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4VsW Cod Assessment for 1978

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INTRODUCTION

In this year's assessment, a new catch-per-unit effort series was developed that combined data for Canadian otter trawls and Spanish pair trawls and a new method described in Schnute (1977) was used to derive the equilibrium Shaefer curve. This stock remains in a critical state and the recruitment relationship derived below implies that recovery may be slow. For 1977, 10,600 mt were caught, over 50% over quota. The catch per-unit-effort was quite high but the fishery has changed a great deal and thus this figure may not be consistent with past figures. Optimism derived from this piece of data could not be supported by the rest of the analysis.

Research Cruise Data

As always, the research cruise data continued to be highly variable. The total number estimated from the 1977 survey is encouraging, if it is believable, but the number of age one and two fish found should cause concern. Table 1 shows numbers estimated and mature Z's. GM regressions were run between the effort data developed below and the two Z series in Table 1. The fit was not significant in either case and for both the intercept on the Z axis was negative. Since the data implies a negative natural mortality, it indicates a trend towards catching a higher percentage of available fish in more recent years. This implies that we should be skeptical of increases in estimated total numbers.

Nominal Catches

Tables 2 and 2a show the breakdown in nominal catch by country since 1966. Several features are important to note. Canada's portion of the catch rose from about one third on average from 1966 to 1976 to almost 100%. This and changes in mesh regulations in the silver hake and squid fisheries altered the size and weight distribution of the catch. The end of the Spanish fishery, also meant an end to the most reliable effort series for this stock.

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From 1973 to 1976, there were quotas on the stock that did not appear to restrict catch. In 1977 the quota was restrictive but, for some reason, catches above quota were allowed, in fact the catch was over 50% above quota. This may be a conservative figure as it appears that the quota caused some reporting of 4VsW cod as being caught in other areas.

Effort and Catch-per-Unit Effort

The standard catch-per-unit-effort figure used for the fishery in the past was derived from data for Spanish pair trawls 150-500 tons (tonnage class 4). With the end of Spanish involement in this fishery a new effort figure had to be found. Since the Spanish catch usually accounted for at least half the total prior to 1977 and their fishing was directed almost exclusively towards cod, an effort index that ignores their fishery would not be very representative. Hence it was decided to use a combined index of three gears - Spanish pair trawls 150-500 tons, Canadian otter trawls 150-500 tons and Canadian otter trawls 500-1000 tons. These three gear classes account for the most catch. Thus, the index should be fairly representative of the catch though if the catchability of the three gears differs very much, the combined CPUE figure may not correlate well with biomass. After looking at many data series for the three gear classes, the catch-per-unit-effort figures that were most consistent and comparable appeared to be total directed catch in February and March divided by total directed effort in these months. In most years these two months accounted for the highest proportion of the catch though this has been changing since the Canadian inshore fishery, which is concentrated later in the year, increased in importance as the total catch decreased. These catch-per-unit-effort figures were combined as follows: To standardize efficiency, each series was divided by the average of the series. A weighted average was then taken across the three series using the amount of directed catch for that gear class for the year. These figures are shown in Table 3, along with the percentage of catch accounted for by the effort series used and the number of standardized effort units.

A method of deriving standardized catch-per-unit effort figures for a mixed fishery is given in Chikuni (1976). CPUE is regressed against percent of the stock in the catch for each period. The points on the curve corresponding to a constant percent are then taken as the CPUE series. This method was tried for various subsets of the Canadian otter trawl data. The only data that gave enough significant regressions was for tonnage class 5 in 4Vs from February to April. This series is included in Table 3 for comparison.

Some features of the data in Table 3 should be noted. The Spanish series shows more variation than any of the Canadian ones. This may be because the Spanish fishery was directed almost exclusively to cod whereas the Canadian fishery may be directed by chance and by what is available. The abnormally high values in the Spanish series and final series for 1968 shows up in various other series not presented here and to some extent in the 4Vs series. This value is not consistent with other data. Less of the total catch is accounted for by the effort used in recent years for two reasons. Though catches have fallen, the catch taken by inshore gears has stayed fairly constant (Table 4). At the same time in the otter trawl fishery as the

amount of catch decreases more of the catch appears as bycatch from trips directed at other species. The improvement in the CPUE in 1977 is partly because the Spanish series ended in 1976 and partly because the CPUE in 1977 looked fairly good in most Canadian series.

In the last few years the longline catch has been a sizeable part of the total. However, the availability of effort data for this gear is quite variable and what data is available shows large fluctuations over even relatively short periods. Thus longline CPUE was not included in the index.

Removals-at-age

This year the sampling of this stock was improved though it is not yet adequate. There were 19 commercial samples taken of the Canadian catch. Of these, three were from longline catches and the rest from otter trawls. Nine of the otter trawl samples were taken in March, eleven in the first quarter. There was not enough spread in the sampling to allow calculation of removals by quarter. It would also be useful to obtain samples of the catch of other gears.

Sampling of foreign catch was also improved this year thanks to our international observer program. Length frequencies were available for the bycatch to the USSR and Cuban silver hake fisheries and the Japanese squid fishery. The foreign catch was aged using the Canadian research vessel catch age-length key. Catches from countries other than those previously mentioned were waited up using samples for countries using similar gear.

Removals at age are shown in Table 5. The decrease in foreign catch and changes in the silver hake fishery have caused a marked improvement in the numbers of young fish removed. The mode of the catch is at 5 years of age and this peak is more marked than previously. An added reason for this is increase in percent of catch taken by longline. This appears to have added to the change in the overall selection pattern.

Weights at age were also derived from these samples. The final figures were smoothed using a von Bertalanffy curve. The only figures altered much by this smoothing were in the oldest ages and were based on few data points. The values derived were:

Age	1	2	3	4	5	6	7	8	9
Weight	.119	.362	.759	1.304	1.977	2.754	3.609	4.517	5.456

Age	10	11	12	13	14	15	16
Weight	6.405	7.350	8.277	9.175	10.039	10.862	11.640

These weights are bigger than those derived in past analyses and may indicate density dependent growth.

Catch versus Effort

A new method of deriving the equilibrium Shaefer cruve for a stock is presented in Schnute (1977). This method developes equations for the dynamics involved in the interaction between catch and effort and fits them to the data. The parameters derived can then be used to derive the equilibrium curve. For 4VsW cod the method worked reasonably well. The r^2 of the fit was .60 and the result is shown in Figure 1. The MSY is about 56,000 mt and the MSY effort is about 37,000 units. Figure 1 also shows the results of two regressions of catch on effort.

In the 1960's the catch was around the MSY level except for the anomalous 1968 point mentioned above. After that, rising effort pushed the points away from the equilibrium curve. However, there was no initial rise in catch as would be expected. This was probably due to the drop in recruitment that started around 1967. In the past two years the points are well below the curve indicating that the stock is not presently being overfished.

The Schnute analysis also provides a means of estimating next years catch if effort is known. Predicted catch for given effort in 1978 is shown in Figure 2.

Cohort Analysis

A cohort analysis was run using the removals at age for ages 1-12. Starting F's were adjusted until the GM regressions of weighted F vs effort and biomass vs CPUE gave good correlations and approximately went through the origin. The resulting estimates of numbers-at-age and F's are given in Tables 5 and 6.

The CPUE estimates the average biomass over the time period for which the data is taken. Therefore the figures in Table 3 estimate the average biomass during February and March. To estimate biomass at the start of the year, the CPUE must be corrected. This was done as follows: If Z_1 is the total mortality for Janaury and Z_2 is the total mortality for February and March then,

$$\text{CPUE} = k \cdot B e^{-Z_1} \cdot \frac{(1 - e^{-Z_2})}{Z_2}$$

So the biomass B is estimated by,

$$\frac{\text{CPUE} \cdot e^{Z_1} \left(Z_2 \right)}{1 - e^{-Z_2}}$$

Z_2 was estimated by taking the proportion of catch taken in February and March times the weighted F and adding it to 1/6 of M. F was estimated by

taking 1/10 of the rest of F and 1/12 of M. Table 8 shows the proportion of catch taken in February and March, the factor

$$e^{Z_1}\left(\frac{Z_2}{1 - e^{-Z_2}}\right)$$

and the corrected CPUE.

The plots of weighted F vs effort and biomass vs CPUE exhibit some scatter. This is to be expected because, due to poor sampling in recent years, there is probably quite a bit of variance in the estimates of removals-at-age. The regression of effort vs WF gave the following equation:

$$\text{Effort} = -2309 + 239248\ WF \qquad r = .89$$

In the regression of biomass on CPUE, two points were problems. These were the 1968 and 1977 points. As discussed earlier, the 1968 CPUE is unaccountably high. The 1977 point may indicate a change in the relationship between biomass and CPUE due to change in the fishery. The 1968 point was left out of the regression and the resulting equation was:

$$\text{Biomass} = 6195 + 146{,}809\ CPUE \qquad r = .84$$

The amount of correction of numbers and F's that occurs during the cohort analysis is proportional to the cumulated F's from the starting value to the value at question. The relationship is discussed in Pope (1972). Reasonable correction occurs with cumulated F's of about 3 and above. Table 9 shows cumulated F's for our analysis. This shows that most of the values for 1972 and before are probably quite well estimated.

Figure 3 shows the catch and biomass points found in the analysis and an estimated equilibrium curve. The Schnute analysis does not estimate the carrying capacity very well. But using the MSY from that analysis and taking the biomass at MSY for the 1967 point in the cohort (since the 1967 point is approximately at the MSY point in Figure 1) a curve can be estimated.

Recruitment

It is felt that the two major determinants of recruitment at age one are mature population and the silver hake fishery that took small cod as bycatch. In past analysis, a linear regression of numbers of ones vs effort in the silver hake fishery was tried. In last years analysis the correlation in this regression was low. However, the hypothesis of a linear relationship does not make sense in the long run. If the silver hake fishery does take many small cod and the recruitment is curtailed, eventually the number of mature cod will be affected and the recruitment will stay low even if silver hake effort drops. The following equation was postulated as an alternative.

$$\text{Number of ones} = a \cdot (\text{4+ population previous year})^{b} \cdot (\text{silver hake effort})^{c}$$

Effort for the silver hake fishery was an adjusted series obtained from D. Clay (personnal communication, Table 10). The 1977 point was not used because a firm effort figure is not yet available and the cod bycatch selection in the fishery has changed markedly. The natural log of the above equation was fitted by linear regression and the final equation was:

$$\text{Number of ones} = .000767\ (\text{4+ population previous year})^{1.82} \cdot (\text{silver hake effort})^{-.26} \qquad r = .995$$

The mature population explained 84% of the variation but the remaining variation is almost totally explained by the silver hake effort.

Figure 6 shows number of one year olds versus 4+ population the year before. Both this figure and the regression give an increasing curve with increasing slope. This relationship obviously cannot hold for all levels of mature population. However, in this period the population has been depressed and what we have fitted is just the lower portion of a recruitment function. It is likely that the curve would level off at higher population values. If this part of the recruitment curve is correct, there is reason for some concern. Its shape implies that recruitment rises very slowly as population improves if the population is very low. Hence recovery may also be very slow.

Yield per Recruit

Yield per recruit calculations were done for the 1977 partial recruitment and weights-at-age. The partial recruitment at present appears to be .0004, .04, .2, .8, 1, 1, .9, .9, .9, .9, .9, .9. The present drop in value at ages 1 and 2 is due to the reduction in foreign catch and changes in the silver hake fishery. The peak at 5 and 6 year olds is produced by the increase in the proportion of catch taken by longline. The analysis produced an F_{max} of .402 and an $F_{0.1}$ of .236. The curve is shown in Figure 7.

Projections

Projections were run with the 1977 population from the cohort analysis, and the 1977 partial recruitment and weights-at-age. It was hard to decide on recruitment because of changes in the silver hake fishery. However, this has little affect upon projections of two or three years and an average value of 20,000 was used. Because of the depressed recruitment and slow recovery implied by the recruitment curve, the population does not appear to be able to recover under $F_{0.1}$ or 2/3 F_{MSY}. 2/3 F_{MSY} is .25, this value was derived from the WF vs effort curve and

the MSY effort. Projections were run using .1 for 1978 (this will give a catch equal to the quota) and values of .1, .236, and .25 thereafter. The results are shown in Table 11.

SUMMARY

The overall picture derivable from the data is that this stock is still in trouble though it has stopped its decline and has stabilized somewhat. Better recruitment may result from the changes in the silver hake fishery but the recruitment function derived showed that recruitment would still probably remain low until the number of mature fish improves. To allow this improvement over the next few years it will be necessary to keep F below 0.1. This would mean keeping the quota (catch and bycatch) at 7000-7500 mt.

Again a plea is extended for improved sampling. Five or six samples per quarter from each of the otter trawl and longline catches and some samples from catches of other gears should be considered a minimum level.

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TABLE 1. Div. 4VsW Cod: survey population estimates (numbers at age x 10^{-3} and mortality of fully recruited age groups).

AGE	1970	1971	1972	1973	1974	1975	1976	1977
1	1,480	1,539	6,210	16,128	6,084	3,372	2,242	808
2	16,388	7,680	9,657	122,779	32,961	8,395	14,066	10,145
3	5,250	35,664	9,635	104,965	19,246	13,017	16,098	26,372
4	7,669	8,027	33,848	59,948	5,623	6,171	10,187	17,059
5	3,735	15,803	5,571	22,524	2,017	2,959	6,621	11,353
6	1,217	5,771	6,111	1,870	2,244	675	1,264	4,893
7	1,502	3,459	1,688	2,907	372	867	656	1,081
8	462	1,475	547	901	563	235	1,308	878
9	104	638	495	431	224	433	0	244
10+	711	471	153	910	340	234	1,180	223
TOTALS	38,518	80,531	73,915	333,363	69,574	36,358	53,622	73,056
$\bar{Z}_{5+/6+}$	-0.42	1.12	0.73	1.87	0.84	0.21	0.41	
$\bar{Z}_{6+/7+}$	-0.41	1.41	0.57	1.61	0.72	-0.25	0.60	

Table 2. Div. 4Vsw Cod - Nominal catches (mt).

Year	Canada	France	Portugal	Spain	USSR	Others	Total	Div 4Vs	Div 4W	Catch Quota
1966	17,690	1,494	-	43,157	5,473	356	68,170	27,136	41,007	-
1967	18,464	77	102	33,934	1,068	512	54,157	26,607	27,550	-
1968	24,888	225	-	50,418	4,865	29	80,425	48,781	31,644	-
1969	14,188	217	-	32,305	2,783	664	50,157	22,309	27,848	-
1970	11,818	420	296	41,926	2,521	446	57,427	28,632	28,795	-
1971	17,064	4	18	30,864	4,506	107	52,563	24,128	28,435	-
1972	19,987	495	856	28,542	4,646	7,119	61,645	36,533	25,112	-
1973	15,929	922	849	30,883	2,918	2,569	54,070	23,401	30,669	60,500
1974	10,700	34	1,464	27,384	3,097	1,060	43,740	19,610	24,130	60,000
1975	9,939	1,867	546	15,611	3,042	1,512	32,517	11,694	20,823	60,000
1976	9,567	697	-	11,090	1,018	2,035	24,407	11,553	12,854	30,000
1977	10,359	68	-	2	94	44	10,567	-	-	7,000
								1978	Directed	0
									By-catch	7,000

Table 2a. Breakdown of 'Other' category.

Year	Bulgaria	Cuba	Denmark	FRG	Ireland	Italy	Japan	Norway	Poland	USA	Total
1975	4	481	622	5	4	-	-	381	-	15	1,512
1976	-	587	1417	-	-	-	-	26	-	5	2,035
1977[1]	-	15	-	-	-	3	1	-	22	3	44

1 Preliminary statistics

Table 3. Effort and catch-per-unit-effort calculation.

Year	Spanish pair trawl - t.c. 4 rate/ ave. rate	catch	% of Spanish catch	CANADA - MQ Otter trawl - t.c. 4 rate/ ave. rate	catch	Otter trawl - t.c. 5 rate/ ave. rate	catch	%of Canadian Catch	Catch accounted for by effort	% of total catch	Adjusted C.P.U.E.	Total Effort Units	4Vs-OTB5 CAN-MQ-CPUE adjusted to 80% Cod catch (see text)
1967	1.547	33851	100	1.143	6724	1.298	1076	42	41651	77	1.475	36717	1.177
1968	2.039	50308	100	1.099	5483	1.286	3602	37	59393	74	1.907	42174	1.472
1969	1.471	31675	98	1.005	2030	.969	1844	27	35549	71	1.418	35372	1.002
1970	1.218	38550	92	.860	1999	1.052	2104	35	42653	74	1.193	48137	0.944
1971	.996	29341	95	.910	2847	1.147	3305	36	35493	68	1.003	52406	0.929
1972	.942	13267	46	1.193	4294	.991	5246	48	22807	37	1.001	61583	0.933
1973	.676	15271	49	.920	2107	.945	2844	31	20222	37	0.739	73166	1.241
1974	.497	9587	35	.753	1335	.662	1229	24	12151	28	0.542	80701	0.724
1975	.193	5704	37	1.153	2127	.841	1795	39	9626	30	0.526	61819	0.881
1976	.420	4760	43	.926	1774	.866	1072	30	7606	31	0.601	40611	0.676
1977	-	-	-	1.039	1455	.943	1283	26	2738	26	0.994	10631	1.021

1. t.c. = tonnage class

2. Rates all calculated as Feb-March, 4W and 4Vs total from directed catch.

TABLF 4: Div. 4Vs-W cod. Canadian nominal catches by otter trawls and other gears.

	Div. 4Vs		Div. 4W	
Year	Trawls	Other gear	Trawls	Other Gear
1958	4258	2092	4892	5731
59	4181	1286	7294	7308
60	1924	750	10228	5488
61	1135	136	12895	5531
62	1495	93	11762	4229
63	1258	34	7779	4063
64	2059	41	7324	4906
65	7366	106	10293	5338
66	6375	156	6614	4545
67	6729	132	6463	5140
68	9501	66	8367	6954
69	3539	51	4424	6174
70	3054	22	3596	5146
71	5826	41	4745	6452
72	9856	119	4732	5280
73	6397	77	4723	4731
74	4640	60	1343	4658
75	1815	72	3556	4496
76	3496	301	934	4836
77	2505	93	2270	5232

TABLE 5: REMOVALS-AT-AGE (IN THOUSANDS)

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	1055	206	938	536	486	869	896	533	557	674	355	1
2	6726	2057	6120	3420	3488	6025	8261	4763	3298	3750	1978	68
3	10269	4858	10990	4010	5558	6634	8095	11111	8614	4321	1860	303
4	12660	7733	16616	13055	14196	8065	12245	6792	9217	3459	3418	889
5	10139	9370	15245	10026	13472	8449	9289	9441	7024	4421	4775	1518
6	4461	4338	8297	6073	4539	10262	8780	3818	2718	2536	2392	805
7	3256	1467	3482	2144	1942	5160	3432	2979	944	2627	1426	401
8	1590	1239	895	510	759	1849	1919	3717	1320	607	609	156
9	856	664	816	237	236	496	358	1164	413	497	184	98
10	496	647	361	50	72	114	393	273	369	660	49	35
11	666	325	152	95	137	131	79	299	15	153	22	35
12	24	65	211	58	56	72	2	3	5	126	107	42
13	14	16	33	12	9	98	37	7	0	36	1	20
14	0	5	17	2	12	12	0	5	0	9	4	11
15	2	7	1	2	4	51	1	5	0	9	1	8
16	1	2	10	2	3	17	1	20	0	18	1	9
	52215	32999	64184	40232	44969	48304	53788	44930	34494	23903	17182	4399

TABLE 6: POPULATION NUMBERS FROM COHORT ANALYSIS (IN THOUSANDS)

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	151725	112994	74412	88983	71336	78657	57622	45741	39404	20281	15710	18389
2	105106	123267	92326	60075	72286	57965	63613	46366	36968	31757	15995	12541
3	73499	79968	99061	70052	46090	56027	42006	44607	33651	27282	22607	11306
4	50814	50884	61076	71161	53726	32707	39868	27067	26467	19757	18427	14826
5	25062	30148	34663	34970	46449	31142	19480	21562	16015	13330	13046	11994
6	9446	11345	16205	14585	19559	25839	17852	7544	9111	6756	6913	6361
7	7453	3697	5363	5760	6447	11907	11870	6671	2722	5000	3237	3496
8	3709	3156	1700	1240	2776	3521	5079	6613	2766	1374	1716	1360
9	2353	1598	1463	582	554	1586	1210	2422	2051	1071	576	854
10	1735	1152	707	459	262	240	850	666	930	1305	427	305
11	949	922	358	252	331	149	93	340	299	428	472	305
12	64	174	502	155	121	147	4	5	8	231	212	366
	431914	419354	387835	348175	319935	299886	259546	209604	170391	128572	99338	84103

TABLE 7: FISHING MORTALITY FROM COHORT ANALYSIS

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	.009	.002	.014	.007	.008	.012	.017	.013	.016	.037	.025	.000
2	.073	.019	.076	.065	.055	.122	.155	.121	.104	.140	.147	.006
3	.168	.069	.131	.065	.143	.140	.239	.322	.333	.192	.095	.030
4	.322	.184	.358	.227	.345	.318	.415	.325	.486	.215	.229	.060
5	.593	.421	.666	.381	.386	.356	.749	.661	.663	.457	.518	.150
6	.738	.549	.834	.616	.296	.578	.784	.819	.400	.536	.482	.150
7	.659	.577	1.264	.530	.405	.652	.385	.680	.483	.869	.667	.135
8	.642	.569	.872	.606	.360	.868	.540	.971	.749	.670	.498	.135
9	.514	.615	.959	.598	.636	.424	.396	.757	.252	.720	.435	.135
10	.380	.970	.830	.128	.362	.744	.716	.603	.577	.818	.136	.135
11	1.496	.461	.634	.538	.612	3.507	2.734	3.575	.057	.503	.053	.135
12	.525	.525	.615	.525	.705	.765	.900	1.065	1.185	.900	.800	.135
WF	.162	.102	.233	.149	.180	.216	.288	.306	.304	.276	.255	.067

Table 8. Corrected catch-per-unit-effort.

Year	Percent of Catch taken in Feb. and Mar.	Correction factor	Corrected CPUE
1967	.293	.946	1.559
1968	.482	.904	2.109
1969	.496	.925	1.532
1970	.460	.919	1.298
1971	.414	.914	1.098
1972	.450	.893	1.121
1973	.344	.900	.821
1974	.293	.906	.598
1975	.281	.912	.576
1976	.246	.920	.654
1977	.199	.956	1.040

See text for explanation

TABLE 9: CUMULATED F'S

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	3.962	4.049	3.832	3.180	2.695	2.049	1.354	.689	.311	.214	.031	.000
2	5.008	3.954	4.047	3.818	3.173	2.687	2.036	1.336	.676	.295	.177	.006
3	4.863	4.935	3.936	3.971	3.753	3.118	2.565	1.881	1.216	.572	.155	.030
4	8.367	4.696	4.865	3.805	3.906	3.610	2.978	2.326	1.559	.883	.379	.060
5	8.192	8.045	4.512	4.508	3.578	3.561	3.292	2.563	2.001	1.073	.668	.150
6	7.555	7.599	7.625	3.846	4.127	3.192	3.204	2.543	1.902	1.338	.617	.150
7	3.693	6.817	7.050	6.790	3.230	3.830	2.614	2.420	1.723	1.502	.802	.135
8	3.330	3.033	6.240	5.786	6.260	2.825	3.178	2.229	1.740	1.240	.633	.135
9	2.643	2.688	2.464	5.367	5.180	5.900	1.956	2.638	1.258	.990	.570	.135
10	1.456	2.129	2.073	1.506	4.769	4.543	5.476	1.560	1.881	1.006	.271	.135
11	2.021	1.076	1.159	1.243	1.377	4.407	3.799	4.760	.957	1.303	.188	.135
12	.525	.525	.615	.525	.705	.765	.900	1.065	1.185	.900	.800	.135

Table 10. Adjusted Silver hake Effort.[1]

Year	Hours Fished
1966	46449
1967	4105
1968	25711
1969	40096
1970	82485
1971	103816
1972	70083
1973	127950
1974	94501
1975	96217
1976	45251
1977	?

1. D. Clay personal communication.

TABLE 11. PROJECTIONS

YEAR	POPULATION No. x 10^{-3}	POPULATION WEIGHT (MT)	CATCH No. x 10^{-3}	CATCH WEIGHT (MT)	MATURE F
1977	75934	97853	4351	10085	.15
1978	77985	102446	2842	7149	.10
1979	81122	111175	2843	7633	.10
			6359	17003	.236
			6700	17906	.25
1980	83730	119724	2967	8232	.10
	80584	108950	6082	16429	.236
	80280	107913	6352	17109	.25
1981	85620	126295	3114	8747	.10
	80299	106276	6022	15940	.236
	79813	104470	6254	16451	.25

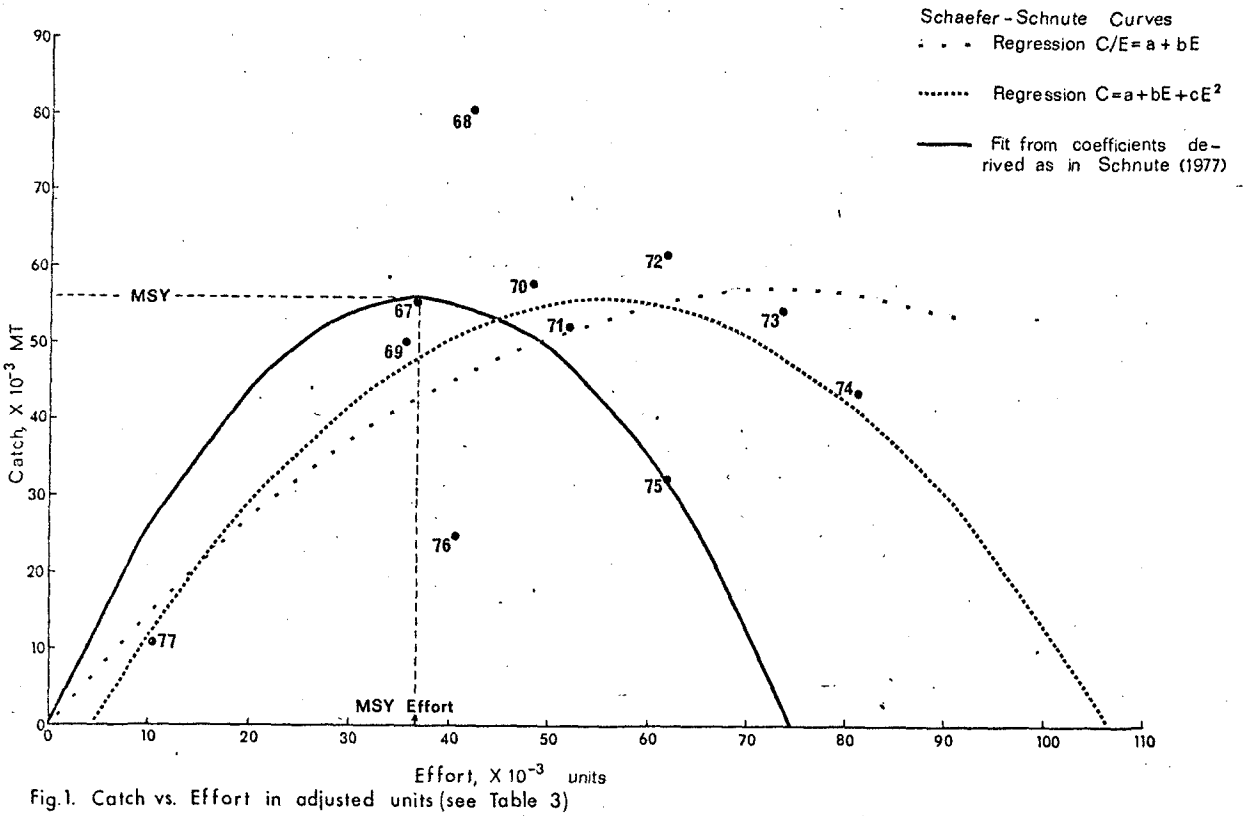


Fig. 1. Catch vs. Effort in adjusted units (see Table 3)

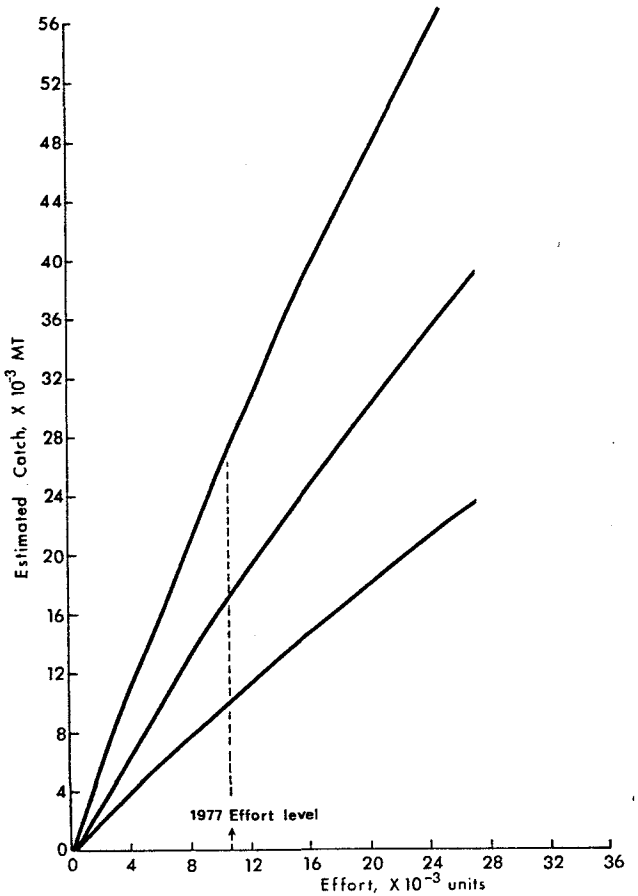


Fig. 2. Predicted Catch as a function of adjusted effort; showing 95% confidence limits, 1978.

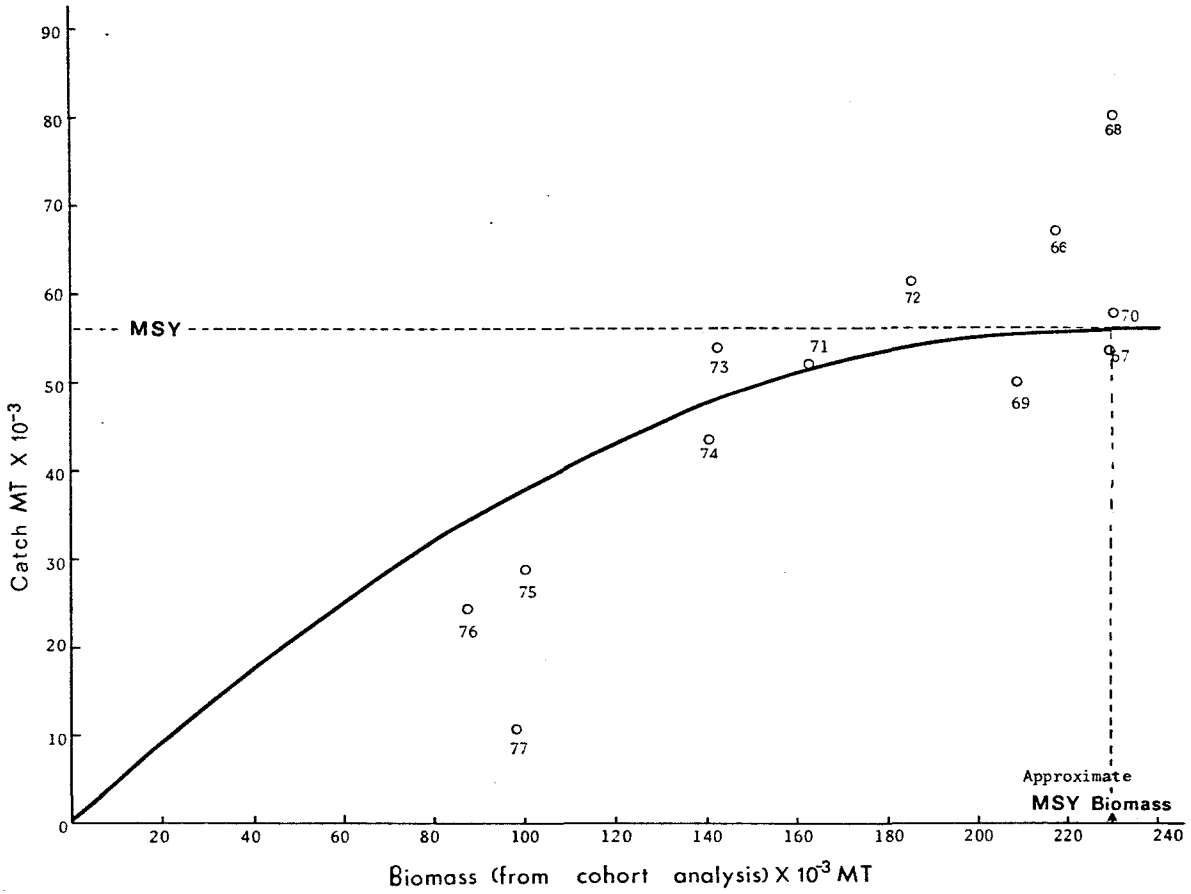


Fig. 3. Yield vs. biomass with estimated equilibrium curve

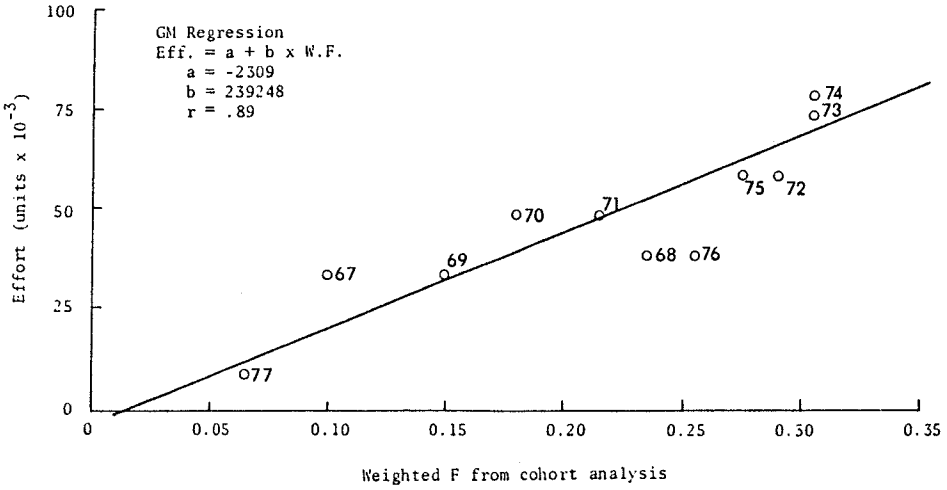


Figure 4. Weighted F vs. Effort.

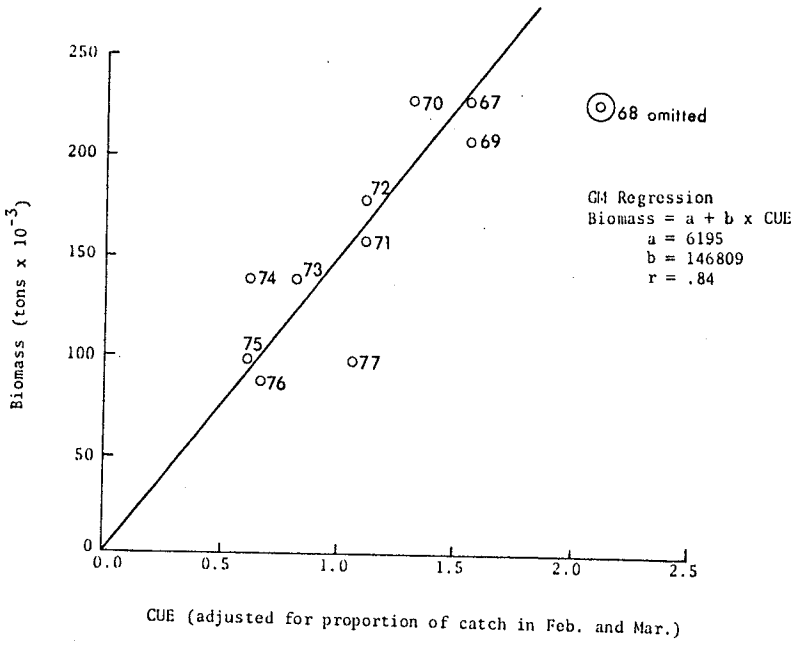
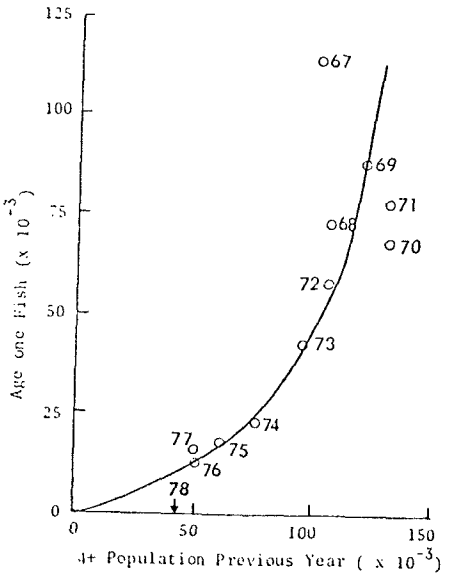


Figure 5. Biomass vs. CUE



Regression of age 1 fish (Z) on 4+ pop. previous year (X) and effort in silver hake fishery (Y).

$$Z = \frac{.00077X^{1.82}}{Y^{.26}}$$

r = .995

X alone explains 84% of the variation

Figure 6. Recruitment.

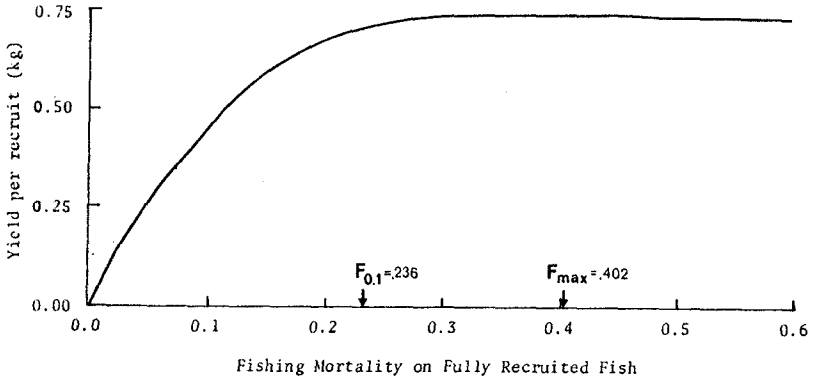


Figure 7. Yield per recruit (kg) vs. fishing mortality.

4VsW Cod Assessment

TABLE 1. AGE DISTRIBUTIONS

Table 1a. Research Surveys

AGE	1970	1971	1972	1973	1974	1975	1976	1977
1	3.8	1.9	8.4	4.8	8.7	9.3	4.2	1.1
2	42.5	9.5	13.1	36.8	47.4	23.1	26.2	13.9
3	13.6	44.3	13.0	31.5	27.7	35.8	30.0	36.1
4	19.9	10.0	45.8	18.0	8.1	17.0	19.0	23.4
5	9.7	19.6	7.5	6.8	2.9	8.1	12.3	15.5
6	3.2	7.2	8.3	.6	3.2	1.9	2.4	6.7
7	3.9	4.3	2.3	.9	.5	2.4	1.2	1.5
8	1.2	1.8	.7	.3	.8	.6	2.4	1.2
9	.3	.8	.7	.1	.3	1.2	-	.3
10+	1.8	.6	.2	.3	.5	.6	2.2	.3

Table 1b. Catch

AGE	1970	1971	1972	1973	1974	1975	1976	1977
1	1.1	1.8	1.7	1.2	1.6	2.8	2.1	-
2	7.8	12.5	15.4	10.6	9.6	15.7	11.5	1.5
3	12.4	13.7	15.0	24.7	25.0	18.1	10.8	6.9
4	31.6	16.7	22.8	15.1	26.7	14.5	19.9	20.2
5	30.0	17.5	17.3	21.0	20.4	18.5	27.8	34.5
6	10.1	21.2	16.3	8.5	7.9	10.6	13.9	18.3
7	4.3	10.7	6.4	6.6	2.7	11.0	8.3	9.1
8	1.7	3.8	3.6	8.3	3.8	2.5	3.5	3.5
9	.5	1.0	.7	2.6	1.2	2.1	1.1	2.2
10+	.7	1.0	1.0	1.4	1.1	4.2	1.1	3.6

Table 1c. VPA Numbers

AGE	1970	1971	1972	1973	1974	1975	1976	1977
1	.223	.262	.222	.218	.231	.193	.151	.209
2	.226	.193	.245	.221	.217	.237	.198	.143
3	.144	.187	.162	.213	.197	.203	.218	.171
4	.168	.109	.154	.129	.155	.147	.177	.192
5	.145	.104	.075	.103	.094	.099	.126	.137
6	.061	.086	.069	.036	.053	.050	.067	.072
7	.020	.040	.046	.032	.016	.037	.031	.040
8	.009	.012	.020	.032	.016	.010	.017	.015
9	.002	.005	.005	.012	.012	.008	.006	.010
10	.001	.001	.003	.003	.005	.010	.004	.003
11	.001	-	-	.002	.002	.003	.005	.003
12	-	-	-	-	-	.002	.002	.004

POPULATI[ ]NUMBERS

	1966	1967	1968	1969	1970	71	1972	1973	1974	1975	1976	1977
1	151725	112994	74412	88883	71336	57	57622	45741	39404	25823	15710	18389
2	105106	123267	92326	60075	72286	65	63613	46366	36968	31757	20532	12541
3	73499	79968	99061	70052	46090	27	42006	44607	33651	27282	22607	15020
4	50814	50884	61076	71161	53726	07	39868	27067	26467	19757	18427	16826
5	25062	30148	34663	34970	46449	42	19480	21562	16015	13330	13046	11994
6	9446	11345	16205	14585	19559	39	17852	7544	9111	6756	6913	6361
7	7453	3697	5363	5760	6447	07	11870	6671	2722	5000	3237	3496
8	3709	3156	1700	1240	2776	21	5079	6613	2766	1374	1716	1360
9	2353	1598	1463	582	554	86	1210	2422	2051	1071	576	654
10	1735	1152	707	459	262	40	850	666	930	1305	427	305
11	949	972	358	252	331	49	93	340	299	428	472	305
12	64	174	502	155	121	47	4	5	8	231	212	366
	431914	419354	387835	348175	319935	86	259546	209604	170391	134113	103874	87817

FISHI[ ]G MORTALITY

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	.008	.002	.014	.007	.008	.012	.017	.013	.016	.029	.025	.000
2	.073	.019	.076	.065	.055	.122	.155	.121	.104	.140	.113	.006
3	.168	.069	.131	.065	.143	.140	.239	.322	.333	.192	.095	.022
4	.322	.184	.358	.227	.345	.318	.415	.325	.486	.215	.229	.060
5	.593	.421	.666	.381	.388	.356	.749	.661	.663	.457	.318	.150
6	.738	.549	.834	.616	.296	.578	.784	.819	.400	.536	.482	.150
7	.659	.577	1.264	.538	.405	.652	.385	.680	.483	.869	.667	.135
8	.642	.569	.872	.606	.368	.868	.540	.971	.749	.670	.498	.135
9	.514	.615	.959	.598	.638	.424	.396	.757	.252	.720	.435	.135
10	.380	.970	.830	.128	.362	.744	.716	.603	.577	.818	.136	.135
11	1.496	.461	.634	.538	.618	3.507	2.734	3.575	.057	.503	.053	.135
12	.525	.525	.615	.525	.705	.765	.900	1.065	1.185	.900	.800	.135
	.162	.102	.233	.149	.180	.216	.288	.306	.277	.238	.219	.058

TABLE 2. New VPA, Partial Recruitment .0004, .04, .15, .4, 1, 1, .9, .9 .....

Table 3. Weighted F an Fishable Biomass

YEAR	WEIGH ED F[1]	FISHABLE BIOMASS (MT)[2]
1966	.391	153,036
67	.330	156,731
68	.490	159,238
69	.315	146,273
1970	.307	179,509
71	.394	130,867
72	.468	135,011
73	.523	103,754
74	.441	97,882
1975	.389	74,486
76	.364	68,631
77	.118	78,986

[1] weight F weighted using ca ch.

[2] fishable biomass vs partial recruitment of
.0004, .04, .15, .4, 1, 1, 9, .9, ... in 1977
.02, .14, .25, .5, 1, 1, ...before

Table 4. Projections.

A. Constant Recruitment (20,000)
quota in 1978
2/3 F_{MSY} after

Year	Pop N	Pop Wt	Catch N	Catch Wt	Mature F
1977	87817	111242.12	4351	10084.50	.1500
1978	87714	119527.84	2780	7000.16	.0871
1979	89141	131190.14	7528	20980.70	.2500
1980	86098	126188.69	6555	19469.94	.2500
1981	84392	121086.29	6147	18367.70	.2500
1982	83354	116768.38	5979	17630.30	.2500
1983	82515	111895.45	5832	16755.26	.2500
1984	81901	107595.21	5720	15967.02	.2500
1985	81410	103574.03	5630	15229.94	.2500
1986	81099	100744.94	5573	14711.38	.2500

B. Recruitment: 20,000 in 1978, 1979, 1980
25,000 after
quota in 1974
2/3 F_{MSY} after

Year	Pop N	Pop Wt	Catch N	Catch Wt	Mature F
1977	87817	111242.12	4351	10084.50	.1500
1978	87714	119527.84	2780	7000.16	.0871
1979	89141	131190.14	7528	20980.70	.2500
1980	86098	126188.69	6555	19469.94	.2500
1981	89392	121675.98	6147	18367.75	.2500
1982	92447	118829.53	6017	17643.63	.2500
1983	94926	116459.83	5980	16852.14	.2500
1984	96929	115550.29	6094	16356.84	.2500
1985	98376	115337.70	6394	16386.50	.2500
1986	99301	115891.36	6586	16548.94	.2500

C. Constant Recruitment (20,000)
Constant quota of 7,000 mt

Year	Pop N	Pop Wt	Catch N	Catch Wt	Mature F
1977	87817	111242.12	4351	10084.50	.1500
1978	87714	119527.84	2780	7000.16	.0871
1979	89141	131190.14	2499	7000.12	.0775
1980	90601	142239.63	2285	7000.09	.0724
1981	91845	151045.42	2183	7000.07	.0679
1982	92893	158553.82	2120	7000.06	.0639
1983	93482	162425.93	2091	7000.06	.0620
1984	93733	163643.72	2086	7000.06	.0615
1985	93533	161044.47	2114	7000.06	.0626
1986	93106	156576.83	2162	7000.06	.0647

D. Recruitment: 20,000 in 1978, 1979, 1980
25,000 after
Constant quota of 7,000 mt

Year	Pop N	Pop Wt	Catch N	Catch Wt	Mature F
1977	87817	111242.12	4351	10084.50	.1500
1978	87714	119527.84	2780	7000.16	.0871
1979	89141	131190.14	2499	7000.12	.0775
1980	90601	142239.63	2285	7000.09	.0724
1981	96845	151635.11	2183	7000.07	.0679
1982	101987	160615.09	2128	7000.06	.0638
1983	105919	167012.99	2121	7000.06	.0618
1984	108888	171770.55	2151	7000.05	.0605
1985	110881	173529.72	2224	7000.05	.0596
1986	112204	173948.27	2281	7000.05	.0592

Fig. 1. Yield-per-recruit (kg) vs. fishing mortality.

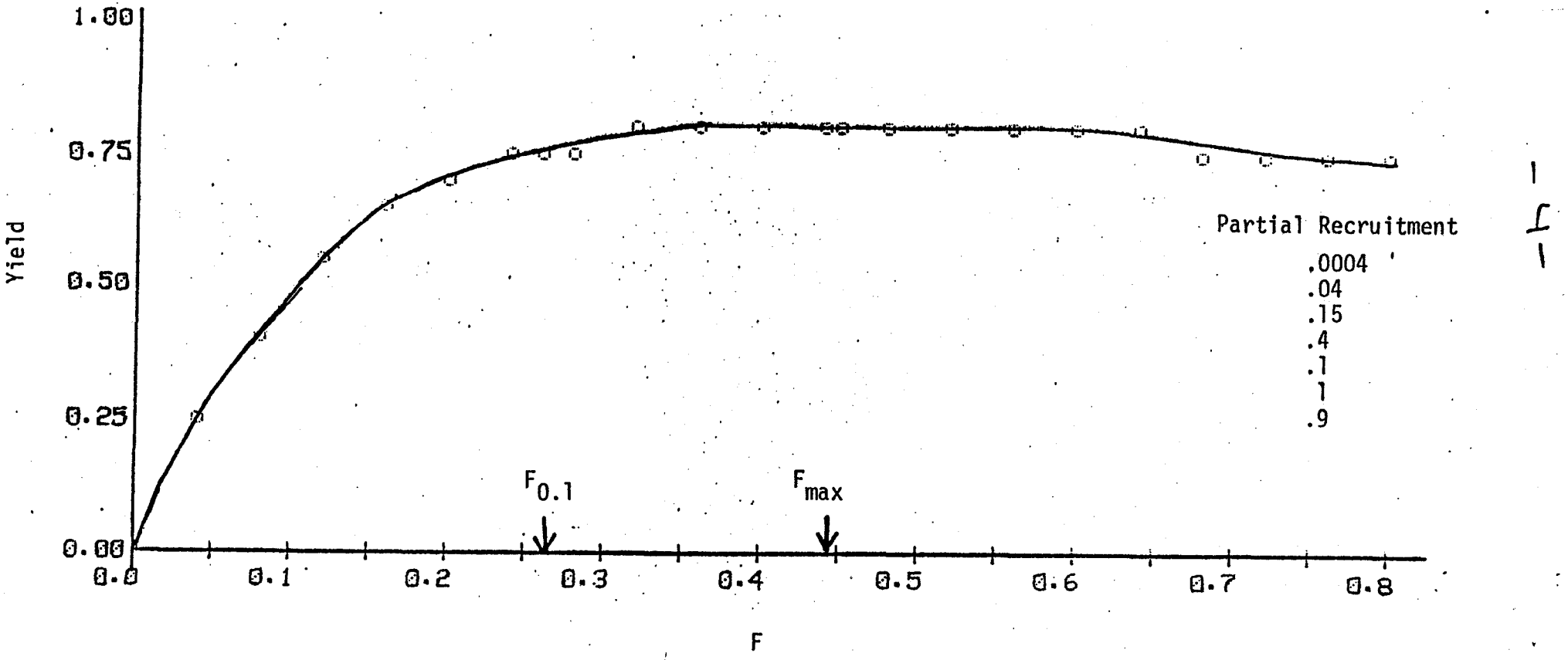


Fig. 2. Weighted F vs. Effort

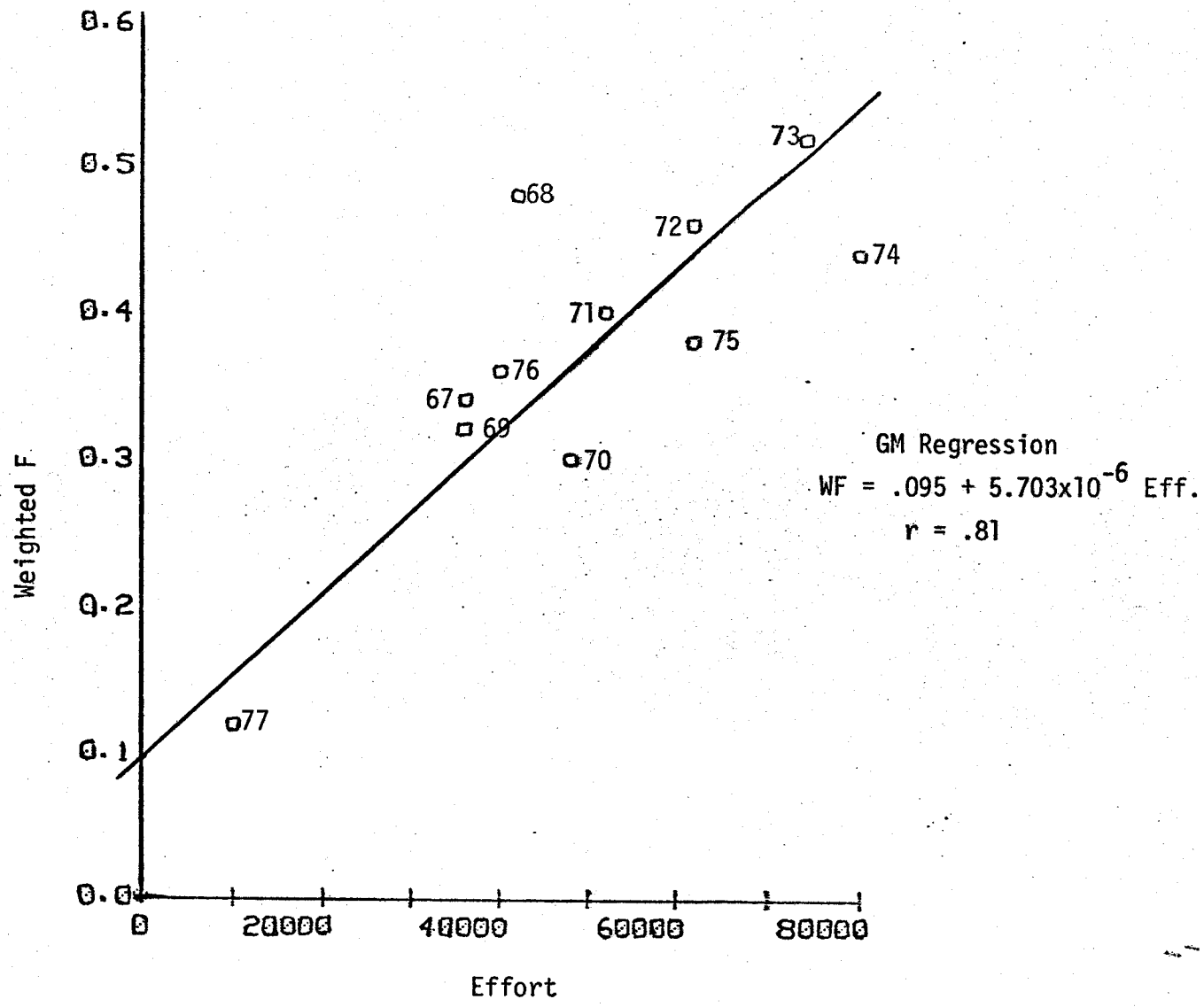


Fig. 3. Fishable biomass vs. CPUE.