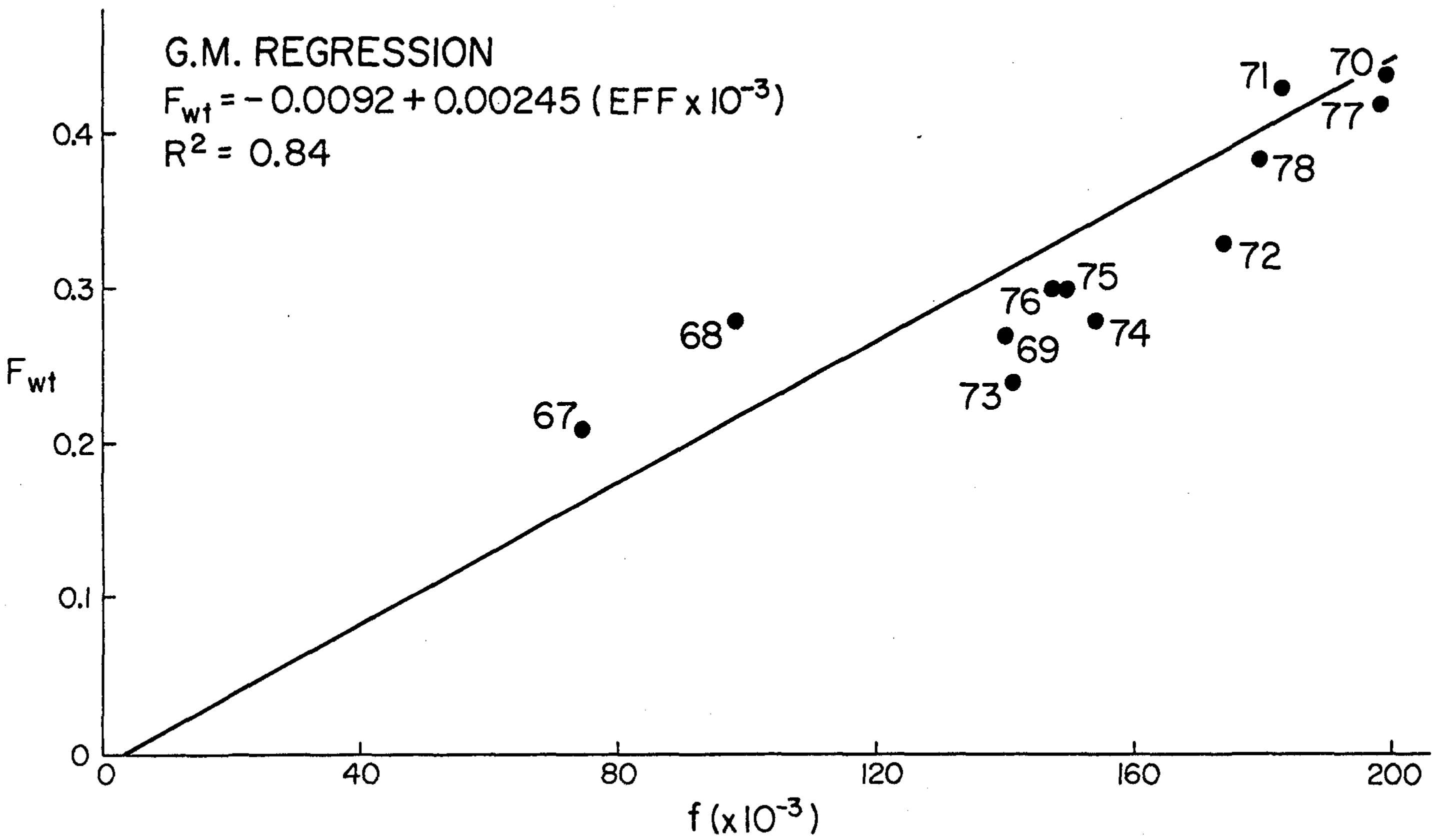

Figure 14. Fishing mortality versus fishing effort (adjusted by learning).

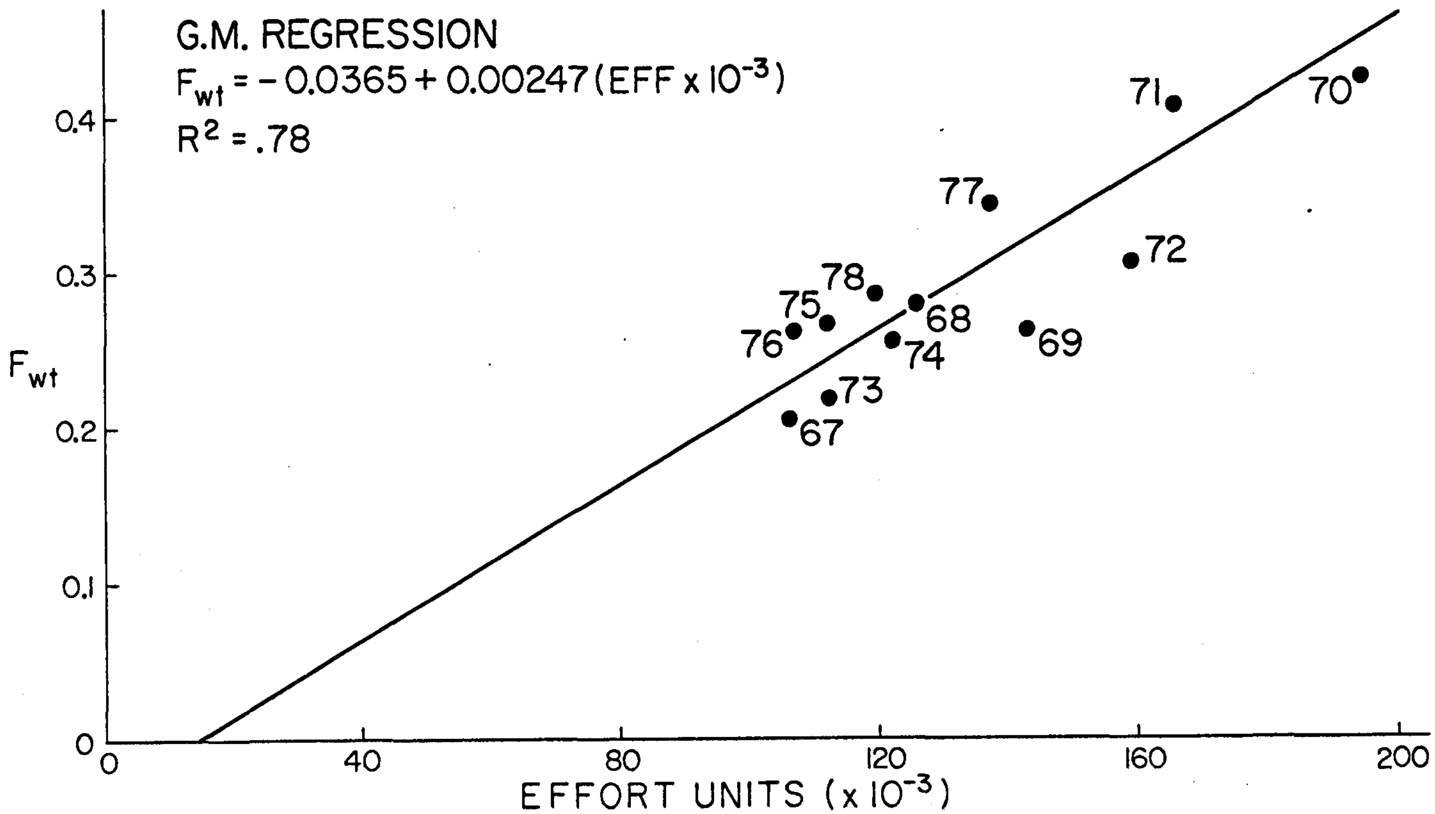

Figure 15. Fishing mortality versus fishing effort (unadjusted for learning).

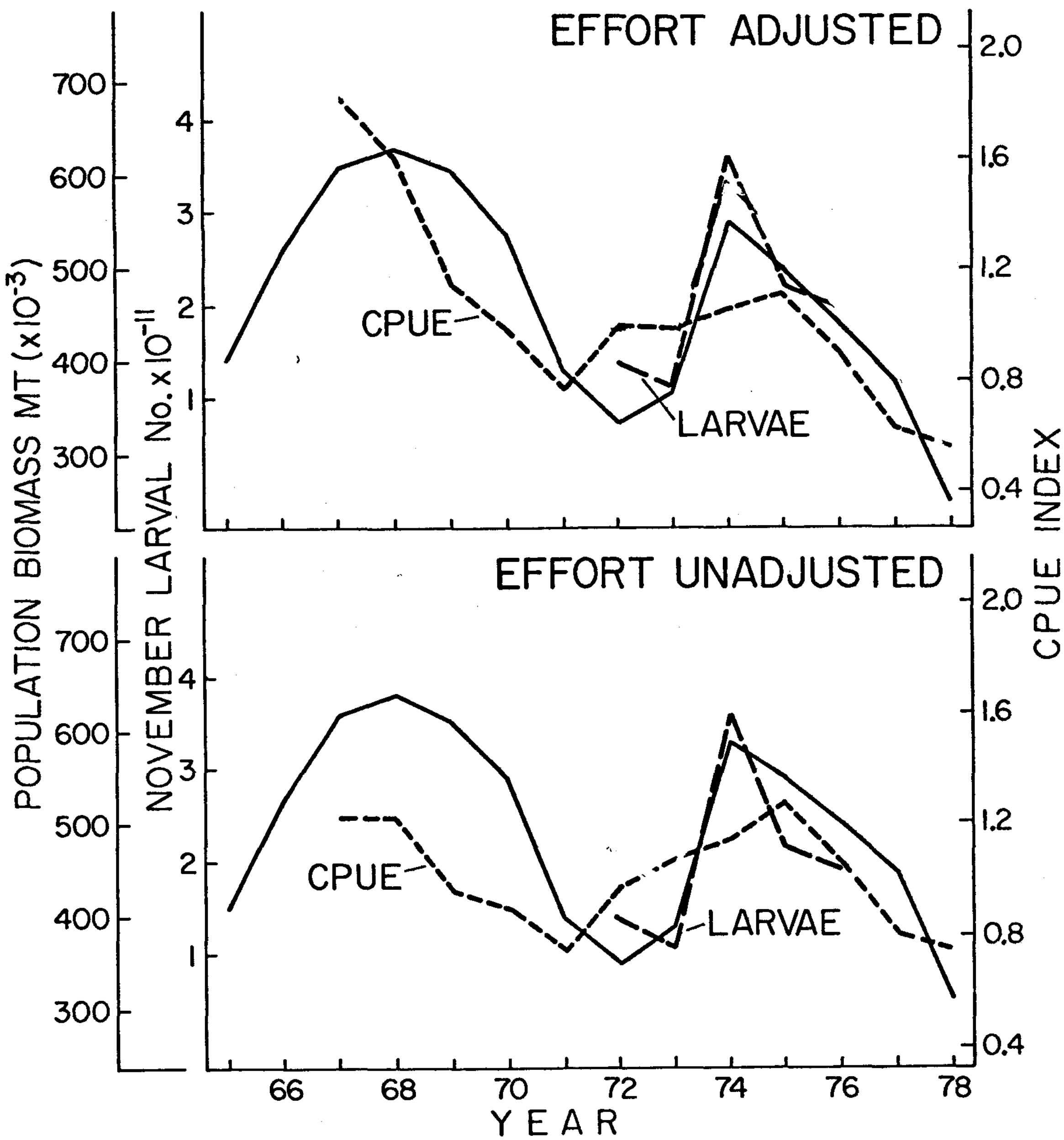

Figure 16. Recruited biomass from cohort analysis (solid line) and CPUE index versus time.

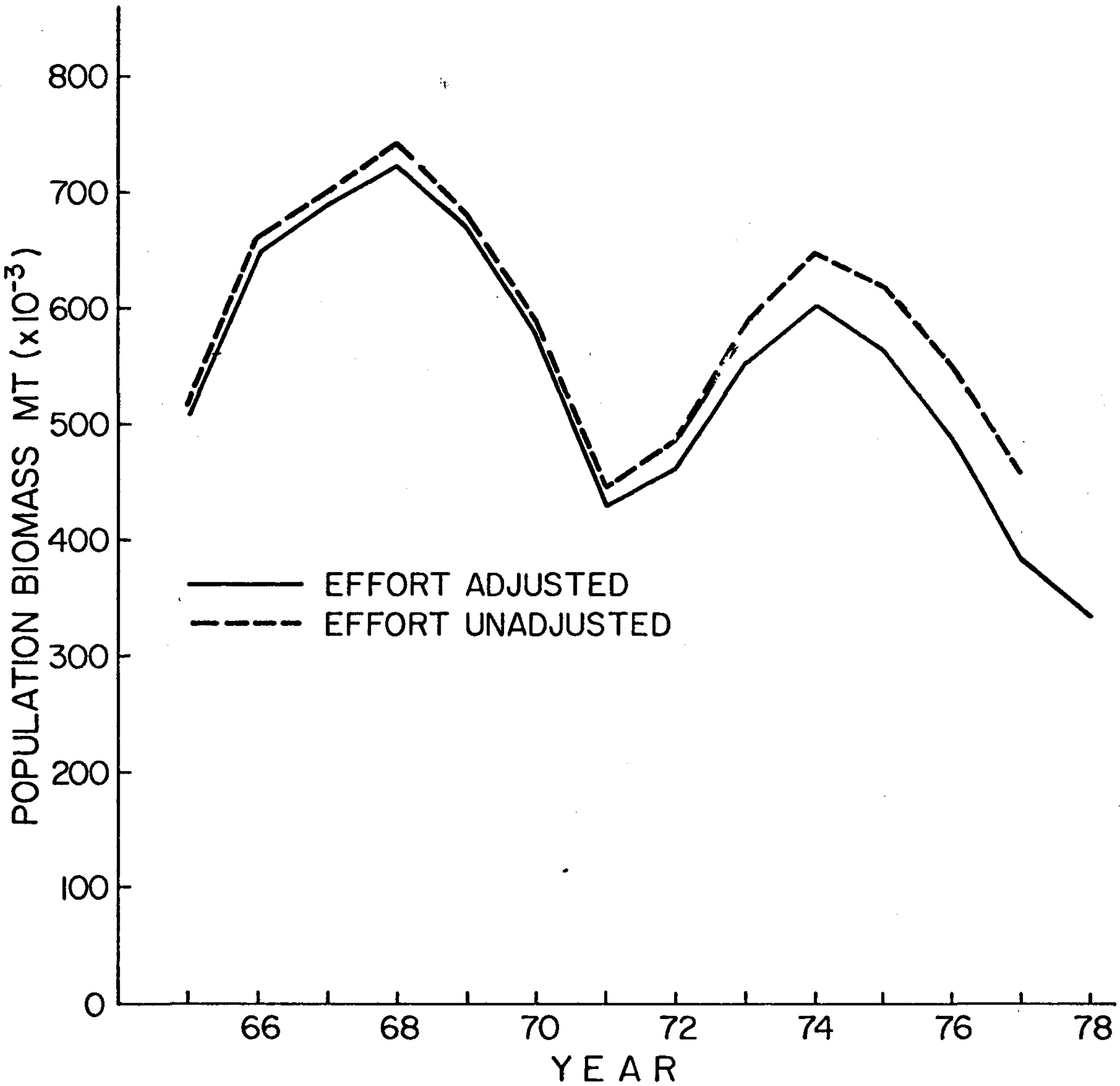

Figure 17. Population biomass estimated from cohort analysis.

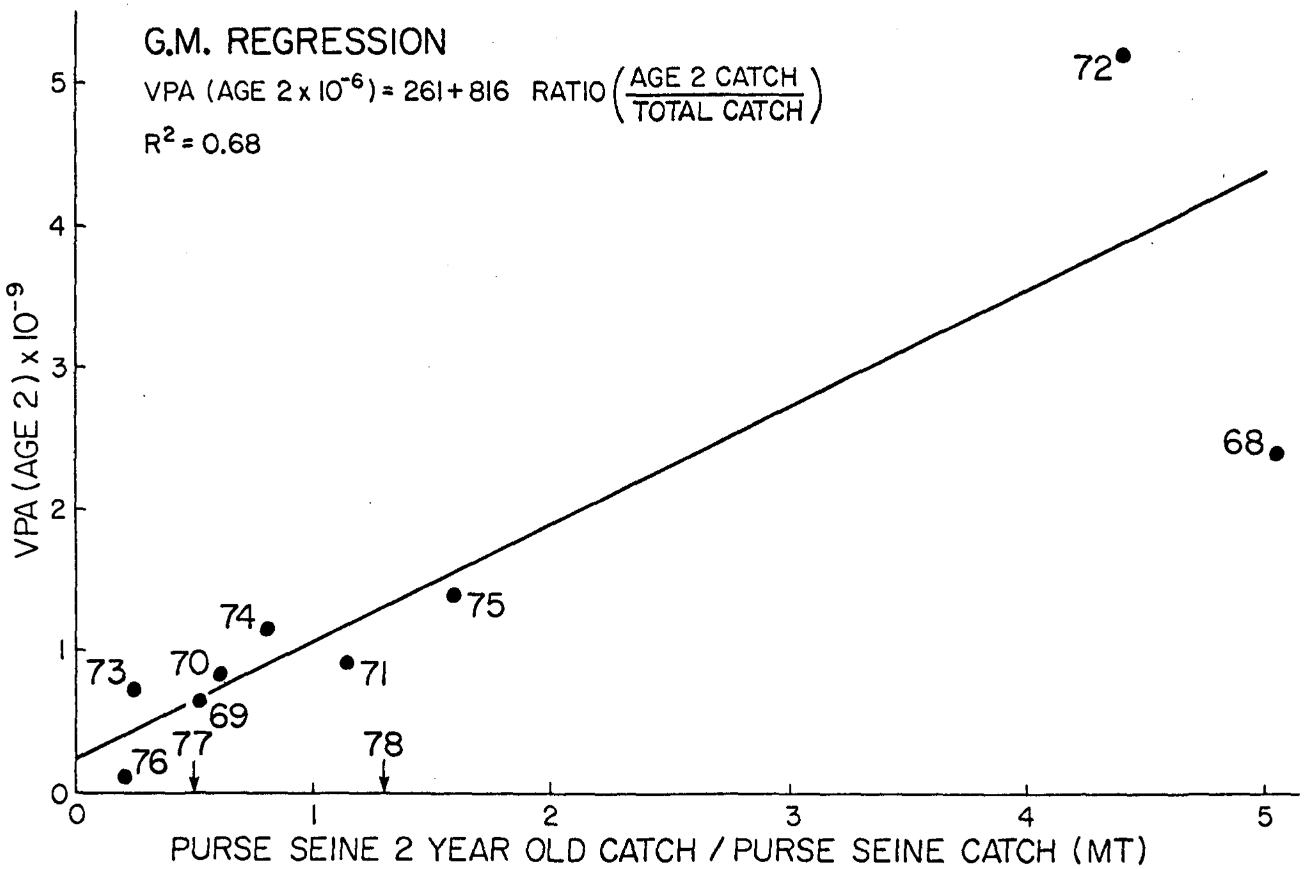

Figure 18. Relationship between cohort analysis estimate of two year olds and the proportion of 2 year olds in the purse seine catch (fishing year shown).

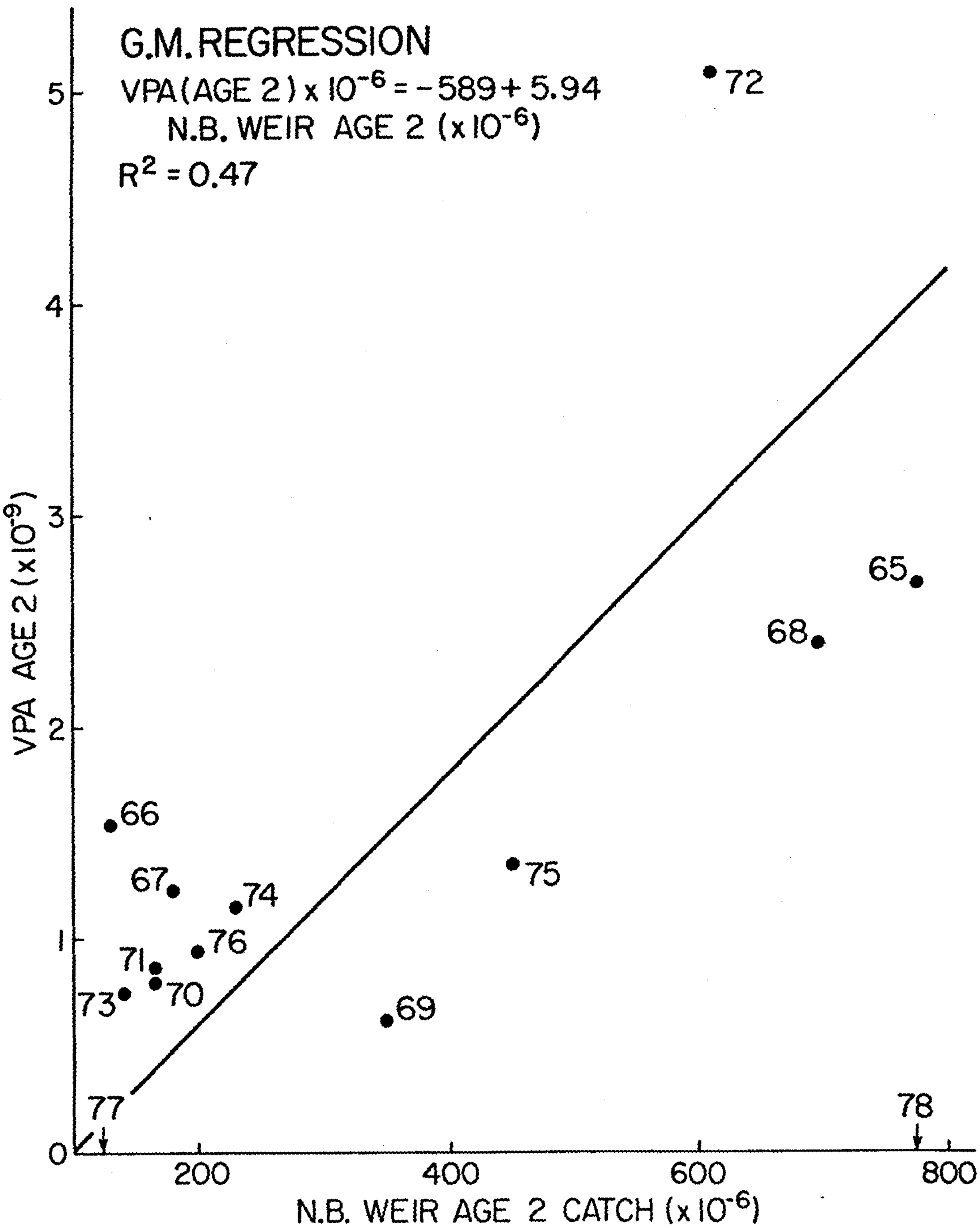

Figure 19. Relationship between cohort analysis estimate of two year olds and N. B. weir catch of two year olds (fishing year indicated).

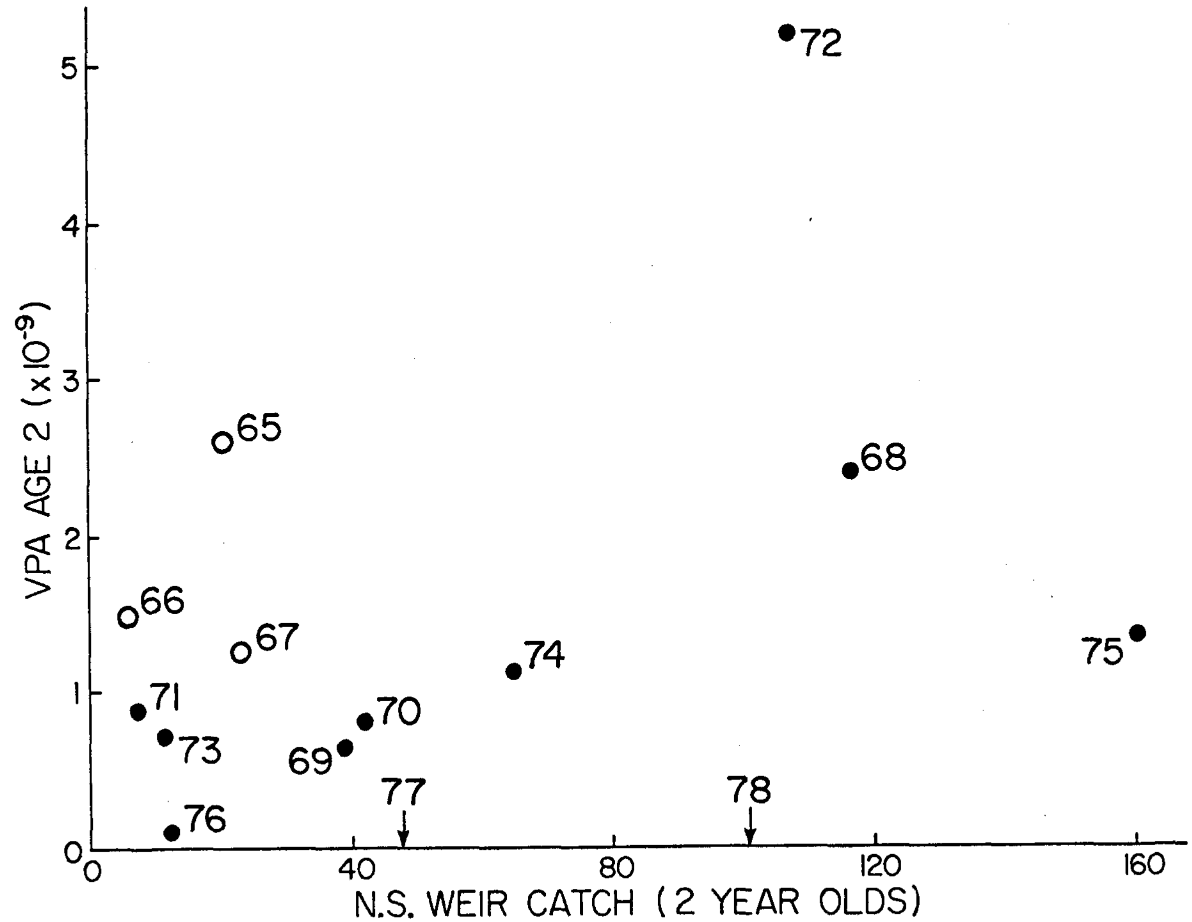

Figure 20. Relationship between cohort analysis estimates of two year olds and N. B. weir catch of two year olds (fishing year indicated).

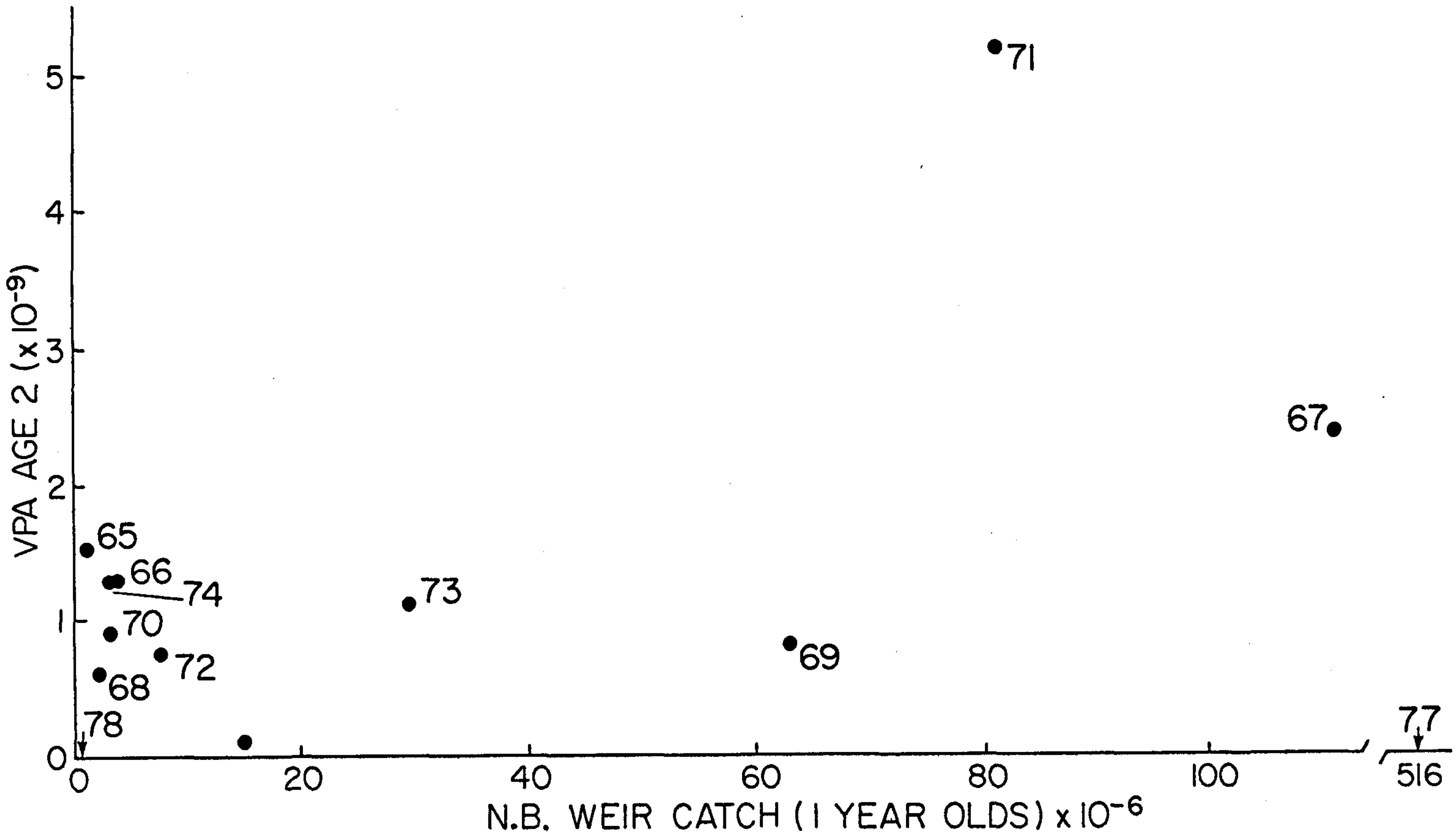

Figure 21. Relationship between cohort analysis estimates of two year olds and N. B. weir catch of one year olds (fishing year indicated).

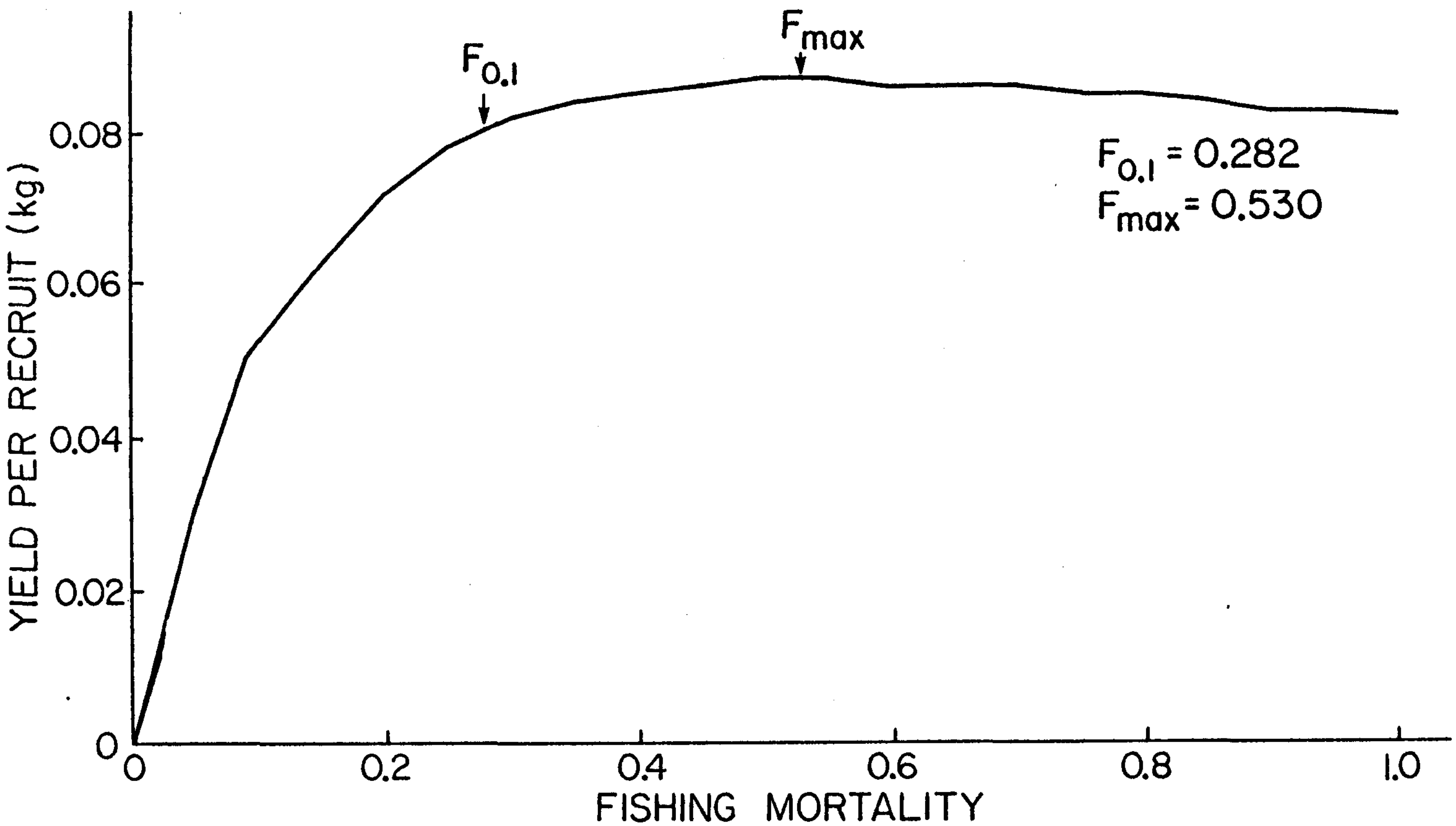

Figure 22. Yield per recruit curve.

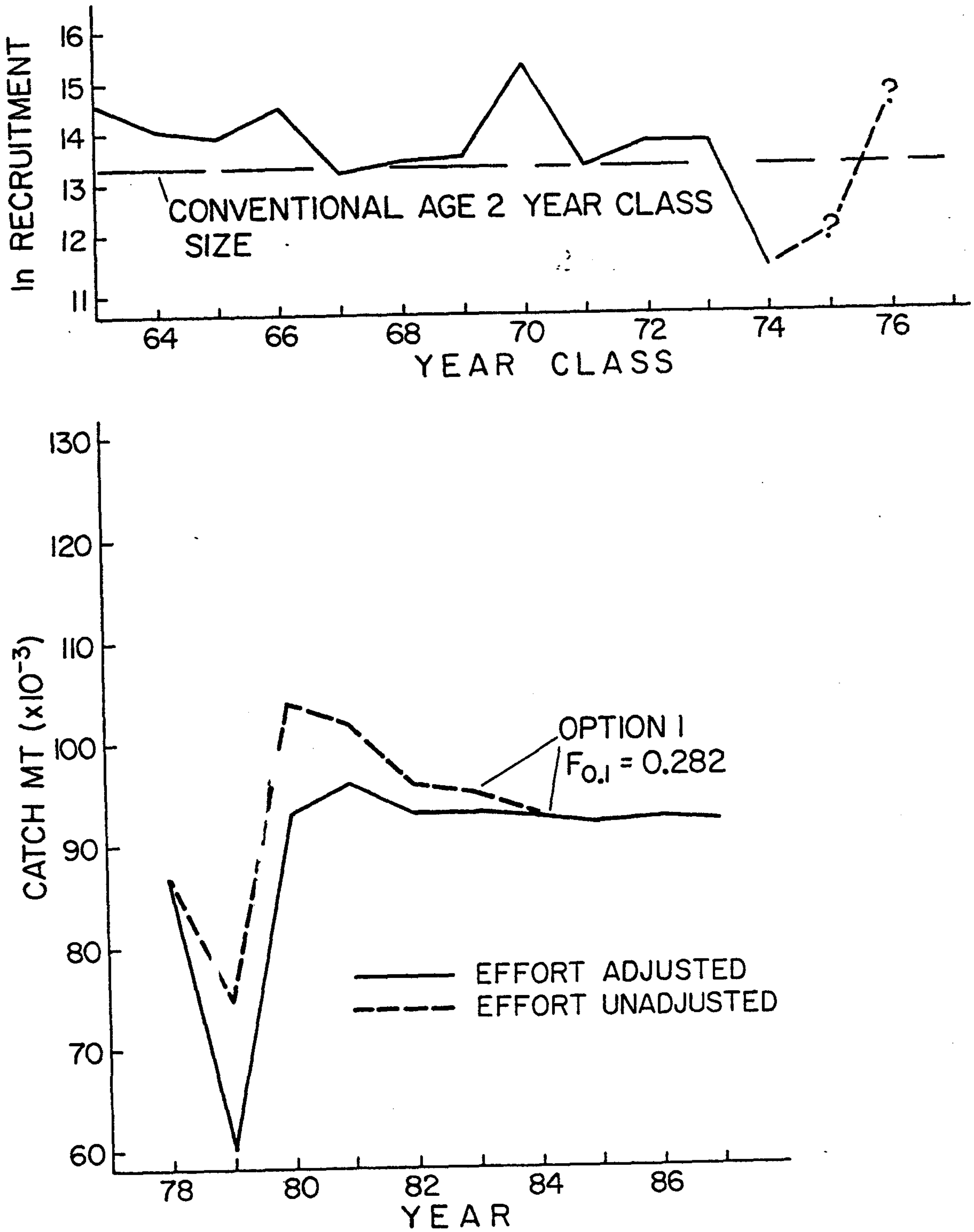

Figure 23. Catch projections at $F_{0.1}$ and mean recruitment (1965 - 1976).

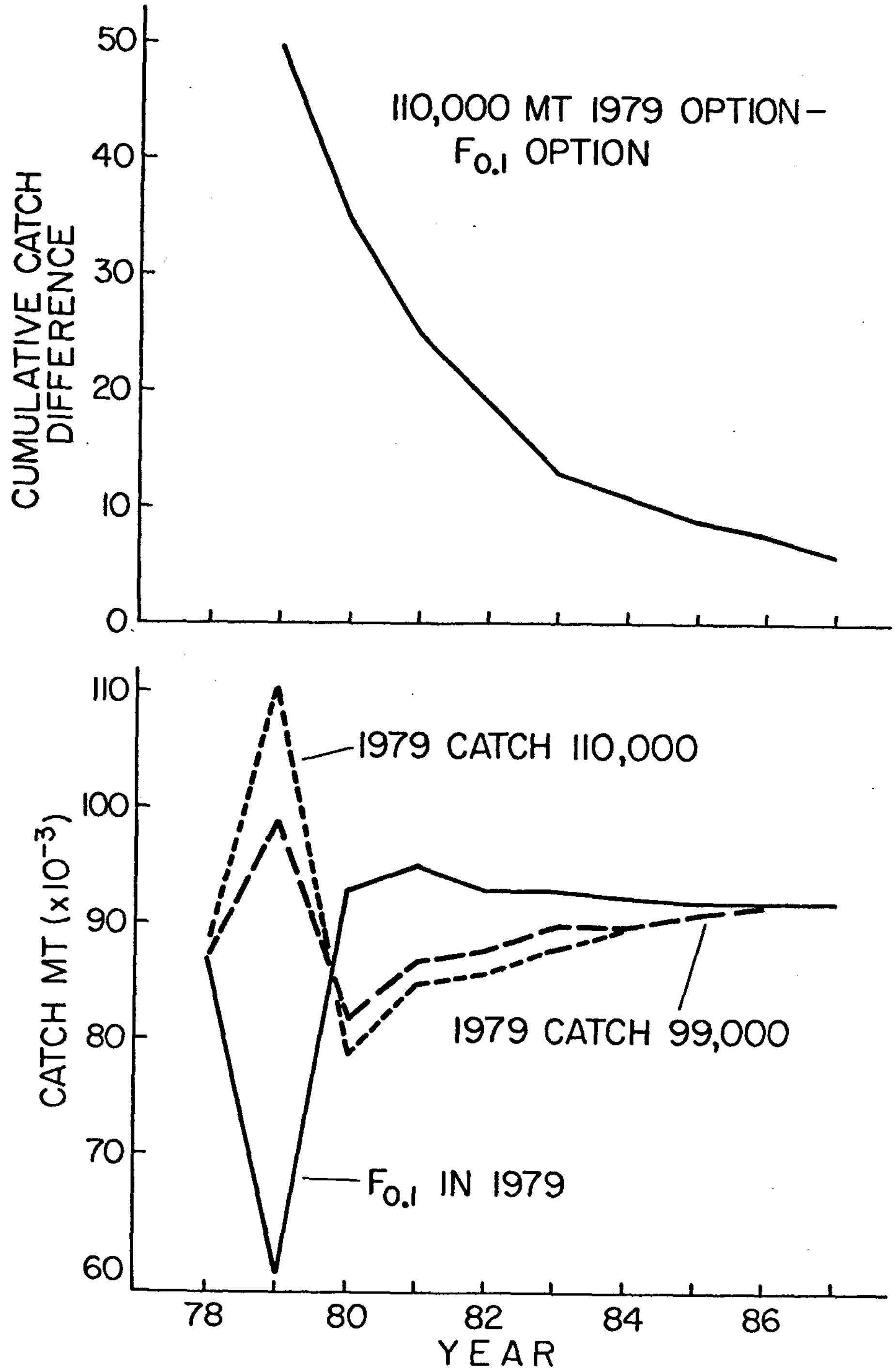

Figure 24. Catch projections (see text for explanation of options).