CAFSAC RES DOC 78/ 19

ICNAF Div 4X - Haddock
Spring 1978 Status Report

by

Robert N. O'Boyle

Department of Fisheries and Environment
Marine Fish Division
Bedford Institute of Oceanography
Dartmouth, N.S.

Introduction

The history of annual haddock catches is illustrated in Figure 1. From the earliest years to about 1960, catches have fluctuated between 10-20000 mt with about an equal split between Canada and the U.S.A. During this period the major part of Canada's catch was landed by longliners while the U.S. landings are almost wholely from otter trawlers. In the 1960's, Canadian otter trawl particpation increased dramatically while U.S. catches markedly declined. Between 1963-68, the U.S.S.R. became involved and reported catches of over 10000 mt in 1966. Total catches during this period reached levels as high as 37000 mt (1966). The high exploitation produced dramatic declines in the catch rates and resulted in setting of quotas and closure of the spawning season (March-April) in 1970 and all subsequent years.

A breakdown of catches by country, year and area is given in Table I. Catches from statistical 4x5 are believed to be from the Div. 5Y stock (Halliday and McCracken, 1970; McCracken, 1956, 1960) and are not used in the assessment. In 1975, 1976 and 1977, a quota of 15000 mt was set. In all years, particularly the last, the quota was overrun by a considerable margin. Reported catches in 1977 were 21304 mt with almost all of the overrun taken by Canada (quota of 13,4000 mt). Since the by-catch regulation was imposed in 1975, unreported discarding has become a serious problem in this fishery. Estimates of 2000 mt in both 1975 and 1976 and 400 mt in 1977 have been made (Art Longard, pers. comm.), and initial estimates show that discarding in 1978 could top 2000 mt. These estimates are probably on the low side. However, even with these, catches in 1975-77 have fluctuated around 20000 mt.

Fisheries System and Data Processing Group Contribution No. 28

Catch Composition

Composition of landings has been analysed for the period 1962-1977 inclusive. No commercial samples are available from the USSR and Spanish landings. Thus, their landings are adjusted on the basis of Canadian and USA samples. It has been observed (Hennemuth et al., 1964) that Div. 4X-R haddock landings have a substantially different size and age composition from those of Div. 4X-MNOPQ. Consequently, the age composition is weighted separately for these areas. Otter trawl and line landings are also weighted separately when samples are available. Small Canadian Danish seine and shrimp trawl landings are combined with Canadian Otter trawl landings, and gillnet with line landings, as landings of there minor years have not been sampled. The USA commercial sampling data has only recently been provided. Therefore, for the purposes of this report, USA landing compositions for 1962-64 were taken from Schultz and Halliday (MS 1969) while from 1965, USA landings were prorated on Canadian sampling data. This should not introduce major errors as Canadian and USA landings have been similar in composition (Hennemuth et al., 1964) and since 1965, USA landings have been small in proportion to those of Canada.

Removals at age are given In Table II. The 1963 year-class dominated the fishery during 1966-71, forming over 50% of the landings by weight. Even in 1973, the 1963 year-class contributed significantly to the fishery. At the present, the 1971, 1972, and 1974 year-classes are providing major support to the fishery.

As stated in the introduction, a serious discard problem has occurred in recent years. There is virtually no sampling information available for these discards. However, Louis Belzile at BIO has provided length-frequency distributions for samples from regular and discarded catches. These show no difference in catch composition. This may be due to such a large quota overrun. Assuming the same catch at age composition as in the 1975, 76 and 77 landings, the discard estimates of 2000, 2000 and 400 mt for these years were split out by age (Table III) and added to the original catch matrix. This table was used for all subsequent analysis.

Commercial Catch Rates

To provide an index of changes in stock abundance, a complete analysis of the reported Canadian catch statistics during 1962-1977 was undertaken. Catches by gear type are given in Table IV.

As stated earlier, otter trawlers have provided the largest catches and thus largest samples of the population. Table V provides a breakdown of otter trawl catches by tonnage class. In the early years, the 0-50 Ton class has been prominent but has declined since 1970. Much of the increased landings in the 1960's are due to the 151-500 and to a lesser extent the 500-900 Ton class. Consequently, the 151-500 Ton otter trawler class was taken as the index gear.

Catches for this class were plotted (Figure 2) by month to decide what time of the year would provide the most stable catchability. Examination of these graphs led to the choice of the July-October period.

Chikuni (1976) has provided a method for compensating for variation in effort due to catchability changes in mixed fisheries. The catch of the desired species per unit of total reported effort for the month is plotted as a function of the percent that the desired species is of the total monthly landings. This provides linear regressions from which one percentage catch can be defined and thus the corresponding catch per unit effort calculated. Multiple R-squares in the present analysis generally exceeded 85%. The catch per unit efforts at the 50% point are given in Table VI.

Commercial catch rates for the U.S. otter trawlers (151-500 Tons) are given for 1963-1977 in Table VI along with research survey estimates for Canada (spring Table VII, and summer Table VIII) and U.S.A. (Fall). All these estimates are plotted as a function of time in Figure 3.

Both the Canadian research survey indices show an increase in abundance since about 1973. What is especially striking is the marked variability in the Canadian summer cruise index. In previous years it has always been difficult to use this data in haddock assessments. It appears that there may be large availability effects in the summer cruise but not the spring cruise. The U.S. fall survey index shows that the population has remained at virtually the same level since 1969. This agrees with neither of the other two research indices nor the two commercial indices, which show steady population increases since 1973. In previous years, the U.S. fall cruise has been used as the main index of abundance. Perhaps this is why previous assessments have been relatively conservative in predicting population biomasses.

Of all the indices, the Canadian commercial rate for 151-500 ton otter trawls provides the best estimate of abundance trends in the fishery and was thus used to calculate effort.

Mortality Rates

Using the catch at age matrix and the derived commercial effort, total mortalities were calculated for the 1963-77 period. Although a general pattern was evident the correlation of Z with E was too weak to be statistically significant. A running average of age 5-11 over the 74-77 period produced a Z of 0.50.

Running averages from the Canadian summer cruises for the 65-69 year-classes in the 1972-77 period produced a mean Z value of 0.571. A summary of the individual Z values for this cruise is provided in Table IX. As can be seen, an availability change between 1976-77 has produced all negative total mortalities for this period.

As the data were too variable to calculate natural mortality, an M of 0.2 was taken for all subsequent analysis.

Partial Recruitment

Prior to 1973, the minimum allowed mesh size was 114 mm (4 1/2" - manila wet). Since that period, the minimum has been 130 mm (5 1/8" - manila wet). Clark et al. (1974) provide selectivity ogives for various mesh sizes in this fishery (Table X). Fishing mortalities for the 1962-72 period were averaged from the fall 1977 4X haddock assessment and the partial recruitment pattern for this period calculated. From Table X and mean lengths at age for this period, the selection due to 4 1/2" otter trawl fishery was calculated and extracted from the 1962-72 recruitment. The new 5 1/8" mesh selection was then multiplied by the remainder to give the partial recruitment pattern for the 1973-77 period. This calculation assumes that only the selection due to the otter trawl fishery has changed over the 1962-77 period. Although it may be wrong, it is a good starting point for the cohort analysis.

The final recruitment pattern is given in Figure 4. Haddock first enter the fishery at age 1-2, are 50% recruited by age 4 and fully recruited by age 6. The drop in recruitment at higher age may be due to the longliner involvement in the fishery.

Cohort Analysis

The catch at age used was the summation of Tables II and III. Terminal completed Fs were obtained from last fall's assessment while incomplete Fs were taken as 0.3 times the partial recruitment pattern. Natural mortality was taken as 0.2.

After 2-3 iterations, the relationship between the fishable biomass and the Canadian commercial catch per unit effort (adjusted to beginning of year) became fairly linear, having on R^2 of 0.81 and an intercept not significantly different from 0 (Figure 5). However the top right hand side of the table remained unadjusted. To verify this part of the table, numbers for ages 1 + 2 of the 1969-1975 year-classes were plotted against the comparable estimates from the Canadian summer cruise. Adjustments to the selectivity and mature F produced an R^2 of 0.89 for this relationship (Figure 6). For projection purposes this is the most important part of the table.

The cohort results are summarized in Table XI. They reflect the changes in the fishery as described by the abundance indices gives in Figure 3. Population numbers were highest in 1964 following recruitment of the 1963 year-class. Numbers steadily declined to reach a minimum of 82532 x 10^3 in 1971 after which the population underwent a dramatic increase in numbers. The 1977 population level is similar to that found in 1966-67.

As in previous assessments, the 1970 year-class is shown to be the second lowest in the recorded history of the stock. The 1971 and 72 year-classes are both very strong, followed closely by 1973-74. However the biggest year-class in recent years is that of 1975. It is only slightly lower than the 1962 year-class. In general, recruitment in recent years is very strong and points towards high yields in the near future.

The fishing mortalities (weighted on fishable population) are low in 1962-63, increase to a maximum of .39 in 1969 and drop to a minimum of 0.155 in 1975. Recently it has increased to just over 0.20.

Yield Projections

To see how catch levels have fluctuated in relation to some presently undefined equilibrium state, catch was plotted as a function of the fishing mortality, weighted on the fishable population, (Figure 7). There is a very clear pattern of initial overexploitation followed by underexploitation. Presently, the stock appears to be approaching as MSY of 23-25000 mt. Certainly the recent high production rates in the stock indicate that this may be the case.

A yield per recruit model using 1977 weights at age (Table XII), partial recruitment as in Figure 4 and an M of 0.2 produced a fully recruited $F_{0.1}$ of 0.45 (Figure 8). This is considerably in excess of the 1977 F of 0.30. The yield per recruit relationship is particularly sensitive to density dependent growth. Although it has to be investigated further, there does appear to be density dependent growth in this stock (Figure 9). Thus the yield per recruit model can only provide us with an index of how efficiently the stock is being fished under the present recruitment and growth condition. Thus it can be stated that the stock is at present being dramatically underexploited.

Catch projections were run at various F and quota levels to determine immediate sustainable yields from the stock. Recruitment estimates were sampled off a log normal distribution for the 1973-77 period while all other initial conditions were as given in the final year of the cohort analysis. A complete summary of the runs is given in Table XIII.

Under present catch levels, the fishable biomass will increase to 147000 mt by 1980. An increase to 25000 mt will cause only a slight decrease in the rate of stock increase. Raising the quota to 30000 mt will result in plateauing of the fishable biomass at 130000 mt. The stock will experience F values of 0.4 at these higher levels. However, historically, the stock has not been able to sustain such high exploitation rates and it is most probable that the stock would undergo serious declines at a quota of 30000 mt.

Keeping the fishing mortality at its present level of 0.3 would result in a gradual increase in mature numbers as well as higher catches. By 1980, the catch should approach 28000 mt. At higher fishing mortalities, the fishable biomass undergoes declines, which is in agreement with the quota results.

It appears evident that setting the TAC at 25000 mt would not result in overexploitation of the stock while allowing it to increase to perhaps an equilibrium state.

Summary

Available research and commercial data indicates that the 4X haddock stock is undergoing dramatic increases in abundance. Present catch levels are around 20000 mt annually. The MSY appears to lie between 22-25000 mt. Maintaining an F of 0.3 will result in a slow increase in stock size until equilibrium is reached while permitting increased catch rates. A TAC of 25000 mt for 1979 would not result in overexploitation and should produce a fishing mortality of just under 0.3, the desired level.

REFERENCES:

1) McCracken, F., (1956). Cod and Haddock tagging off Lockeport, N.S. Fish. Res. Bd. Canada, Atlantic Prog. Rept. 64: 10-15.

2) McCracken, F., (1960). Studies of Haddock in the Passamaquoddy region. J. Fish Res. Bd. Can. 17: 175-180.

3) Chikuni, S., (1976). Problems in monitoring abundance in the multi-species and multi-gear groundfish fisheries in the Bering Sea. FAO Tech. Paper No. 155: 23-36.

4) Clark, McCracken & Templeman, (1958). Cited in ICNAF, Annual Proceedings supl. (1961), Vol. II, Serial No. 932.

5) Halliday, R. & F. McCracken, (1970). Movement of Haddock tagged off Digby, Nova Scotia. ICNAF Res. Bull. 7: 8-14.

6) Hennemuth, R.C., M.D. Grosslein & F.D. McCracken, (1964). Abundance, age composition of landings and total mortality of haddock caught of southern Nova Scotia, 1956-1961. ICNAF Res. Bull. 1: 43-73.

7) O'Boyle, R.N., (1977). ICNAF Div. 4X haddock, Fall 1977 status report. CAFSAC Working Paper 77/40.

8) Schultz, R.L. & R.G. Halliday, MS (1969). Abundance, age composition and survival of haddock from Southern Nova Scotian grounds 1962-68. ICNAF Res. Doc 69/86, Serial No. 2252.

Table I. ICNAF Div. 4X Haddock nominal catches (metric tons round) by Statistical areas.

YEAR	AREA	Canada	USA	USSR	SPAIN	OTHERS	TOTAL	
1962	4X-MNOPQR	10118	5761	-	-	-	15879	
	4X-S	1419	627	-	-	-	2046	
1963	4X-MNOPQR	14385	6397	400	-	28	21210	
	4X-S	2378	826	-	-	-	3204	
1964	4X-MNOPQR	24468	7577	1108	-	40	33193	
	4X-S	1875	911	-	-	-	2786	
1965	4X-MNOPQR	20562	2450	2582	-	-	25594	
	4X-S	2178	1235	-	-	-	3413	
1966	4X-MNOPQR	25492	1392	10065	143	-	37092	
	4X-S	4051	1081	-	-	-	5132	
1967	4X-MNOPQR	29098	2941	199	78	-	32316	
	4X-S	2914	2073	-	-	-	4987	
1968	4X-MNOPQR	27277	2857	335	116	36	30621	
	4X-S	1560	299	-	-	-	1859	
1969	4X-MNOPQR	27419	1647	-	473	19	29558	
	4X-S	655	183	-	-	-	838	
1970	4X-MNOPQR	15561	1634	2	370	12	17579	
	4X-S	451	109	-	-	-	560	
1971	4X-MNOPQR	16064	654	97	347	1	17163	
	4X-S	340	97	-	-	-	437	
1972	4X-MNOPQR	12394	409	10	470	1	13284	
	4X-S	176	39	-	-	-	215	
1973	4X-MNOPQR	12580	248	13	108	3	12952	
	4X-S	100	24	-	-	-	124	
1974	4X-MNOPQR	12434	668	35	-	97	13234	
	4X-S	-	-	-	-	-	-	
1975	4X-MNOPQR	16509	2143	39	-	9	18250	(20250)*
	4X-S	-	-	-	-	-	-	
1976	4X-MNOPQR	16338	986	-	-	100	17424	(19424)*
	4X-S	-	-	-	-	-	-	
1977	4X-MNOPQR	19659	1637	2	-	5	21304	(21704)*
	4X-S	53	13	-	-	-	66	

* includes unreported discards

Table II. Removals at age (x 10^{-3}) from 4X-MNO-PQR

Age	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	-	-	-	-	-	-	-	-	-	-	41	150	1	37	18	2
2	139	713	155	70	219	22	665	10	1055	788	22	3077	694	2175	1296	639
3	4524	2013	1272	3038	18341	515	297	2016	724	1617	3434	113	4653	4568	1644	2383
4	1415	7185	4286	1981	9796	20380	1164	1968	1502	788	1841	2247	309	5164	4261	2020
5	1778	3087	9337	3153	3167	9148	17448	1621	379	1422	509	1067	1779	485	3682	2997
6	1708	1649	3018	5409	2149	1039	4684	11243	524	404	645	527	509	1103	434	3237
7	1648	1415	1492	1973	3747	735	713	3220	4536	69	90	600	189	247	807	440
8	973	593	1370	1000	840	1052	518	455	1863	3316	57	322	269	172	154	481
9	645	478	612	745	409	187	672	249	133	1020	1166	259	186	62	71	92
10	232	152	416	288	424	102	190	194	96	163	512	614	269	32	95	148
11	205	113	297	203	88	90	131	172	175	181	26	55	552	165	39	22
12	64	59	168	114	62	23	65	94	27	146	193	13	24	229	103	4
13+	100	43	36	113	84	81	89	69	37	105	92	6	4	11	157	92
TOTAL	13431	17500	22455	18087	39327	33373	26635	21311	11050	10017	8628	9050	9438	14450	12761	12557
Landings (mt)	15879	21210	33193	25594	37092	32316	30621	29558	17579	17163	13284	12952	13234	18250	17424	21304

Table III. Estimated unreported discard at age since imposure of by-catch regulation (X 10^{-3}).

	1975	1976	1977
1	7	4	0
2	381	246	35
3	799	311	129
4	903	806	109
5	85	697	162
6	193	83	175
7	44	153	24
8	31	30	26
9	11	14	5
10	6	18	8
11	29	8	1
12	41	20	0
13+	2	30	5
TOTAL	2532	2420	679
Discard WT(mt)	2000	2000	400

TABLE IV

Catch of Haddock in Metric Tons
By Fishing Gear for Canadian (Maritimes and Quebec)
4x Fishery 1962 - 1977

YEAR	OTTER TRAWL SIDE AND STERN	LONGLINE	DANISH SEINE	GILLNET	OTHERS
1962	7813	3724	-	-	-
1963	12063	4700	-	-	-
1964	20532	5811	-	-	-
1965	18048	4692	-	-	-
1966	25800	3743	-	-	-
1967	28696	3108	208	-	-
1968	25515	2997	99	226	-
1969	24333	3302	195	242	2
1970	11750	3907	211	86	58
1971	12152	3940	198	72	42
1972	7586	4841	55	58	30
1973	6097	6402	38	143	-
1974	6033	6464	-	166	87
1975	10488	5223	-	176	93
1976	10843	5347	-	389	86
1977	13101	1802	4	13	143

TABLE V

Catch of Haddock in Metric Tons
By Vessel Size for Canadian (Maritime & Quebec 4x)
Side and Stern Otter Trawlers 1962 - 1977

Year	Vessel Size (Tons)				Other
	0 - 50	51 - 150	151 - 500	500 - 900	
1962	5224	1973	403	-	184
1963	5926	3230	3053	-	44
1964	3118	3964	11128	-	
1965	4605	4182	9284	-	
1966	8872	9094	7141	186	
1967	7479	7983	10422	2149	
1968	4753	6938	10620	3272	
1969	2619	4144	9646	7779	
1970	2050	3165	3622	2832	
1971	1715	2714	4741	2950	
1972	1182	1662	2758	1944	
1973	916	967	2569	1666	
1974	2533	1898	1146	556	
1975	2742	3427	2426	1893	
1976	2080	2619	3044	3100	
1977	2218	3356	3626	3901	

Table VI . Catch per unit effort indices of 4X Haddock stock.

	Research Surveys			Commercial Statistics	
Year	Canadian Surveys Spring Age 2 - 13+ kg/tow	Canadian Surveys Summer Age 2 - 12+ kg/tow	US Surveys Fall Age 2 - 9+ kg/tow	Canada Otter Trawlers 151-500 Tons mt/hr fished	U.S. Otter Trawlers 151-500 Tons mt/day fished
1963			42.060	.340	6.5
1964			18.897	.264	7.5
1965			17.574	.266	6.5
1966			22.070	.251	4.7
1967			21.162	.233	5.4
1968			13.974	.205	4.5
1969			8.235	.246 (.195)[1]	3.4
1970	187.855	20.786	9.002	.180	3.2
1971	151.761	29.070	10.856	.132	2.5
1972	152.705	12.424	9.180	.141	3.3
1973	-	20.082	11.741	.104	2.5
1974	207.983	45.205	11.533	.124	-
1975	243.192	20.735	10.741	.165 (.183)[2]	4.4
1976	355.426	24.072	10.737	.183 (.204)[2]	5.0
1977	319.640	85.571		.240 (.245)[2]	7.4

[1] estimated

[2] adjusted for unreported discards

Table VII. Mean catch per tow at age (number) calculated for Haddock in Canadian spring bottom trawl surveys in 4X.

Year	1970	1971	1972	1974	1975	1976	1977
Age							
1	26.80	-	5.03	2.65	3.47	10.04	7.87
2	16.26	2.00	.50	23.17	8.17	26.31	32.09
3	3.71	.50	54.24	34.06	22.16	17.39	35.54
4	13.13	.50	22.81	2.00	70.44	64.48	26.22
5	6.39	8.01	8.18	22.24	5.27	78.88	48.46
6	16.66	6.02	12.66	15.20	28.01	15.02	46.10
7	68.70	14.31	5.64	3.77	9.20	18.98	5.16
8	6.08	43.46	6.43	5.98	2.83	3.10	5.03
9	1.63	6.70	5.83	4.05	1.64	3.25	3.24
10	.25	1.00	.00	4.59	1.34	.84	1.85
11	.20	.25	.00	13.11	1.98	.41	.24
12	.00	.25	.00	.69	3.66	1.16	.06
13	.00	.00	.00	.00	.00	1.07	.18
14	.00	.00	.00	.00	.00	.15	.23
15	.00	.00	.00	.00	.00	.00	.07
TOTAL	159.00	83.00	121.33	131.49	158.19	241.07	212.32
No. of Sets	5.0	4.0	6.0	8.7	37.0	28.0	34.0

No cruise in 4X in 1973

Table VIII. Stratified mean catch per tow at age (number) calculated for haddock in Canadian summer bottom trawl surveys in Div. 4X-MNOPQR.

Age	1970	1971	1972	1973	1974	1975	1976	1977
0								0.007
1	4.872	0.099	4.404	4.976	9.622	5.518	4.617	5.249
2	3.921	9.263	0.195	19.053	19.726	3.466	5.272	27.747
3	1.148	3.933	2.732	0.479	27.258	4.383	3.394	32.192
4	2.167	1.729	1.160	2.464	0.807	6.013	3.405	9.284
5	0.881	2.489	0.761	1.131	3.635	0.394	6.175	9.432
6	1.982	1.131	0.825	0.423	0.812	1.417	0.467	5.453
7	5.073	1.746	0.543	0.569	0.448	0.510	0.553	0.640
8	0.704	4.424	0.808	0.429	0.517	0.287	0.101	0.854
9	0.293	0.504	1.106	0.287	0.286	0.136	0.026	0.116
10	0.258	0.078	0.037	0.371	0.211	0.0428	0.033	0.093
11	0.069	0.035	0.005	0.018	0.299	0.246	0.008	0.008
12+	0.017	0.053	0.004	0.008	-	0.153	0.284	0.284
NK	-	-	0.066	-	-	-	0.074	0.007
Total	21.385	25.484	12.646	30.207	63.621	22.564	24.411	91.367

Table IX. Total mortality coefficients (Z) for Haddock, computed from stratified mean catch per tow at age (number) in Canadian summer bottom trawl surveys in Div 4 , 1970-77.

Age	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77
			Sex Combined				
1-2	-	-	-	-	-	-	-
2-3	⁻0.643	⁻0.681	⁻1.465	⁻1.377	1.021	0.046	⁻1.793
3-4	⁻0.003	1.221	⁻0.9	⁻0.358	1.504	0.021	⁻1.809
4-5	⁻0.409	1.221	0.103	⁻0.521	1.511	0.252	⁻1.006
5-6	⁻0.138	0.82	0.026	⁻0.389	0.718	⁻0.027	⁻1.019
6-7	⁻0.25	1.105	0.588	0.331	0.942	⁻0.17	0.124
7-8	0.127	0.735	0.372	⁻0.056	0.464	0.941	⁻0.315
8-9	0.137	0.771	0.235	0.095	0.445	1.616	⁻0.434
9-10	0.333	1.387	1.036	0.405	1.338	2.392	⁻0.138
10-11	1.321	2.612	1.093	0.305	1.9	1.398	⁻1.267
11-12	2.011	2.713	0.727	0.216	⁻0.151	1.677	1.445

TABLE X. Selection ogives used in the assessments for haddock

Length 2 cm groups	Haddock: percentage retention [a] (mesh size in inches) Subareas 3,4, and 5					
	3"	4"	41/2"	5"	51/2"	6"
10-11	2					
12-13	5					
14-15	10					
16-17	18					
18-19	28	1				
20-21	40	3				
22-23	54	6	1			
24-25	66	10	3			
26-27	77	18	5	.01		
28-29	86	28	11	.02		
30-31	92	41	18	.04	1	
32-33	96	54	28	.08	2	
34-35	98	67	40	.14	3	1
36-37	99	78	54	.22	6	2
38-39	100	87	68	.34	11	3
40-41		93	79	.47	18	6
42-43		96	81	.60	28	11
44-45		98	93	.73	40	18
46-47		99	97	.83	54	28
48-49		100	98	.90	67	41
50-51			99	.95	78	54
52-53			100	.97	87	67
54-55				.98	92	78
56-57				100	96	87
58-59					98	93
60-61					99	96
62-63					100	98
64-65						99
66-67						100
Selection factor	3.1	3.1	3.2	3.2	3.3	3.3
Quartile sel. span	4 cm.					

(a) Prepared from data given by Clark, McCracken and Templeman (1958). The ogives are for the otter trawl, double manila codend.

Table XI . Cohort analysis estimates of population numbers ($X10^{-3}$) and fishing mortality for 4X Haddock stock during 1962-1977.

POPULATION NUMBERS

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1	25262	92996	209382	22257	10330	18321	14496	16706	33077	10775	75014
2	30643	20699	76139	171427	18222	8458	15000	11868	13678	27082	8822
3	70996	24963	16302	62197	140289	14721	6905	11679	9708	10244	21459
4	22782	54033	18616	12196	48174	98264	11587	5384	7738	7293	6924
5	13104	17372	37737	11364	8192	30577	62011	8433	2628	4976	5258
6	10306	9120	11430	22448	6451	3842	16757	34983	5438	1808	2788
7	5854	6892	5975	6627	13485	3337	2205	9481	18468	3978	1115
8	4226	3302	4362	3542	3641	7650	2067	1160	4849	11016	3194
9	2422	2579	2167	2332	1995	2221	5311	1224	538	2284	6019
10	1772	1399	1679	1220	1235	1263	1649	3741	776	320	947
11	612	1241	1008	998	739	628	942	1178	2887	549	115
12	461	315	914	556	634	525	432	653	809	2205	286
	188459	234912	385711	317165	253387	189806	139363	106491	100595	82532	131941

	1973	1974	1975	1976	1977
1	56364	34737	43539	83036	29423
2	61379	46011	28439	35607	67964
3	7203	47469	37043	20971	27757
4	14462	5795	34654	25472	15401
5	4003	9808	4465	22882	16270
6	3844	2312	6420	3140	14772
7	1699	2671	1432	4084	2103
8	831	848	2016	909	2475
9	2564	389	451	1467	578
10	3873	1865	151	303	1124
11	312	2615	1283	89	146
12	71	206	1642	875	30
	156605	154725	161534	198835	178043

FISHING MORTALITY

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.003	.000	.001	.000
2	.005	.039	.002	.000	.013	.003	.050	.001	.089	.033	.003	.057	.017	.105	.049
3	.073	.093	.090	.055	.156	.039	.049	.212	.086	.192	.195	.017	.115	.175	.109
4	.071	.159	.294	.198	.255	.260	.118	.517	.241	.127	.348	.188	.061	.215	.248
5	.162	.219	.319	.366	.557	.401	.372	.239	.174	.380	.113	.349	.224	.152	.238
6	.202	.223	.345	.310	.459	.355	.369	.439	.113	.284	.295	.164	.279	.252	.201
7	.373	.257	.323	.399	.367	.279	.442	.471	.317	.019	.093	.495	.081	.254	.301
8	.294	.221	.426	.374	.294	.165	.324	.568	.553	.404	.020	.559	.432	.118	.253
9	.349	.229	.374	.436	.257	.098	.151	.255	.319	.680	.241	.118	.751	.197	.066
10	.156	.120	.320	.302	.477	.093	.136	.059	.147	.826	.909	.193	.174	.327	.531
11	.463	.106	.394	.255	.141	.173	.167	.176	.069	.453	.288	.216	.266	.183	.879
12	.166	.230	.226	.255	.114	.050	.181	.172	.037	.076	1.309	.226	.137	.199	.168
F_N	.085	.090	.075	.072	.194	.224	.249	.269	.140	.157	.083	.070	.073	.127	.092
F_R	.147	.180	.296	.222	.253	.276	.328	.390	.260	.280	.217	.201	.155	.199	.217

	1977
1	.000
2	.011
3	.105
4	.165
5	.240
6	.292
7	.277
8	.255
9	.204
10	.163
11	.191
12	.158
F_N	.090
F_R	.208

Table XII. Adjusted mean weights (kg) for 4X Haddock stock derived from commercial statistics.

Age	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	-	-	-	-	-	-	-	-	-	-	.56	.27	.18	.23	.23	.27
2	.56	.5	.5	.36	.31	.32	.37	.56	.57	.5	.45	.51	.46	.52	.52	.41
3	.75	.78	.75	.65	.67	.62	.62	.75	.9	.96	.9	.75	.82	.82	.81	.77
4	1.15	1.05	1.0	1.0	.85	.85	.9	.88	1.05	1.25	1.35	1.25	1.1	1.2	1.19	1.18
5	1.4	1.45	1.3	1.2	1.23	1.05	1.1	1.15	1.16	1.4	1.6	1.8	1.7	1.55	1.6	1.67
6	1.6	1.7	1.7	1.56	1.5	1.45	1.3	1.35	1.43	1.5	1.75	2.0	2.3	2.25	2.1	2.29
7	2.2	1.85	1.95	1.95	1.8	1.8	1.7	1.6	1.65	1.75	1.9	2.2	2.5	2.85	2.95	3.00
8	2.12	2.35	2.04	2.2	2.18	2.05	2.05	2.0	1.95	1.95	2.1	2.3	2.6	3.0	3.5	3.19
9	1.9	2.25	2.5	2.3	2.5	2.36	2.3	2.45	2.3	2.3	2.3	2.5	2.8	3.2	3.6	3.53
10	2.4	2.2	2.4	2.63	2.5	2.7	2.52	2.5	2.82	2.65	2.8	2.7	2.95	3.8	3.8	3.58
11	2.86	2.7	2.42	2.5	2.75	2.7	3.0	2.7	2.8	3.25	3.0	3.3	3.2	3.5	4.1	3.49
12	2.7	3.2	3.0	2.7	2.6	2.89	2.9	3.3	2.85	3.0	3.7	3.4	3.8	3.7	4.0	3.34
13+	3.99	3.25	3.61	3.3	3.0	2.8	2.95	3.06	3.6	3.0	3.2	4.2	3.9	4.4	4.2	3.73

Table XIII. Catch projections for 4X haddock stock.

A. Quota Basis

YEAR	POP N	POP WT	SD	MATURE N	MATURE WT	SD	CATCH N	CATCH WT	SD	MATURE F
1) 22000 MT										
1977	178043	157231.42	0	69744	110206.73	0	13139	21816.20	0	.2947
1978	189333	174298.74	7876	78853	124093.23	0	13371	22000.00	0	.2673
1979	199648	185691.24	14607	86811	140549.08	901	12763	22000.00	0	.2495
1980	194652	194052.90	18532	87000	147390.89	6768	12513	22000.00	0	.2253
1981	186837	202905.28	24805	91944	159745.67	19497	12050	22000.00	0	.2069
2) 25000 MT										
1977	178043	157231.42	0	69744	110206.73	0	13139	21816.20	0	.2947
1978	189333	174298.74	7876	78853	124093.23	0	15195	25000.00	0	.3100
1979	197999	182224.13	14607	85223	137146.84	901	14592	25000.00	0	.2979
1980	191666	187168.45	18526	84064	140553.29	6773	14396	25000.00	0	.2755
1981	182698	192600.75	24764	87777	149513.07	19474	13956	25000.00	0	.2584
3) 30000 MT										
1977	178043	157231.42	0	69744	110206.73	0	13139	21816.20	0	.2947
1978	189333	174298.74	7876	78853	124093.23	0	18234	30000.00	0	.3855
1979	195252	176445.61	14607	82575	131476.44	901	17700	30000.00	0	.3908
1980	186634	175665.07	18517	79122	129133.44	6782	17672	30000.00	0	.3794
1981	175632	175300.80	24690	80848	132349.60	19435	17371	30000.00	0	.3741

B. F Basis

YEAR	POP N	POP WT	SD	MATURE N	MATURE WT	SD	CATCH N	CATCH WT	SD	MATURE F
1) 0.3										
1977	178043	157231.42	0	69744	110206.73	0	13139	21816.20	0	.2947
1978	189333	174298.74	7876	78853	124093.23	0	15603	25238.22	1	.3000
1979	197699	182021.89	14607	84962	136985.35	901	15417	26138.96	100	.3000
1980	190750	185680.44	18431	83197	139108.80	6667	16175	27681.03	1403	.3000
1981	180419	187971.19	23448	85598	144981.15	17827	16523	28839.67	3060	.3000
2) 0.4										
1977	178043	157231.42	0	69744	110206.73	0	13139	21816.20	0	.2947
1978	189333	174298.74	7876	78853	124093.23	0	20190	32478.96	1	.4000
1979	193592	173685.14	14606	81024	128830.91	901	18948	31547.38	133	.4000
1980	184267	171134.22	18387	76843	124682.43	6643	19240	31844.42	1833	.4000
1981	172391	168557.88	22972	77745	125740.95	17273	19275	32027.81	3880	.4000
3) 0.45										
1977	178043	157231.42	0	69744	110206.73	0	13139	21816.20	0	.2947
1978	189333	174298.74	7876	78853	124093.23	0	22381	35905.56	1	.4500
1979	191633	169741.78	14606	79149	124976.68	901	20482	33790.40	149	.4500
1980	181313	164590.77	18365	73953	118197.96	6631	20486	33338.13	2041	.4500
1981	168870	160207.17	22744	74310	117475.08	17005	20361	33005.80	4258	.4500

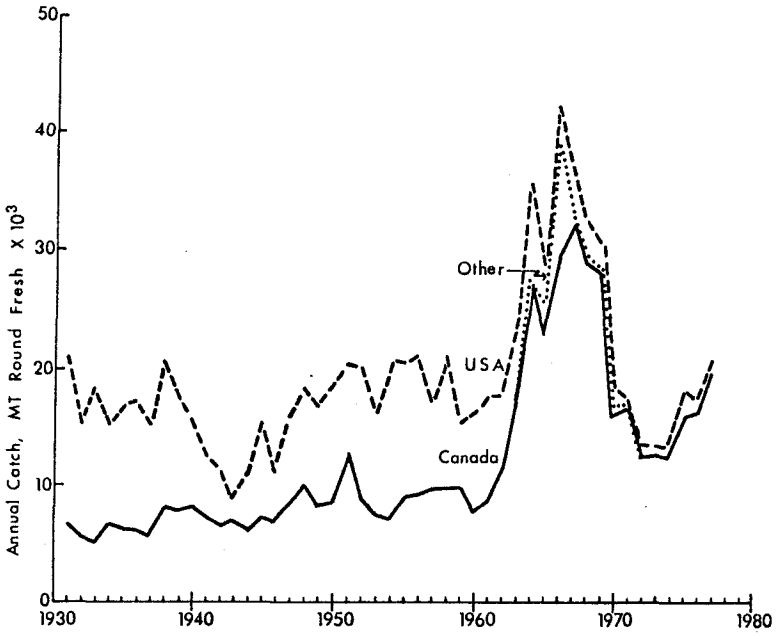
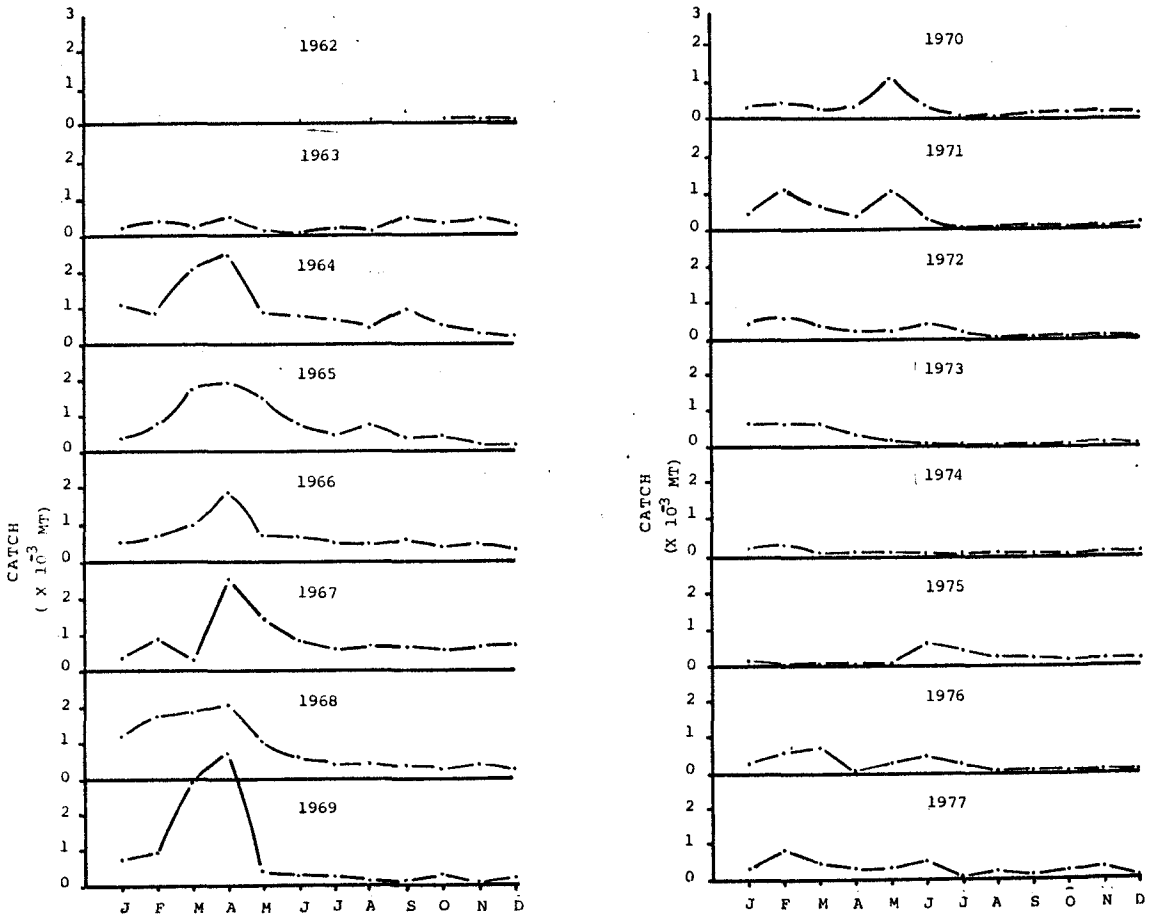


Fig. 1. Total Annual Catch, 1931-77

Figure 2. 4X HADDOCK NOMINAL CATCHES FOR STERN AND SIDE OTTER TRAWLERS COMBINED (150-500 MT)



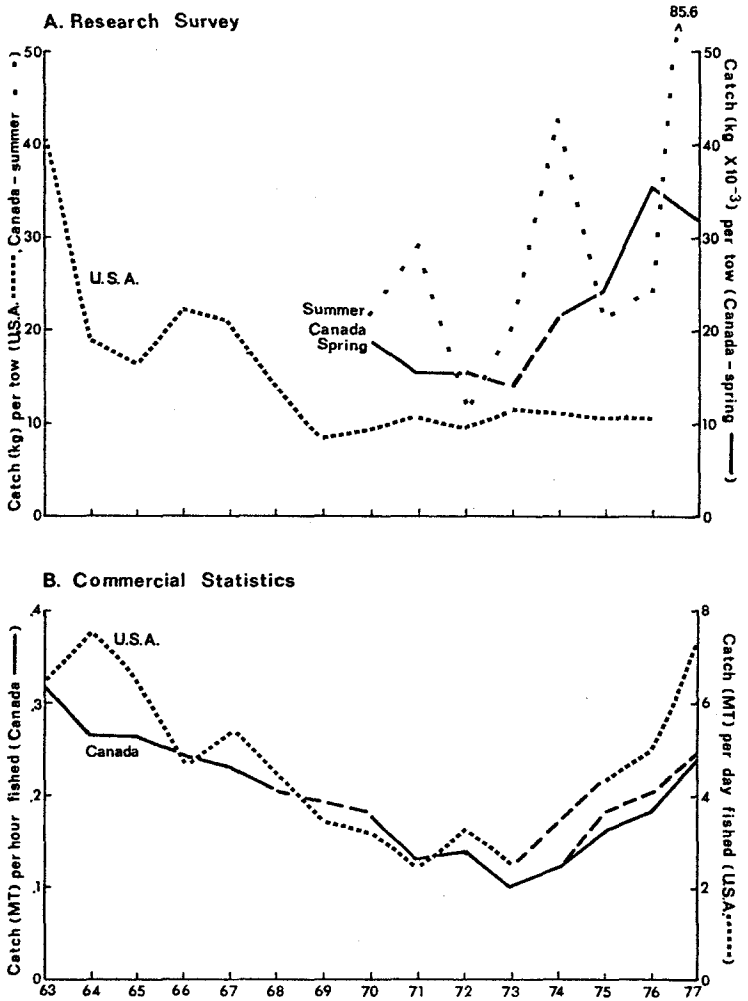


Fig. 3 Catch per unit effort indices for 4X Haddock Stock

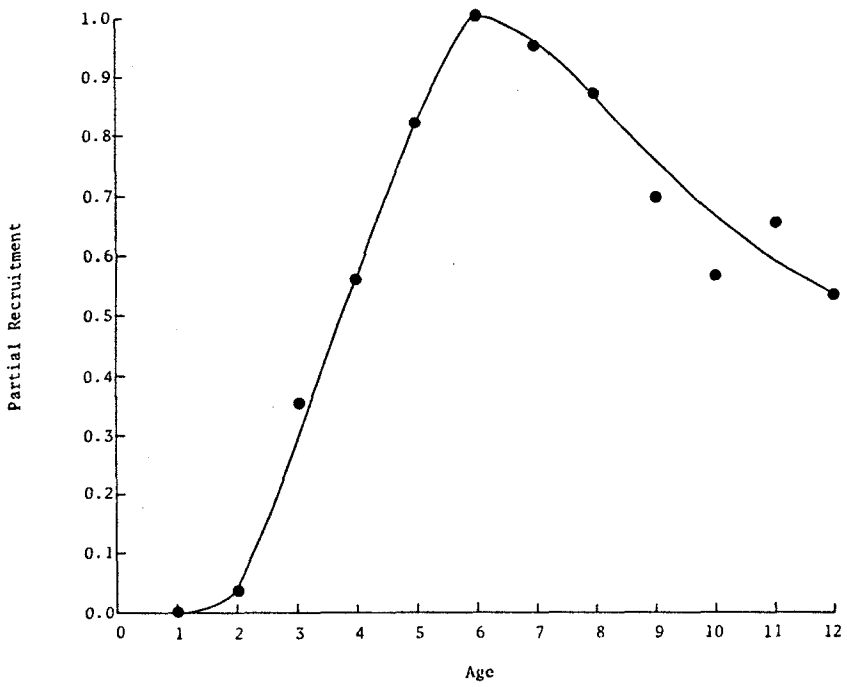


Figure 4 . Partial recruitment pattern as used in cohort analysis, yield per recruit relationship and catch projections.

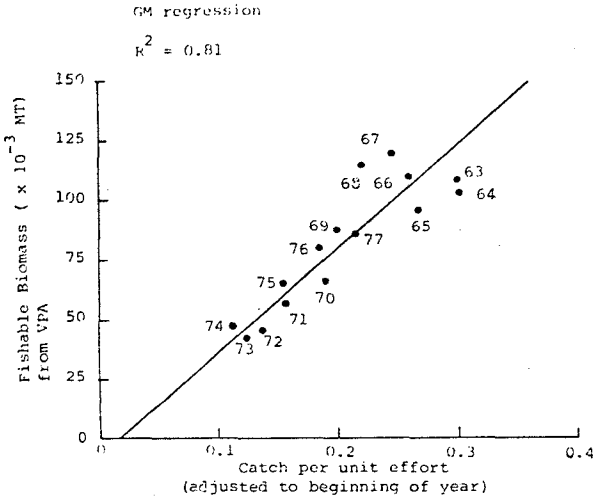


Figure 5 Relationship between fishable biomass from VPA and Canadian commercial catch per unit effort (151-500 ton otter trawlers).

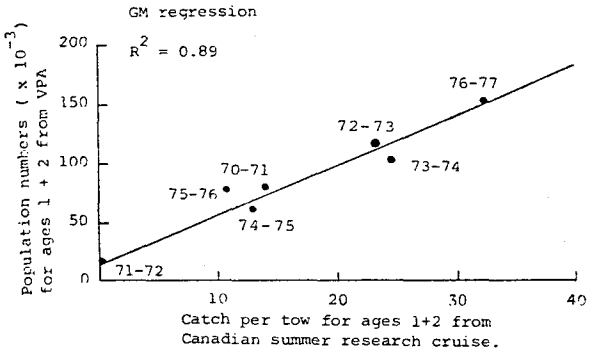


Figure 6 Relationship between observed strength of ages 1 and 2 and estimated (VPA)

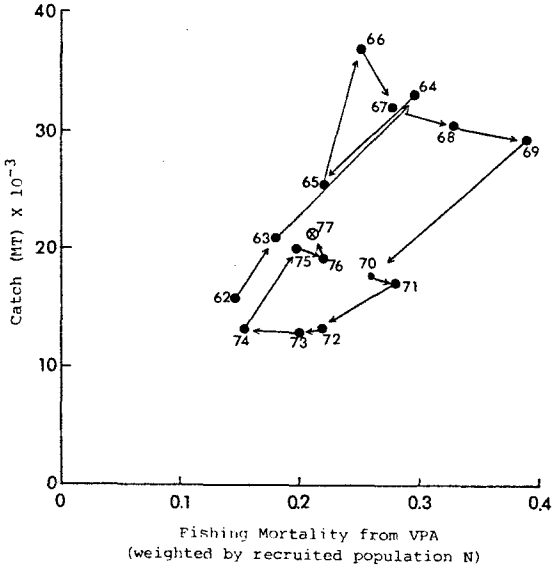


Figure 7 Relationship between Catch (MT) and Fully Recruited F from VPA

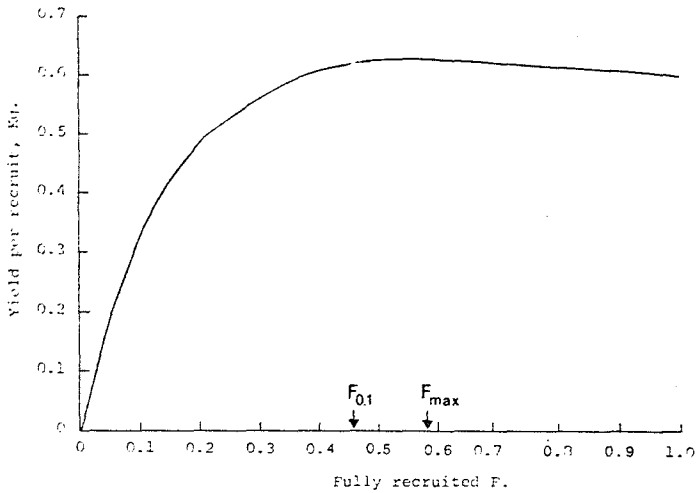


Figure 8 Yield per recruit relationship for 4X haddock in 1977.

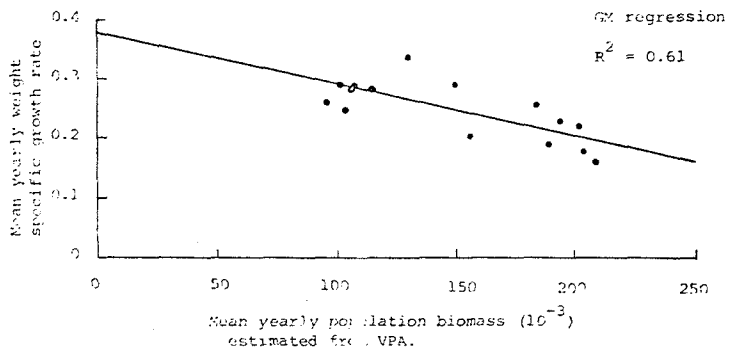
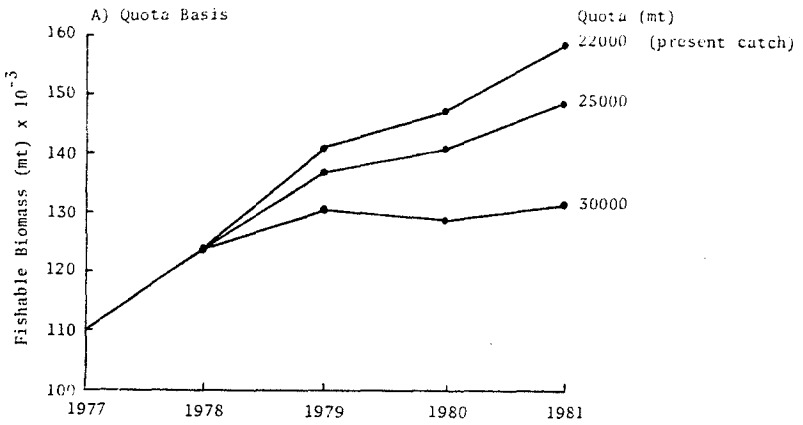


Figure 9 Density dependent growth in 4X haddock stock.



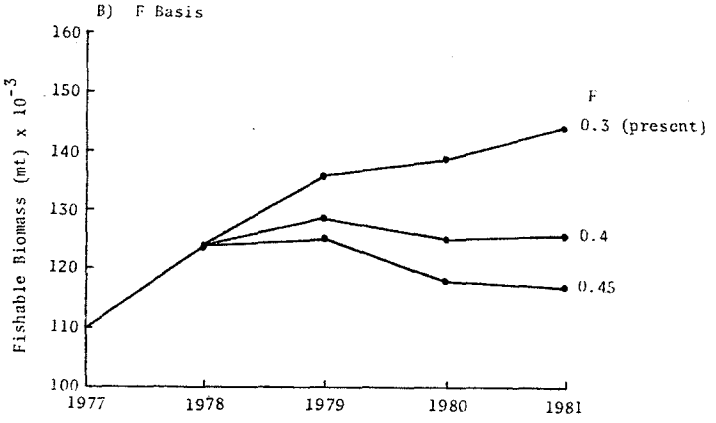


Figure 10. Catch Projections for 4X Haddock

1
8
1