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Assessment of the silver hake (*Merluccius bilinearis*) stock  
in Divisions 4VWX, using provisional 1979 data

by

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Introduction

The silver hake (*Merluccius bilinearis*) stock of NAFO division 4VWX has had an extremely variable history during the past twenty years. Catches have ranged from nearly 300,000 tonnes in 1973 to 3,000 tonnes in both 1967 and 1968. The last three years (1977-1979) have seen a stabilization at approximately 50,000 tonnes. The provisional catch for 1979 is 51,566.

Catches

Provisional catch statistics were taken from NAFO Circular Letters (monthly), FLASH data system, and the Statistics Branch, Department of Fisheries and Oceans, Canada (Table 1).

Catch-at-age

Length frequency samples were collected on a weekly basis from May until November by the International Observer Program. For March and April (prior to commencement of IOP monitoring) Soviet samples have been provided for ICNAF and are available. These samples were weighted by month, ICNAF division 4W with sexes combined. The resulting catch-at-length was broken down by an age-length-key provided by the Aging Unit, Marine Fish Division, St. Andrews Biological Station, New Brunswick, Canada.

The catch-at-age table (Table 2) is that used in the last assessment (Clay, 1979) with the 1979 catch added.

Weight-at-age

The weight-at-age for ages 1 to 5 and 6+ have been calculated for all years (1970-1979) (Table 3). These weights were multiplied by the catch-at-age to give the catch biomass-at-age (Table 4). The total catch biomass and the reported catch for each year are given on the same table - the differences range from near zero for 1976 to 16% for 1972. These differences indicate the accuracy of the weight-at-age data; the years 1970, 1971, 1973, 1974, 1976, 1977, and 1979 appear to be good estimates, 1978 data are still provisional and will be updated, and 1972 and 1975 have some yet to be identified error in their estimates.

The oldest age group in 1978 and 1979 appears to be lighter at age than the average prior to 1977. This may be due to more males surviving to the 5 and 6 age classes than previously. Males with their significantly slower growth would drop the mean weight of such an age-class. There has also been a shift in weight-at-age for the 2 and 3 year olds in 1979. The point at which the biomass of a cohort gained through growth equals the biomass lost through natural mortality has dropped by one year. This drop has affected the yield-per-recruit and suggests heavier fishing will be necessary to remove the fish at younger ages. It is important to note this observation is based on only one years provisional data. For this reason the weight-at-age used for this assessment is the average of those of 1976 to 1979.

Age	1	2	3	4	5	6+
Weight (kg)	.050	.130	.200	.250	.315	.500

#### Natural Mortality

The natural mortality used in previous assessments ( $M = 0.4$ ) was based on work done by Terre and Mari (1977) on the earlier catch at age table of Doubleday et al. (1976). As no better estimates were obtained in preliminary tests of these data the same  $M$  was used this year as last.

#### Virtual Population Analysis (VPA)

Arbitrary partial recruitments (PR) were applied to the last year of fishing. From these, improved estimates of the PR were obtained and the starting fishing mortalities (F) calculated from the effort - F relationship of Clay (1979). This value of F was adjusted until the relationship between F and effort (f) reached its highest value. The final partial recruitment (normalized to 1 at the highest fishing mortality) was then calculated for 1970-1978 data inclusive (Figure 1a). The F table used for these calculations showed the PR pattern in 1977 and 1978 has departed from the pattern of previous years. An upwards shift of one year has occurred in the fully recruited age groups. Taking this shift into account (Figure 1b) a normalized partial recruitment (NPR) was chosen as follows:-

Age	1	2	3	4	5	6+
NPR	0.05	0.52	1.0	0.97	0.75	0.65

The results of the VPA are consistent with earlier years and the projections made for 1979 by Clay (1979) (Table 5).

#### Validation of the VPA

The mean fishing mortality for ages 2 to 5 was plotted against effort (f) (Figure 2). The regression was:

$$F_{(2-5)} = 0.87 + 1 \times 10^{-5} f \quad (r^2 = 0.88, n = 10)$$

The catch per unit effort (CPUE) estimated from that part of the USSR fleet with Canadian observers on board was 2.2 tonnes per hour. This is higher than the 1.5 tonnes per hour CPUE of 1978 (Clay, 1979). The CPUE for 1979 gives an estimated effort of approximately 23,000 hours. This value puts the 1979 point for mean F of 2-5 year olds at 0.27 and the fully recruited F for the PR's used at 0.33.

The fishable biomass of age 2+ (population numbers of Table 5 multiplied by the normalized partial recruitments) regressed against the CPUE in tonnes (Figure 3) gives the equation:-

$$CPUE = 1.3 + 1 \times 10^{-6} \text{BIOMASS (2+)}, \quad (r^2 = 0.23, n = 10)$$

### Yield Per Recruit

The yield per recruit (YPR) is 0.064 kg at a fully recruited  $F_{0.1}$  of 0.673. The  $F_{max}$  is 2.09 with a YPR of 0.072 kg.

### Recruitment

Prediction of future year-class strength has always proved difficult to achieve. With silver hake, recruitment was the single most important factor in catch projections. This is because two year-classes (2 and 3) have generally made up over 75% of the catch composition and before 1976 age 2 fish made up approximately 70% of the catch. Clay (1979) used a relationship between the natural logarithm of squid numbers in any year to the number of one year olds in the VPA of the following year to predict recruitment. This relationship appears to hold with the addition of the 1979 data (Figure 4). The equation is: -

$$(\text{Pop}_1 \times 10^{-6}) = 2629 - 292 \times (\ln \text{ squid nos.} \times 10^{-6}), (r^2 = 0.82, n=8)$$

Note: Either the 1972 population of age 1 fish or the 1971 estimate of squid numbers appear to be anomolous to this relationship and therefore they have not been included.

### Catch Projection

The recruitment for 1980, predicted from the squid numbers of the 1979 groundfish cruise, will be  $1.06 \times 10^9$  fish. Using this value, a catch projection was run with the following parameters:-

Numbers-at-age (79)	- Table 5
Catch-at-age (79)	- Table 2
Weight-at-age	see text
Partial recruitment	- see text
$F_{0.1}$	- 0.67
M	- 0.4

The results give a catch for 1980 of 98,000 tonnes (Table 6). To indicate the effect of different levels of  $F_{0.1}$  a series of catch projections were run with F values between 0.4 and 1.4 (Figure 3). The relationship between F and catch appears to be nearly linear up to an F of 1.0.

### Discussion

The catch projection for 1980 is 98,000 tonnes. This is higher than the 65,000 tonnes resulting from the earlier projections of Clay (1979) using a recruitment of  $1.4 \times 10^9$  fish for 1979 and the actual catch in 1979. An increase appears warranted as the commercial CPUE is up by one third indicating an increase in biomass and the partial recruitment is shifting to the older age groups. The only note of caution is the apparent reduction in population biomass with the input recruitment over the next five years. Because of the shift in partial recruitment away from the one year olds (see Table 4) the recruitment now has less effect on the catch projection of the year in question. In fact raising the recruitment by 13% only increased the projected catch 0.6% (Figure 3). A series of projections indicate the level of fishing required to stabilize the catch (50,000 tonnes) at the predicted recruitment level of  $1.06 \times 10^8$  fish is an  $F = 0.3$ . Using 80,000 tonnes at an  $F = 0.5$ . Because of the relatively low recruitment predicted for 1980 it would be advisable to set the total allowable catch level at a conservative level of 80,000 tonnes (see Figure 6 for typical results of different management strategies).

### Acknowledgements

Dianne Beanlands assisted in the calculations required for this assessment. The analyses were conducted using the APL assessment packages of Rivard and Doubleday (1979) and Marshall (1978).

### References

- Clay, D. 1979. Silver hake (Merluccius bilinearis) in Divisions 4VWX: A stock assessment on an estimate of the total allowable catch for 1980. ICNAF Res. Doc. 79/VI/48.
- Doubleday, W.G., J.J. Hunt, and R.G. Halliday. 1976. The divisions 4VWX Silver hake fishery. ICNAF Res. Doc. 76/VI/59.
- Marshall, W. 1978. APL programs for the assessment of exploited fish stocks. CAFSAC Res. Doc. 78/12.
- Rivard, D. and W.G. Doubleday. 1979. APL programs for stock assessment, including a sensitivity analysis with respect to input parameters. Fish. Mar. Serv. (Canada). Tech. Rept. 853.
- Terre, J.J. and A. Mari. 1977. Preliminary estimates of natural mortality for the Silver hake stock in ICNAF Division 4VWX. ICNAF Res. Doc. 77/VI/6.

Table 1. Provisional Catch Statistics (1979) from ICNAF Circular Letters.

SILVER HAKE CATCH (TONNES)

COUNTRY	National Allocation	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
CANADA	10,000			8				87 <sup>a</sup>	56 <sup>a</sup>	1		1		153
USSR	44,940				2,190	12,932	14,947	11,617	2,541	713				44,940
CUBA	8,070					23	209	483	266	173	258	360		1,772
BULGARIA	6,860						2,387	2,156	96					4,639
JAPAN	-							13	7	5	23	2		50
FRANCE (SPM)	100													-
USA	2													
OTHER	30													12 <sup>b</sup>
TOTALS	70,002			8	2,190	12,955	17,543	14,356	2,966	892	281	363		51,566

a - Japanese developmental charters from Canada.

b - Taken from Flash Information System. Total represents the by-catches from Fed. Rep. Germany, Italy, Poland and Spain

Table 2. Catch at age table for 4VWX Silver hake.

Age/Year	Catch numbers ('000's of fish) for 4VWX Silver hake									
	1970*	1971*	1972*	1973	1974	1975	1976	1977	1978	1979
1	125484	146043	253744	256893	135582	148215	159687	11078	21468	18652
2	580982	369582	534271	1487089	411973	415730	359111	83376	69398	83765
3	369703	227813	265045	155463	103574	73476	73909	88087	85485	83338
4	125785	101239	84805	86185	4854	42593	41191	16229	37652	52258
5	22281	28011	26164	44699	10167	18010	8331	2749	25165	17114
6+	12574	15415	15132	34527	3746	37843	7288	1360	15210	7240

\* no age length key available for these years; a master age length key using 1973 to 1979 data was used.

Table 3. Weight at age table for 4VWX Silver hake

Age/Year	Catch Weight (g) at age for 4VWX Silver hake									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	57	36	55	46	68	64	62	52	43	42
2	127	131	113	128	137	153	147	126	100	146
3	182	197	194	233	224	229	232	198	168	198
4	251	258	258	263	353	276	273	279	218	250
5	351	361	361	365	392	327	317	374	254	333
6+	556	538	569	605	590	528	525	684	384	412

Table 4. Biomass at age table for 4VMX Silver hake.

Age/Year	Biomass (tonnes of fish) at age for 4VMX Silver hake									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	9522	6609	21557	11768	9177	9486	9971	826	927	777
2	106745	62711	66858	190932	56556	63658	52682	10139	6958	12220
3	29135	29683	24374	36239	23168	16771	17154	15220	14353	16507
4	10295	11887	10513	22629	1716	11775	11082	6463	8214	13063
5	5484	6654	5896	16301	3989	5881	2440	1667	6394	5692
6+	6754	7539	7416	20881	2159	19981	3830	1338	5844	2982
TOTAL	167,935	125,083	136,614	298,750	96,765	127,552	97,159	35,653	42,690	51,241
Reported Catch	169,045	128,653	114,048	298,621	95,745	116,286	97,184	35,762	48,200	51,566

Table 5. The population numbers and fishing mortality table using the catch at age of Table 2 and the parameters listed in the text.

parameters listed in the text.											
Population Numbers											
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
1	2345268	1736695	3372770	1628002	1415146	1668148	1332185	930358	982090	1382129	
2	1536595	1470251	1045787	2055119	883807	838782	998104	763789	614632	640871	
3	846257	566684	688501	279292	233163	266020	233666	382312	444491	355833	
4	259467	273671	198484	250246	65025	74089	119348	97454	185393	229030	
5	65796	74416	102666	65653	98860	39652	16248	47080	52224	93933	
6+	20387	26290	27542	49381	9384	58035	12296	4316	29328	15094	
TOTAL	5073771	4148008	5435749	4327692	2705385	2944726	2711847	2225309	2308159	2716889	
FISHING MORTALITY											
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
1	0.067	0.107	0.095	0.211	0.123	0.114	0.156	0.015	0.027	0.016	
2	0.598	0.359	0.920	1.776	0.801	0.878	0.560	0.141	0.147	0.172	
3	0.729	0.649	0.612	1.057	0.746	0.402	0.475	0.324	0.263	0.330	
4	0.849	0.580	0.706	0.529	0.095	1.117	0.530	0.224	0.280	0.320	
5	0.517	0.594	0.332	1.545	0.133	0.771	0.926	0.073	0.841	0.247	
6+	0.644	0.567	0.488	0.930	0.266	0.750	0.582	0.184	0.431	0.214	



Table 6. The population, catch, and fishing mortalities from a catch projection to 1983.

Note: In order to correct for the difference in weights-at-age and the true weights the 1979 catch biomass must be divided into 51,566 (true catch) to provide a correction factor of 1.020. All the catch biomass totals of this table are then multiplied by this correction factor to give the true values.

POPULATION NUMBERS					
	1979	1980	1981	1982	1983
1	1382129	1060000	1060000	1060000	1060000
2	640871	911307	687027	687027	687027
3	355833	861849	430488	324542	324542
4	229030	171479	123746	147219	110987
5	93933	111470	59839	43182	51373
6+	15094	49160	45105	24213	17473
TOTAL	2716890	2665266	2406206	2286183	2251402
POPULATION BIOMASS					
	1979	1980	1981	1982	1983
1	69106.45	53000.00	53000.00	53000.00	53000.00
2	83313.23	118469.97	89313.56	89313.56	89313.56
3	71166.60	72369.89	86097.68	64908.35	64908.35
4	57257.50	42869.79	30936.41	36804.72	27746.78
5	29588.89	35112.98	18849.17	13602.26	16182.46
6+	7547.00	24580.03	22552.74	12106.65	8736.60
TOTAL	317979.67	346402.66	300749.56	269735.53	259887.75
CATCH NUMBERS					
	1979	1980	1981	1982	1983
1	18652	28942	28942	28942	28942
2	83765	224369	169150	169150	169150
3	83338	149342	177670	133944	133944
4	52258	69224	49955	59431	44804
5	17114	37024	19875	14343	17063
6+	7240	14565	13364	7174	5177
TOTAL	262367	523465	458955	412983	399080
CATCH BIOMASS					
	1979	1980	1981	1982	1983
1	933	1447	1447	1447	1447
2	10889	29168	21989	21989	21989
3	16668	29868	35534	26789	26789
4	13064	17306	12489	14858	11201
5	5391	11663	6261	4518	5375
6+	3620	7282	6682	3587	2588
TOTAL	50565	96734	84402	73188	69390
CORRECTED					
TOTAL	51566	98648	86090	74651	70777
FISHING MORTALITY					
	1979	1980	1981	1982	1983
1	0.017	0.034	0.034	0.034	0.034
2	0.172	0.350	0.350	0.350	0.350
3	0.330	0.673	0.673	0.673	0.673
4	0.320	0.653	0.653	0.653	0.653
5	0.248	0.505	0.505	0.505	0.505
6+	0.835	0.437	0.437	0.437	0.437

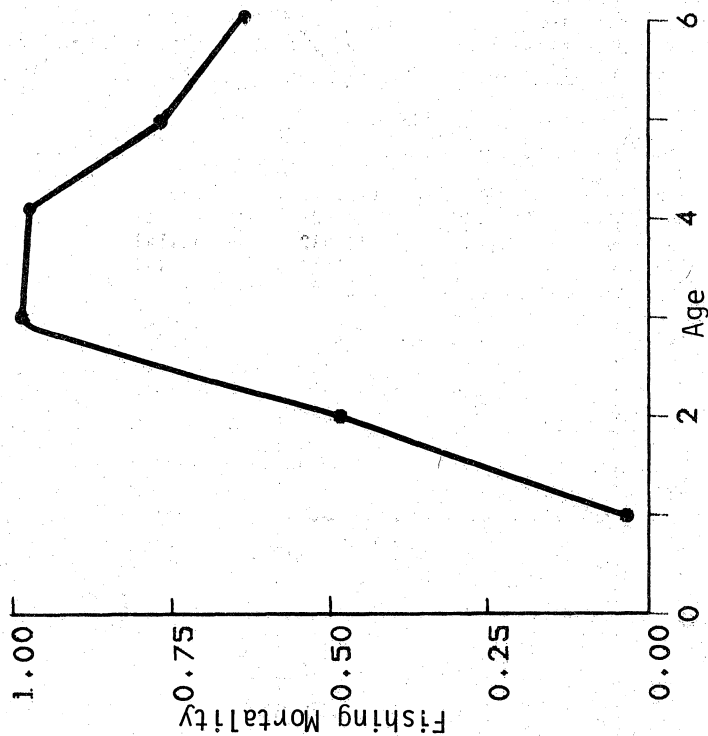


Fig. 1(b). Partial recruitments (normalized to 1) for fully-recruited age-0 groups of 1977 and 1978 data.

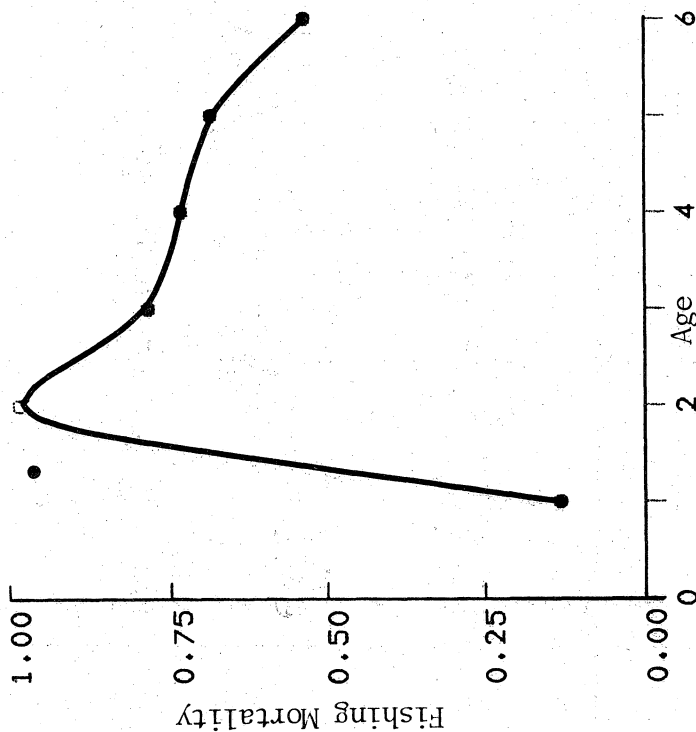


Fig. 1(a). Partial recruitments (normalized to 1) for fully-recruited age-0 groups of the 1970 to 1978 data.

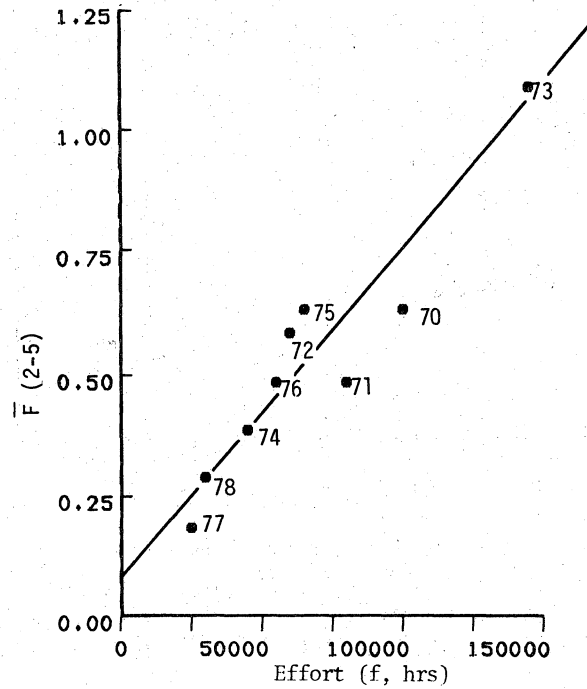


Fig. 2. Mean fishing mortality (F) for ages 2 to 5 against effort (f) at  $M = 0.4$ .  
Regression is  $Y = 0.087 + 0.00001X$ .

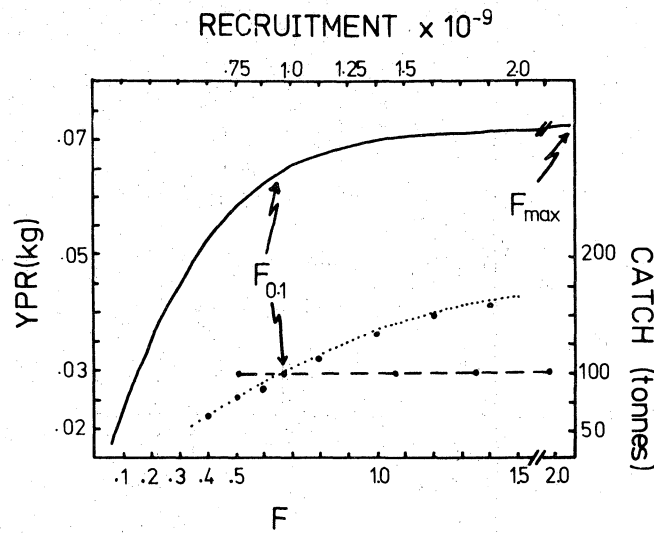


Fig. 3. Yield per recruit (YPR) for silver hake with  $F_{0.1}$  and  $F_{max}$  levels indicated (solid line). Catch projections for various levels of F all other parameters remaining equal (dotted line) and catch projections for various recruitment levels all other parameters remaining equal and  $F = 0.67$  (broken line).

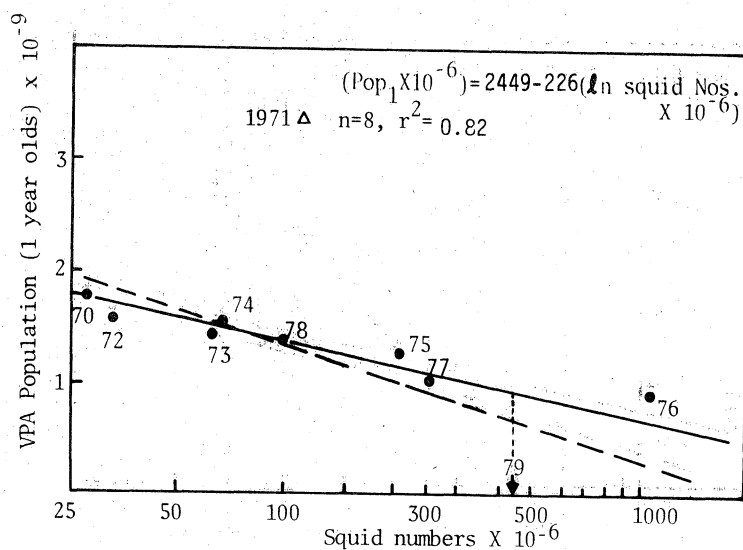


Fig. 4. The Scotian Shelf squid numbers from aerial expansion of Canadian summer R/V cruises. The number of squid for the year marked on the graph are plotted against the number of one year old hake (estimated from VPA) one year later. (The broken line represents the position of the 1979 line).

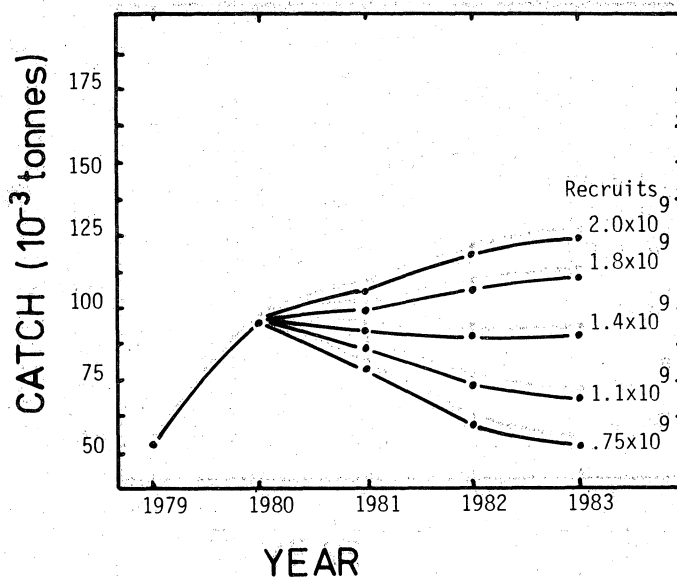


Fig. 5. Catch projections for silver hake for various levels of recruitment with fishing levels at the  $F_{0.1}$  value for 1980. (Other parameters described in text.)