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Silver hake (*Merluccius bilinearis*) in ICNAF Div. 4VWX: a stock
assessment and estimate of the total allowable catch (TAC) for 1979

by

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Introduction

The silver hake *(Merluccius bilinearis)* fishery in ICNAF Div.
4VWX is a relatively new fishery (beginning in 1958) compared to the hake
fishery in neighbouring Subarea 5 which has been in progress for over 40
years (Fritz, 1962). As can be seen in Figure 1 the 4VWX hake fishery has
had a variable history. The USSR has been the major harvesting nation,
taking over 98% of the catch, from 1961 until 1975. In 1976 and 1977 quota
allocations have reduced the USSR catch proportion to 83% and approximately
94% respectively. Detailed histories of the fishery and species biology
can be found in Halliday (1973), Doubleday and Halliday (1976), Noskov (1976),
Doubleday and Hunt (1976), and Doubleday and Hunt (1977).

Although in previous years restrictions have been placed on the
fishery in terms of quotas, 1977 is the first year for restrictions by gear
and area. The most commonly used codend mesh size during 1977 was 60 mm,
compared to 40 mm for previous years (Anon. 1976a).

The general methodology for the present assessment follows that
of Doubleday and Halliday (1976) and Doubleday and Hunt (1976). The hake
from ICNAF Div. 4VWX will be assumed to come from one stock, the bulk of
which comes from Div. 4W.

Catches

Historical catches (Table 1 and Fig. 1) reached a peak of about 299,000 mt
in 1973 and have been subject to catch quota control since then. The catch
was apparently constrained by the TAC's in 1974-76 (TAC 1974=100,000 mt, TAC
1975 = 120,000 mt, TAC 1976 = 100,000 mt). However, the 1977 TAC of 70,000 mt
was substantially under-run, provisional catches being about 36,000 mt and no
major fishing country taking its allocation. Two data sources are available
on the 1977 catch, ICNAF monthly catch reports and weekly vessel catch reports
to the Canadian Government (labelled FLASH data henceforth). There is little
difference between the two data sets (Fig. 2) but, since FLASH data are more
comprehensive, they were chosen as the basis for the calculations.

Numbers removed at age

Numbers removed at age for 1976 and earlier years are taken from
Doubleday and Hunt (MS 1977). In 1977, the Canada-USSR-Cuba international
observer programme collected substantial catch samples throughout the 1977
fishing season. These length-frequency samples were weighted up by catches
by month, sex and country (Cuba, USSR and "others") wherever possible. Monthly
FLASH catch reports include discards in some cases (Table 2). These discards
were assumed to be all less than 25 cm in length - the length reported to be
the maximum size put to fishmeal aboard USSR trawlers, (quantities involved are
trivial).

Otoliths collected through the international observer programme, stratified by size, sex, month and fishing area, were read by J.J. Hunt using criteria developed at ICNAF Ageing Workshops. Unfortunately, time was not available to read sufficient otoliths to sustain this stratification and age-length keys by sex for the whole area and season were constructed. These were enhanced by three point running averages and expressed as percentages at length (Tables 3a and b). These keys were applied to the weighted annual length frequencies to give estimated numbers removed at age in 1977 (Table 4).

Natural mortality

A natural mortality, $M = 0.40$, has been used in previous assessments. The analysis of Terre and Mari (1977) lend support to this value and $M = 0.40$ is again used in this assessment.

Weight at age

New observations on weight at length were taken in 1977 (Clay, 1978a) which give the following length-weight relationship:

$$Wt(g) = 2.055 \times 10^{-3} (TL(cm))^{3.317}$$

This is close to those given by Kohler et al. (1970) which were used in earlier assessments. However, previous mean weights at age were obtained by reading the equivalent weight to the mean length at age from a length-weight table. In this analysis, weights at age were calculated (from the new data obtained in 1977) by adding up the individual weights of all fish by length in each age group and dividing by the number of fish, removing the bias created by the earlier method. The weights at age were found to be:

Age	1	2	3	4	5	6
Weight (kg)	0.044	0.122	0.204	0.298	0.425	0.732
(Previously used)	(0.051)	(0.159)	(0.270)	(0.426)	(0.635)	(0.905)

This implies that previous yield per recruit and projected catches were over-estimated.

Recruitment

Inferences on recruiting year class size have proved difficult to obtain. The most promising relationship to date is that between observed l_1 in September to year-class size at age 2 from VPA (Doubleday and Hunt, MS 1976). This relationship is again used here (Fig. 4). The predicted size of the 1975 year class is 450×10^6 and of the 1976 year class is $1,380 \times 10^6$ fish at age 2. Subsequent year classes are assumed to be about 700×10^6 fish at age 2 (equivalent to $1,000 \times 10^6$ fish at age 1).

Virtual Population Analysis

Arbitrary partial recruitments and starting F values were used in 1977 to generate a matrix of fishing mortalities for earlier years. The mean $F_{ages\ 2-4}$ (unweighted) for 1966-74 were then regressed against fishing effort to obtain an estimate of 1976 fishing mortality. This F was distributed over age-groups using the historical selection pattern for 40-mm mesh nets and the population generated for 1976 projected through 1977 using the known 1977 catch-at-age. The recruitment assumptions for 1975 and subsequent year-classes were as above. The resultant F's at age in 1977 and implied partial recruitments are:

Age	Fishing Mortality	Partial Recruitment
1	0.007	0.003
2	0.270	0.106
3	0.470	0.185
4	1.526	0.600
5	0.813	0.319
6+	2.545	1.000

These values were then used as starting values for virtual population analysis (Table **5**).

Validation of the V.P.A.

Average fishing mortalities were again calculated based upon age 2 to 4 once more and plotted against fishing effort (Figure **3**). Only 1974 through 1976 would be effected by the partial recruitments in 1977. Interestingly, the partial recruitment in 1977 has fallen among the 1 to 3 year olds in response to the implementation of the 60 mm mesh size.

The overall geometric regression (Ricker 1973) fit the data extremely well (r = 0.95) with the line intercepting very close to the origin (Figure **3**). Although the points for this regression seem to be distributed somewhat randomly, the 74 to 76 points form a time series making it a little difficult to comment on the validity of the starting values in 1977. However, it does indicate that the effort data is consistent with changes in exploitation within the fishery.

To check on the validity of the V.P.A. numbers at age the 2+ biomass was plotted against the commercial catch per unit efforts. The 2+ biomass was used since it represented the biomass actually exploited better than the 1+ biomass although both relationships are tight. A G.M. regression produced the following equation

$$C.U.E. = 8.575 \times 10^{-6} B_2+ + 0.227 \qquad r = 0.93$$

where CUE is in hours fished and B_{2+} is in metric tons. The biomass in 1977 is approximately 120,000 mt which predicts a catch per unit effort of 1.26 tons per hour (Fig. **4**). This means that the effort in 1977 was probably near 28,483 hours or 2,734 days. The ratio of days to hours fished was based upon the FLASH data. Once more, FLASH data was used to estimate effort between 1800-2200 days in 1977. Given the changes in the selection of the fishery and closed area it is impressive that the agreement is as concise.

Yield per Recruit

Due to changes in selection and a re-evaluation of mean weight it was necessary to recalculate F_{max} and $F_{0.1}$ for the purpose of management advice. The maximum yield per recruit was 0.075 (Fig. **5**) with F_{max} being 2.8. $F_{0.1}$ was determined to 0.96.

Catch Projection

The catch projection was conducted using F.S.D.P. program PROJECT written in APL for standard stock assessment. Further details about the program are available on request. Standard year classes of 1 x 10^9 fish were designated for 1978 to 1980. The results were as follows:

NUMBERS AT AGE x 10^3

AGE	1977	1978	1979	1980
1	2100000	1000000	1000000	1000000
2	426103	1398402	668373	668373
3	280622	216978	845495	404108
4	23976	115987	121410	473096
5	5835	2785	42740	44739
6	1660	1661	1365	20944
TOTAL	2838196	2735814	2679383	2611259

POPULATION BIOMASS IN METRIC TONS

AGE	1977	1978	1979	1980
1	92400.00	44000.00	44000.00	44000.00
2	51984.57	170605.10	81541.53	81541.53
3	57246.89	44263.53	172480.92	82438.09
4	7144.85	34564.13	36180.14	140982.52
5	2479.88	1183.72	18164.70	19013.97
6	1215.12	1216.18	999.04	15330.66
TOTAL	212471.30	295832.66	353366.33	383306.77

CATCH IN METRIC TONS

	1977	1978	1979	1980
1	498	105	105	105
2	10229	13692	6544	6544
3	17970	5989	23336	11154
4	4836	12742	13338	51973
5	1168	261	4000	4187
6	995	639	525	8060
	35696	33427	47848	82023

FISHING MORTALITY

	1977	1978	1979	1980
1	.007	.003	.003	.003
2	.275	.102	.102	.102
3	.484	.178	.178	.178
4	1.753	.578	.578	.578
5	.856	.307	.307	.307
6	2.545	.963	.963	.963

The 1978 TAC was set at 81,000 mt based upon the criteria of $F_{0.1}$ (Doubleday and Hunt 1977). Based upon the new calculations this figure would drop to 33,000 mt. Indeed, according to the present calcualtions it is impossible to take 81,000 tons in 1978. The 1979 TAC should be set at 48,000 tons. This will allow the biomass to increase from 210,000 mt to 380,000 between 1977 and 1978. The object is the same for this stock, to stabilize the biomass and therefore the catch.

REFERENCES

Clay, D. (1978) Report on The Joint Cruise of the USSR Research Vessel "Foton" (October-November, 1977). (Preliminary Analysis and Data Documentation With Particular Reference to Silver Hake). CAFSAC Working Paper 78/7. (Mimeo)

Doubleday, W.G. and Halliday, R.G. (1976). An Analysis of The Silver Hake Fishery on The Scotian Shelf. ICNAF. Sel. Pap. No 1: 41-58.

Doubleday, W.G.; Hunt, J.J.; and Halliday, R.G. (1976). The 4VWX Silver Hake Fishery. ICNAF Res. Doc. 76/VI/59. pp 17. (Mimeo).

Doubleday, W.G. and Hunt, J.J. (1976). A Revised Assessment of the 4VWX
        Silver Hake Fishery Incorporating Preliminary 1976 Data.
        ICNAF Res. Doc. 76/XII/160. pp 23. (Mimeo).

Doubleday, W.G. and Hunt, J.J. (1977). An Assessment of The Division
        4VWX Silver Hake Fishery Incorporating 1976 Provisional Nominal
        Catch Statistics Reported To 18 April 1977. ICNAF Res. Doc.
        77/VI/44. pp 7. (Mimeo).

Fritz, R.L. (1962). Silver Hake. U.S. Dept. Int. Fish. Leaflet 538.
        pp. 7.

Halliday, R.G. (1973). The Silver Hake Fishery on The Scotian Shelf.
        ICNAF Res. Doc. 73/103. pp 21. (Mimeo). + Addendum I +
        Addendum II. pp 4. (Mimeo).

Kohler, A.C.; Fitzgerald, D.M.; Halliday, R.G.; Scott, J.S.; and Tyler,
        A.V. (1970) Length-Weigth Relationships of Marine Fishes of
        The Canadian Atlantic Region. FRB of Canada Tech. Rep. 164.
        pp 200.

Noskov, A.S. (1976) Estimation of Stock Size and Allowable catch of Silver
        Hake on The Nova Scotia Shelf in ICNAF Division 4W. ICNAF
        Res. Doc. 76/VI/57. pp 13. (Mimeo).

Terré, J.J. and Marí, A. (1977). Preliminary Estimates of Natural Mortality
        For The Silver Hake Stock in ICNAF Divisions 4VWX. ICNAF
        Res. Doc. 77/VI/6. pp 6. (Mimeo).

Table 1. Silver hake landings from ICNAF Div. 4VWX by Division and Country (metric tons round).

Year	ICNAF DIVISION				Total	COUNTRY				
	4Vn	4Vs	4W	4X		Canada	Japan	USSR	USA	Others
1960	–	–	–	187	187	–	–	–	187	–
1961	–	–	–	2	2	–	–	–	2	–
1962	–	–	8,825	29	8,854	–	–	8,825	29	–
1963	168	–	116,388	6,472	123,028	–	–	123,023	5	–
1964	32	–	62,905	18,210	81,147	–	–	81,147	–	–
1965	180	2	49,461	379	50,022	5	–	49,987	27	3[2]
1966	40	0	3,860	6,423	10,323	–	–	10,323	–	–
1967	–	–	1,834	643	2,483	–	6[1]	2,476	1	–
1968	2	237	3,150	58	3,523	5	76[1]	3,441	1	–
1969	–	1,230	43,563	1,558	46,564	–	213[1]	46,323	–	28[3]
1970	–	5,116	158,938	4,991	169,045	–	129	168,916	–	–
1971	11	3,000	119,452	6,190	128,653	–	8	128,633	1	11[4]
1972	–	75	108,769	5,204	114,048	–	63	113,774	–	211[5]
1973	–	3,431	265,105	30,085	298,621	–	88	298,533	–	–
1974	–	712	86,927	8,106	95,745	11[1]	67	95,371	–	296[6]
1975	–	1,512	97,540	17,234	116,286	101	54	112,566	7	3,558
1976	735	44,007	45,837	6,605	97,184	26	78	81,216	1	15,863
1977[7]	–	–	–	–	35,765	921	2	32,090	–	2,752

[1] Not recorded by Division

[2] France (SP)

[3] GDR

[4] Spain

[5] FRG 10 mt, Cuba 201 mt

[6] FRG

[7] Preliminary Statistics

Table 2. Silver hake, Div 4VWX: FLASH catch and discard statistics
metric tons round (discards in parenthesis)

Country Month	USSR	Cuba	Others
Jan	-	-	-
Feb	-	-	-
Mar	1456	83	-
Apr	4411	69	-
May	9659	313	+
June	3398	514	8
July	9194	763	715
Aug	2992	121	76
Sept	934	-	6
Oct	-	-	+
Nov	46	-	85
Dec	-	-	1
Unspecified	(14)	-	921
			(13)
Total	32104	1863	1825
Allocation	44950	8910	16140

Table 3(a). Enchansed age length key for 4VWX Silver hake in 1977. Numbers
are expressed as the percentage of each length group in an
age group.

Male Silver Hake

Length (cm)	Ages					
	1	2	3	4	5	6+
01-16	100.0	0	0	0	0	0
17	96.7	3.3	0	0	0	0
18	89.7	10.2	0	0	0	0
19	81.6	18.4	0	0	0	0
20	70.6	29.4	0	0	0	0
21	57.4	42.6	0	0	0	0
22	42.6	55.5	1.8	0	0	0
23	24.6	72.1	3.3	0	0	0
24	16.5	75.3	8.2	0	0	0
25	7.6	83.0	9.3	0	0	0
26	3.8	82.3	13.9	0	0	0
27	1.6	75.9	22.0	0.5	0	0
28	0	69.0	30.5	0.5	0	0
29	0	57.5	41.6	0.9	0	0
30	0	44.3	53.8	1.9	0	0
31	0	31.5	65.5	2.5	0.5	0
32	0	19.1	70.8.	9.5	0.6	0
33	0	8.5	69.1	21.7	0.7	0
34	0	3.3	61.1	34.7	0.8	0
35	0	1.2	45.7	51.8	1.2	0
36	0	0	28.9	66.7	2.2	2.2
37	0	0	21.0	68.4	0	5.2
38	0	0	20.0	60.0	0	20.0
39	0	0	0	50.0	0	50.0
40	0	0	0	50.0	0	50.0
41	0	0	0	50.0	0	50.0
42-70	0	0	0	0	0	100.0

Table 3 (b)

Female Silver Hake

Length (cm)			Ages			
	1	2	3	4	5	6+
01-16	100.0	0	0	0	0	0
17	97.6	2.4	0	0	0	0
18	93.8	6.3	0	0	0	0
19	89.1	10.9	0	0	0	0
20	79.3	20.7	0	0	0	0
21	71.2	28.8	0	0	0	0
22	64.4	35.6	0	0	0	0
23	46.7	51.7	1.7	0	0	0
24	31.2	62.3	6.6	0	0	0
25	18.3	73.2	8.5	0	0	0
26	5.1	84.8	10.1	0	0	0
27	1.1	80.9	17.0	1.1	0	0
28	0	75.2	23.1	1.7	0	0
29	0	66.0	32.7	1.3	0	0
30	0	52.7	45.7	1.6	0	0
31	0	40.7	56.5	2.4	0.5	0
32	0	29.8	64.0	5.8	0.4	0
33	0	17.5	69.7	11.8	0.9	0
34	0	10.1	68.5	19.2	1.8	0.5
35	0	6.2	59.3	32.5	1.4	0.5
36	0	1.6	50.5	40.8	6.0	1.1
37	0	0	39.0	50.0	9.7	1.3
38	0	0	28.2	51.9	17.6	2.3
39	0	0	22.1	44.2	29.8	3.9
40	0	0	17.3	46.9	32.1	3.7
41	0	0	12.5	39.1	40.6	7.8
42	0	0	4.4	47.8	39.1	8.7
43	0	0	2.9	45.7	37.1	14.3
44	0	0	0	32.0	40.0	28.0
45	0	0	0	27.8	38.9	33.3
46	0	0	0	12.5	31.3	56.3
47	0	0	0	6.7	33.3	60.0
48	0	0	0	6.9	23.5	70.6
49	0	0	0	7.1	14.3	78.6
50	0	0	0	0	16.7	83.3
51	0	0	0	0	13.3	86.7
52	0	0	0	0	20.0	80.0
53	0	0	0	0	11.1	88.9
54-70	0	0	0	0	0	100.0

Table 4. Catch numbers in thousands of 4VWX Silver hake from 1966-1977 (updated from earlier assessments).

YEARS

AGE	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	10220	0	84	21456	208319	65461	149692	102212	80432	143125	78480	11322
2	9795	7576	18218	242169	702322	553957	414279	1449980	405044	376358	480015	83846
3	406	804	1910	19474	68653	202177	102440	118398	49437	42256	39762	88087
4	34	67	159	2154	6234	14761	13167	12715	5087	4347	4195	16228
5	9	18	43	740	2026	3802	5074	4512	2115	1807	1504	2748
6	· 13	26	61	90	1013	3131	0	1094	457	391	138	1359

TABLE 5.

Numbers at Age VPH M = 0.4

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	98408	134414	730577	1942461	1612004	1191757	2998246	1023656	971696	1673993	731527	2100000
2	40118	57597	90101	489652	1284504	910001	745264	1887227	602493	585495	1004930	426103
3	2120	18873	32406	45481	129952	286016	156451	160383	77903	72241	84333	280622
4	1251	1089	11993	20159	14543	30901	26194	21001	10572	11745	13829	23976
5	504	811	675	7909	11750	4645	8629	6778	3668	2922	4314	5835
6+	166	331	529	418	4696	6217	1	1630	850	727	479	1660

Fishing Mortality at Age

| Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	.136	.000	.000	.014	.172	.069	.063	.130	.107	.110	.140	.010
2	.354	.175	.284	.927	1.102	1.361	1.136	2.787	1.721	1.538	.876	.270
3	.266	.053	.075	.740	1.036	1.991	1.608	2.319	1.492	1.253	.858	.470
4	.034	.078	.016	.140	.741	.876	.952	1.345	.886	.602	.463	1.526
5	.022	.027	.081	.121	.237	9.726	1.267	1.677	1.219	1.409	.555	.813
6+	.100	.100	.150	.300	.300	.900	1.000	1.500	1.000	1.000	.423	2.545
Average F 2 - 4	.218	.102	.125	.602	.960	1.409	1.232	2.151	1.366	1.131	0.732	.755
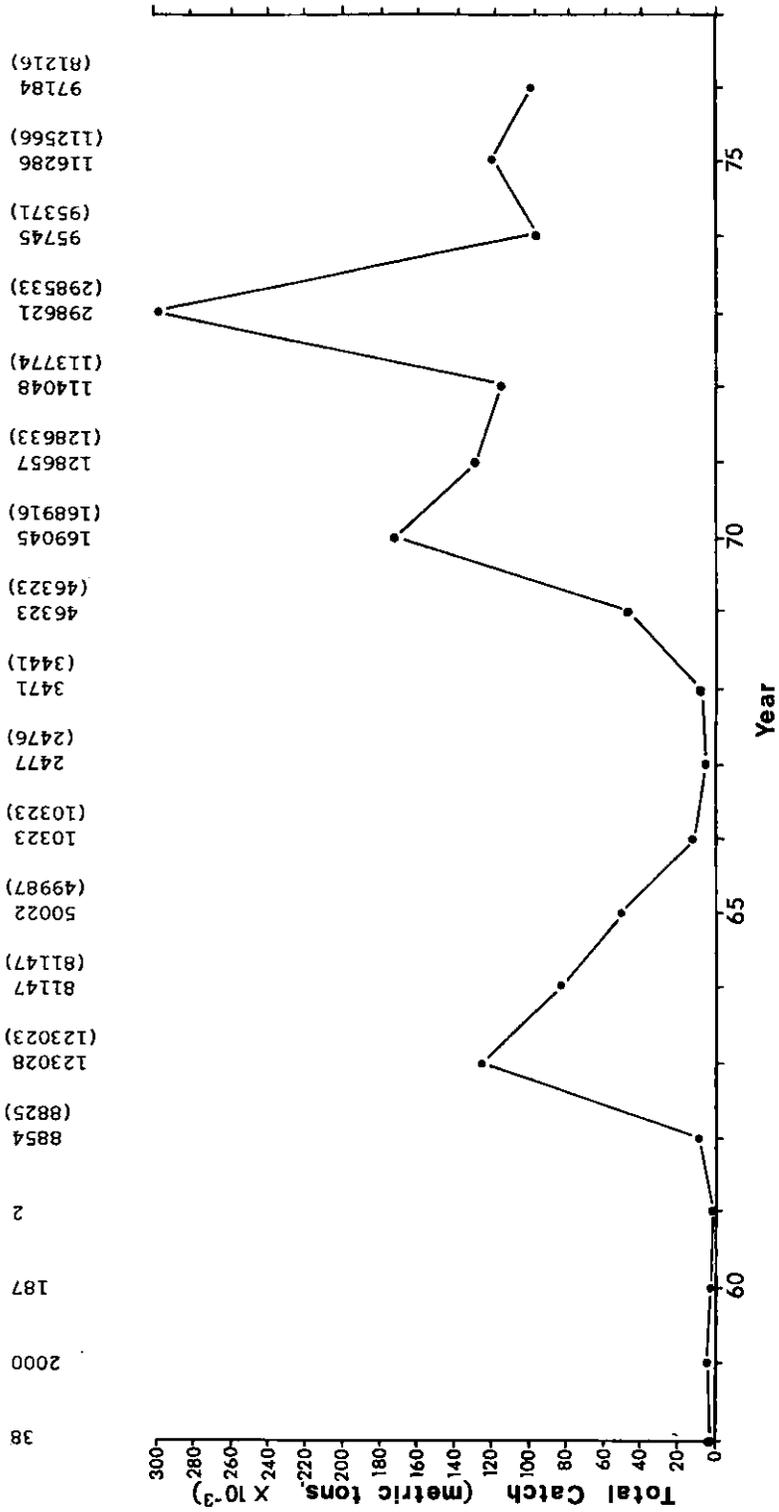
Fig. 1. The catch of silver hake by all countries in ICNAF Div. 4VWX (data taken from ICNAF Statistical Bulletin Vol. 8-Vol. 26). The catch for a year, in metric tons, is given above the graph — the value in brackets is the USSR catch.
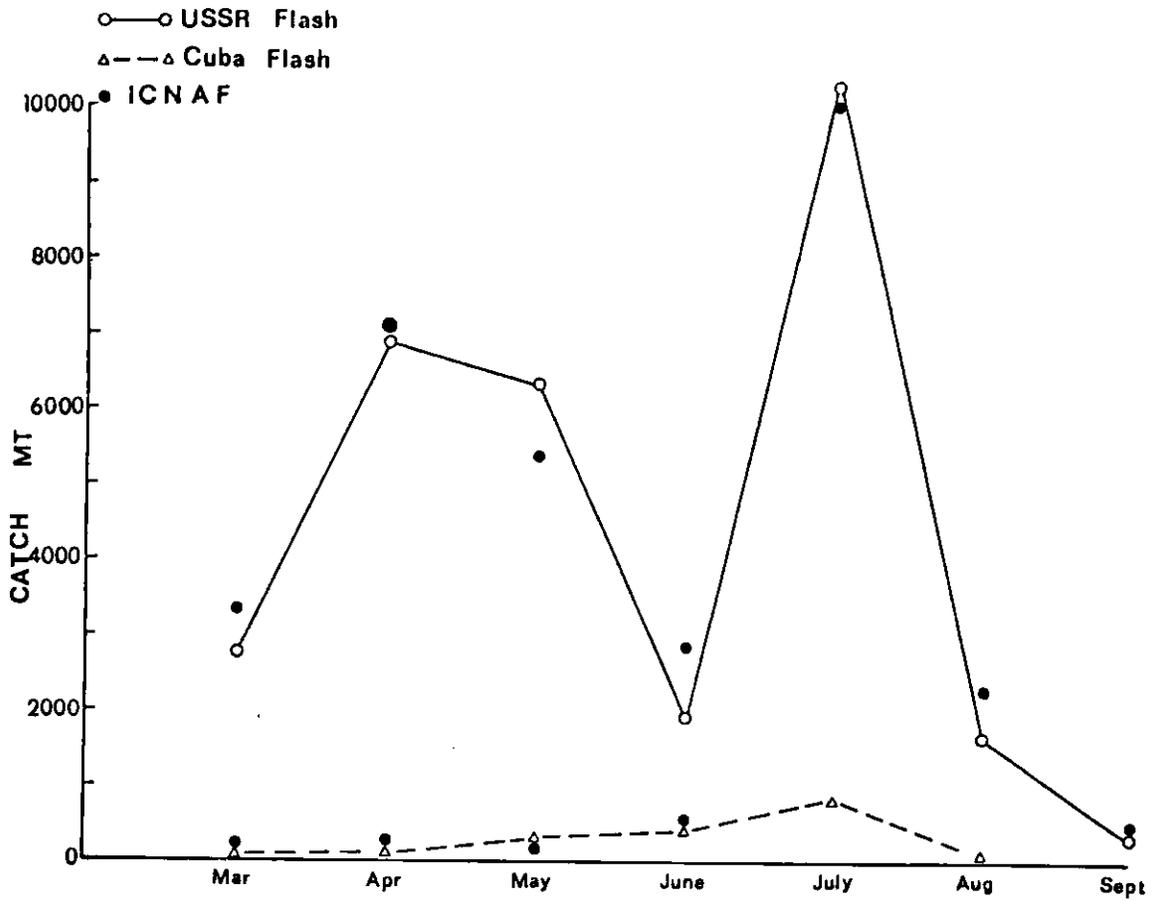
o——o USSR Flash
Δ— —Δ Cuba Flash
● ICNAF

Fig. 2. A comparison of the 1977 catch statistics for silver hake as reported to FLASH by the fishing captains and as reported to ICNAF by the Member Countries. (ICNAF data from provisional catch statistics for individual months of 1977).
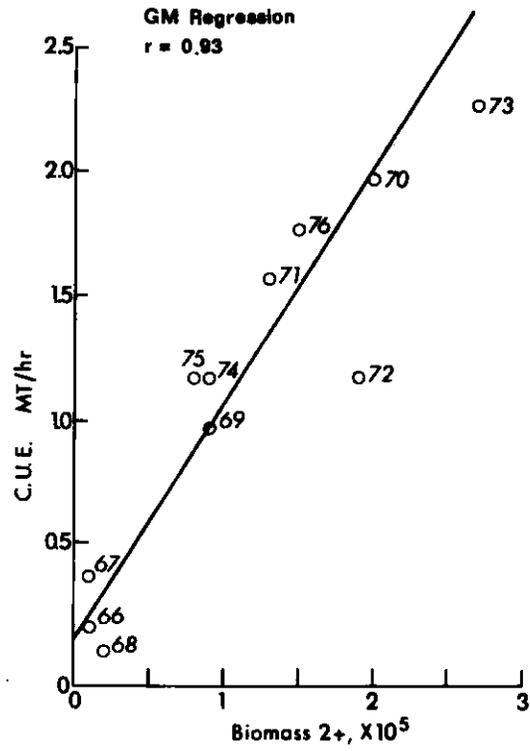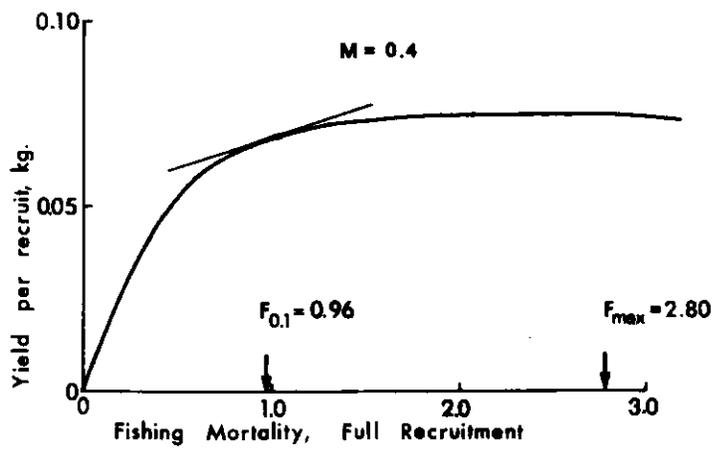
GM Regression
r = 0.95

Effort, days fished X10^3

Fig. 3

Fig. 4

Fig. 5