Not to be cited without prior reference to the author

Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC RES. DOC. 77/25

A Model to Determine Stock Size and Management Options For the Newfoundland Hooded Seal Stock.[1,2]

BY

PATRICK F. LETT

Fisheries Systems and Data Processing Group
Marine Fish Division, Resource Branch
Fisheries and Marine Service
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

1. Fisheries Systems and Data Processing Group Contribution No. 5

2. Preliminary paper written in conjunction with T. Benjaminsen and B. Bergfløt, Norway.

Introduction

For the past 100 years hooded seals have been hunted in their breeding areas in the West Ice which is North of Iceland, and off the eastcoast of Newfoundland. In 1974 another whelping area was rediscovered in the David Strait (Sergeant, 1974).

The only known molting area is east of Greenland in the Denmark Strait. It would seem that the Newfoundland and West Ice stocks molt here in June and July (Nansen, 1924; Silvertsen, 1936, Rasmussen, 1957). This theory has been confirmed by tagging studies. In 1974, 100 sub-adult and adult hooded seals were tagged in the Denmark Strait. Two of these tags were recovered in 1976 and one in 1977 during the Newfoundland hood seal hunt (Øritsland pers. comm.).

Recent regulations have set a quota of 15,000 on the Newfoundland hooded seal stock, based primarily on the average catch of seals, not including Greenland and high arctic catches. A more analytical approach (Øritsland and Benjaminsen, 1975a) calculated a sustainable yield of 24,000 hooded and it was recommended that this be divided into 14,000 pups, 6,000 mature females and 4,000 adult males. However, regulations in 1977 tried to reduce the take of adult females to less than 10% of the overall catch.

Despite the quota the average catch since 1970 has only been 11,420 seals with a low of 7,190 in 1970 and a high of 15,612 in 1975. Indeed, it is only in one year that a level of catch equivalent to the quota was actually achieved. This fact is more related to ice conditions, and the quota and value of harp seal pups, then the size of the hooded seal population. It should also be noted that 2 or 3 hooded seal whelping patches which form up to the south of the Front harp seal stock only represents a fraction of the total hooded seal herd. In fact, hooded seals whelp as single family units or small patches on Arctic ice over the whole North Atlantic. Thus recent concern by the Canadian Industry that the patches along the Front are being overly exploited (T. Curran per. comm.) is probably well-founded, but these concerns should not be extrapolated to the herd as a whole.

It is therefore, the purpose of this paper to evaluate the available data in light of constructing a simulation to test the validity of our present management criteria.

Materials and Methods

The age samples collected from Norwegian catches of hooded seals off Newfoundland in 1971, 1972 (Øritsland and Benjaminsen, 1975a), in 1973, 1974 (Øritsland and Benjaminsen, 1975b) and in 1975 and 1976 are listed in Table 1. In most of the years the samples were from the catch of two or more ships and collected without any selection to age or sex. So even through the precocious 4- year old females seem to be somewhat segregated from the older females (Øritsland and Benjaminsen 1975a) the samples should give a fairly good representation of the catch at eye.

Table 2 shows the total catches of hooded seals off Newfoundland and in the Denmark Strait. Out of a total of 273,475 hooded seals taken off Newfoundland from 1946 to 1977 Norwegian vessels have caught 69%, Canadian vessels larger than 150 feet 24% and landsmen and small vessels 7%. The hunt in the Denmark Strait for moulting hoods in June - July by Norwegian vessels was stopped in 1960. A Danish sealing vessel made some catches here from 1962 to 1966, from 1970 and on hooded seals have been sampled for scientific purpose, every second year by Marine Research Institute, Bergen, Norway.

Production estimated by Survival Indices

Sergeant (1971) developed a method were he attempted to estimate pup production of harp seals from age samples after varying pup catch. He rated each year-class from 0 to 3 in proportion to their strength. The average ratings were then expressed as a proportion of the maximal possible value to give a survival index ranging from 0 - 1.0. A survival index of 0 means that production equals the catch and by plotting the survival index on pup catch the intercept of the regression line on the X axis therefore gives an estimate of pup production. The method was further quantified by Øritsland (1971) by dividing the frequency in sample with the frequency of the corresponding year class in a life table to produce a survival index.

The survival index method was used by Øritsland and Benjaminsen (1975a) to estimate the pup production of hooded seals off Newfoundland from samples collected from 1971 to 1974.

In this paper survival indexes of 5 - 10 year old female hooded seals were calculated for the Norwegian samples collected from 1971 to 1976 (Table 2). The index is expressed as the ratio of frequency in individual sample to average frequency. Weighted means were calculated using weights proportional to the square root of specimens in each sample. The table shows that the high pup catch in 1966 results in a low survival index in all samples. A low catch in 1968 gives, in all samples, a high survival indices.

The survival indexes are plotted against the pup catches in Figure 1. The pup production was estimated by linear regression of survival indexes on pup catches. A G. M. functional regression (Ricker, 1973) was found to be most appropriate. The intercept of the line on the X-axis gives the pup production in the mid-year 1966.

Production estimates for the years 1963 to 1970 were obtained by using different periods in the regression. Table 2 shows that production from 1963 to 1970 seems to have been about stable at somewhat more than 30 thousand.

Calculation of Natural Mortality - variations with age

Pup production based on survival indices has been shown to be stable ranging from a high of 33,800 in 1964 to 30,900 in 1970. Table 3. Between any two years within the 1963 to 1970 period, it has not varied by more than 800 animals.

Adequate samples of female hooded seals were not available until 1971 when Norwegian catches began to be sampled on a regular basis (Table 1). These samples were used to calculate natural mortality in the following manner. First pup production in 1971 and 1972 was assumed to be similar, at 30,900 snimals. By dividing the frequency distribution by the maturity at age a distribution could be determined which was indicative of the population. Basically, this is because females recruit to the whelping areas only when they are pupping (Øritsland, 1975). After applying the fraction of reproductively successful females (Øritsland and Benjaminsen, 1976) the pup production could be broken out into the appropriate age groups thus representing the total stock of females. Since the hunt occurs during a very short period.

(1) $${}_{i}N_{t+1} = ({}_{i}N_{t} - {}_{i}C_{t}) \cdot X \text{ EXP } (-M)$$

where the catch of females in year t of age i is substracted from the population in year t and age i before the natural mortality, M, is applied. Thus.

(2) $$M = \ln \left[\frac{\sum_{i=4}^{i=24} {}_{i}N_{t} - \sum_{i=4}^{i=4} {}_{i}C_{t}}{\sum_{i=5}^{i=25} {}_{i}N_{t+1}} \right]$$

Between 1971 and 1972 the instantaneous rate of natural mortality for hooded seals was determined to be 0.124. This value agrees well with that determined by Øritsland and Benjaminsen (1975) of 0.130 for females from West Ice herd. Lett and Benjaminsen (1977) determined a similar value for harp seals of 0.114.

Eskimo catches in Greeland also influence this estimate of natural mortality, however, it is not known which herd these catches are removed from making it impossible to include in our calculations. The catch of adults and pups only range between 2,000 and 3,000 seals (Kapel 1975) and it is unlikely that the natural mortality would be over-estimated by more than 2% based on these catches.

Virtual Population Analysis

Pup production in 1970 was estimated at 30,900 (Table 3) and this value was assumed for 1971. Based on the partial recruitment, catch frequency, and fertility rate the number of females in each age group was subsequently determined. Given that we assume this starting population, cohorts for a number of years hence can be calculated from catch at age data using equation I. This forward projection from 1971 to 1976 was used to determine starting hunting mortality, F, values for virtual population analysis. F values were determined in somewhat different manner than in other virtual population methods Gulland (1965) since the catch takes place during a short period of time.

Given that

$$(3) \qquad F = \ln\left[\frac{{}_iN_t}{{}_iN_{t+1}}\right] - M$$

by substituting equation (1) for ${}_iN_{t+1}$ the following equation is determined.

$$(4) \qquad F = -\left(\ln \;(1 - {}_iC_t \;/\; {}_iN_t)\; \mathrm{EXP}\;(-M) + M\right)$$

The terminal or starting average hunting mortality value for 1976 was found to be 0.101. Thus total mortality in 1976 is about 0.225 a value substantially higher than that experienced by harp seal (Lett and Benjaminsen 1977).

Since the catch occurs before natural mortality is applied to the population the cohort sizes in the terminal years were estimated using the following equation.

$$(5) \qquad {}_iN_t = \frac{{}_iC_t\; \mathrm{EXP}\;({}_iF_t)}{\mathrm{EXP}\;({}_iF_t) - 1}$$

After the cohort size is determined in the terminal years the equation

$$(6) \qquad {}_iN_t = (N_{t+1} + C_t) \times \mathrm{EXP}\;(M)$$

is applied sequentially, the cohort size within an age-group in each year depending on the cohort size within the age group the year before. Terminal cohort sizes for 25 year old hooded seals was determined by averaging the hunting mortality values for ages 6 to 25 and applying these using equation (5) to the catch of 25 year old animals. The population in 1971 was then determined based on these calculations (Table 4).

Historical Population Estimates and Estimates of Mean Age of Whelping

Catches for this population have been recorded since the second World War (Table 1) although little was done of a scientific nature until 1971. If one assumes that partial recruitment in the fishery has not changed much over the period however, this data becomes very interesting and useful.

One important factor that must be considered is the proportion of Newfoundland and West Ice seals that molt in the Denmark Strait. Since these two herds are surmised to be of about equivalent size it was assumed that 50% of that catch in the Denmark Strait comes from the Front herd and 50% from the West Ice herd. All age groups are fully recruited in the molting patch, while partial recruitment in the whelping area is 0.019, 0.412, 0.558, and 1.000 and so on, for age groups 1, 2, 3 and 4 etc. Furthermore, only the female sector of the hunt is considered.

Since the projection goes back through time, recruitment to the model is through the oldest age group. This is done with a random number generator (77-33), with the value being passed upon estimates between 1970 - 1976 from cohort analysis. The catches in individual years are broken over the age groups in relation to partial recruitment and the population structure. Pup production is calculated from the catch of pups and natural mortality, which was assumed to be the same as that for adults. The following values were calculated with the simulation.

YEAR	ESTIMATED PUP PRODUCTION	ESTIMATED 1+ Female Pop.
1946	27110	-
47	24641	74065
48	31438	70607
49	29500	65785
1950	26264	68107
51	31714	67640
52	22582	59176
53	24495	58442
54	23545	59227
1955	24977	57748
56	28202	57586
57	21443	54239
58	26319	53479
59	25910	52592
1960	25103	54524
61	23373	55540
62	21867	58140
63	25116	60199
64	23770	61105
1965	22651	58957
66	33369	60035
67	35217	55511
68	36166	57392
69	34830	65769
1970	30900	64465

Tests were conducted to determine how sensitive the model was to different level of terminal-age-recruitment. It appears that the model was almost totally insensitive to these values, and cohort size but age 5 was much more dependent on the catch data. It can be seen from the forgoing table that pup production varied considerably, and this it not related to the terminal age recruitment.

One interesting feature of the table is the drop in pup production prior to 1966. The feature is not explainable by poor assumptions concerning the Denmark Strait hunt since there is essentially no hunt in this area following its closure in 1961. Thus either a dramatic change in productivity of the herd suddenly took place, or breeding females emigrated to the Newfoundland whelping area or the total kill of pups is not recorded. However, for what ever reason, it is our belief that data before 1966 is not comparable with that afterwards.

The annual number of 1+ females is plotted in Fig. 2 between 1947 and 1970. It would seen that the stock has been slowly building up since 1960 primarily due to the closure of the Denmark Strait hunt in 1961. This is not surprising when one considers that the average kill between 1947 and 1960 was 23232 animals. Even more significant is the fact that the reduction in kill was 1+ animals, probably a substantial number of breeding females. This is possibly the cause of the change in productivity which occurred in 1966.

It has been proposed by Sergeant (1966, 1973) that mean age of whelping for harp seals is related to the size of the population. Lett and Benjaminsen (1977) and Capstick and Ronald (1976) upon further analysis found this to be indeed the case. Øritsland (1973) presents data on the maturity and reproductive performance of hooded seals in which he uses a combined sample between 1967 and 1972. His conclusions are as follows.

AGE	1963 (Øritsland, 1974)	1969 (Øritsland, 1973)	1971 (Thus Study)
3	0.05	0.12	0.22
4	0.48	0.58	0.89
5	0.75	0.75	0.99
6	0.90	0.86	1.00
7	0.96	0.97	1.00
8	0.98	0.98	1.00
9	0.98	0.98	1.00
10	1.00	1.00	1.00

Unfortunately, Øritsland's (1967 - 1962) sample was removed from the breeding patches, thus only precocious females would be in the sample. He claims his method of counting persistent scars from the corpus luteum is valid since these scars will persist for three years after they have formed. By examining the ovaries of a mature female and counting the number of scars one can evaluate when the animal first matured. Unfortunately there is no way of counting missed pregnancies or being sure when the animal matured after it has ovulated 4 or more times. Thus there is a tendency to overestimate the mean age of maturity.

The 1970 - 1972 sample was taken from the moulting patch and therefore could be evaluated for mature or non-mature animals since all age groups were totally represented. Thus the only sample in which we can have complete confidence are those presented for the first time in this study.

Due to the lack of information iterative numerical method was developed to estimate the mean age and standard deviation of maturity. Using the age frequency and pup production generated by the program to calculated historical population size, a maturity ogive was fitted to the 1+ female population until the number of pups corresponded to the predicted pup production by less than 10 animals. If the required pup production meant the animals less than the age of 3 would have to mature then the standard deviation of the maturity ogive was reduced by a designated increment and the process was reiterated until a suitable fit was obtained. The initial starting ogive and standard deviation was that of Øritsland (1973). It was felt that this was a maximal position for the ogive, and if the mean age of maturity did get greater it was unlikely that the standard deviation would change. Results were obtained from 1947 to 1970.

Two facts were striking. First the standard deviation of maturity, and the mean age of maturity were highly correlated, and that again factors prior to 1966 where different than those afterwards. In other words, mean age jumped from 4.3 yrs. in 1967 to 5.5 yrs. in 1966, for no apparent biological reason.

If maturity, as argued by Lett and Benjaminsen (1977), is a function of the growth rate of hooded seals in the juvenile stages there should be some lag between the position of the ogive and population size of 1+ seals, if indeed there is a density dependent mechanism. This relationship is shown in Fig. 3. It would appear that minor changes in the 1+ female population lead to changes within the position of maturity ogive. That is to say a 9% increase in the stock size caused a 24% increase in the mean age of maturity. For harp seals a 100% increase in stock size lead to a 31% increase in the mean age of maturity (Lett and Benjaminsen, 1977). The mechanism and reason for this is yet to be elucidated.

<u>Numbers at age</u>

Numbers at age were determined by projecting the 1971 population forward using the catch data in Table 4. Each year before that catch, a maturity ogive was applied to the population to calculate pup production which was subsequently divided by two, to give the number of female pups. Equation I was used to project the population ahead.

Maturity, a density dependent function of the population 3 years previous, is given by the equation.

(7) $$\text{Mean Age} = 1.222 \times 10^{-4} \times \text{L POP} - 3.337$$

where MEAN AGE is the mean age of maturity, and L POP is the population lagged by 3 years.

The standard deviation of the maturity ogive is calculated by

(8) $SD = 0.466 \times MEAN\ AGE - 0.9245$

Mean ages of maturity are given in table 5, in addition to numbers of age and pup productions. The population has declined and risen again to a level seen in the late 40's and early 50's. The estimated number of pups in 1977 is 30930 for a total population of 66546 1+ females. Since 1971 the population has achieved a certain level of stability. Pup production between 1971 and 1972 dropped from 33497 to 26827 primarily due to the increase in population size between 1968 and 1969. This effected the maturity ogive such that the mean age of maturity increased from a predicted 3.68 years in 1971 to 4.70 in 1972.

Construction of Simulation

The simulation was written in A Programming Language and is represented in the flow chart in Fig. 4.

The program initiated by entering in the 1977 population size, 1+ female population size 3 years earlier and level of fishing mortality for 1+ seals and pups. The number of years to be simulated constrains the internal clock.

The number of pups are calculated using equations 7 and 8 and applying the results from

(9) $MAT \leftarrow \phi\ [(AGE - MEAN\ AGE) / SD]$

to the total population. The number of pups and 1+ seals killed are then calculated using the partial recruitment

AGE	1	2	3	4	5	6
	0.000	0.000	0.019	0.412	0.558	1

the population is then updated using

(10) $N_{t+1} = [N_t - N_t \times EXP\ (-\partial_t F_t)] \times EDP\ (-M).$

and the pups and adults are shifted along one year in the numbers at age vector.

Different factors of interest are accumulated and printed out when the clock time has expired.

Results of the Simulation

The simulation was used to generate different Shaeffer type curves for varying levels of pup catch and 1+ catch (Fig. 5). Maximum sustainable yield for the stock is about 20,000 pups where there is not hunting of older females. This MSY level for pups declines as more females are removed. The MSY population level with no older female catch is about 55,000 1+ females. Because both adult females and pups are removed it may be impossible to achieve the highest MSY level. In addition, because of the lack of sound data our management objectives should be more conservative and our objective should be more likely 2/3 FMSY (Doubleday, 1976). Implications of different strategies are shown in Fig. 2 A low F on adult females of 0.05 and F on pups of 0.35 allows the population to stay stable. By dropping the hunting mortality to 0.025 on adult females, which is closer to that noted for harps to 2/3 FMSY population level will be achieved about 1984. This means a catch of 9,200 pups and 800 1+ females. This would make the total TAC for 1978 11,000 hooded seals if the 1977 sex ratio in the catch is maintained. This means by 1984 the catch of hooded pups could be 12,000, with an additional 1,000 1+ females. This would mean a future TAC of about 14,000 seals, and this value could rise as our data, and confidence in prediction improves.

TABLE 1

Total catch of hooded seals off Newfoundland and in the Denmark Strait from 1946 - 1977

	NEWFOUNDLAND		DENMARK STRAIT	TOTAL KILL
YEAR	Pups	1+	1+	
1946	5171	734	17767	23672
47	1851	2784	14130	23201
48	8577	7220	16020	31817
49	5021	891	1494	28261
1950	1666	394	17742	19802
51	10461	2948	47607	61016
52	1439	248	16910	18597
53	3716	1850	2902	8473
54	2638	1054	18292	21984
1955	3956	1549	10283	15788
56	6647	7254	12840	26741
57	109	72	21425	21606
58	4712	3856	14950	23518
59	4216	611	6480	11307
1960	3050	1728	7930	12708
61	2272	319	0	2591
62	1067	165	967	1386
63	4632	1662	813	7107
64	4599	6302	360	11261
1965	2869	1327	0	4196
66	16751	8785	782	26318
67	8380	6440	0	14820
68	1208	535	0	1743
69	8821	9552	0	18373
1970	5320	1870	979	8169
71	8041	6905	0	14946
72	6928	5672	869	13469
73	4602	1965	0	6567
74	5991	4008	1201	11200
1975	7652	7960	0	15612
76	6483	5795	323	12601
77	8915	3259	0	12174

Pup catches of hooded seal at Newfoundland and the survival of corresponding year-classes of females by a survival index (frequency in sample/average frequency.) Below the year of sampling is given the number of specimens and the weight given to the sample is calculating the weighted mean.

YEAR CLASS	TOTAL PUP Catch $\times 10^{-3}$	SURVIVAL INDEX						WEIGHTED MEAN
		1971 368 4	1972 583 5	1973 199 3	1974 576 5	1975 361 4	1976 1136 7	
1961	2.3	1.08						1.08
62	1.1	1.22	1.09					1.15
63	4.6	0.93	1.21	1.70				1.24
64	4.6	1.34	0.87	0.97	0.92			1.01
1965	2.9	1.11	0.77	1.09	1.06	0.47		0.89
66	16.8	0.57	0.61	0.87	0.70	0.42	0.74	0.65
67	8.4		0.84	0.91	0.88	1.14	1.09	0.99
68	1.2			1.36	1.37	1.20	1.25	1.30
69	8.8				1.03	1.09	0.92	0.98
1970	5.3					1.15	0.91	1.00
71	8.0						1.05	1.05

TABLE 3

Pup production of hooded seal pups off Newfoundland from 1963 to 1970 estimated from linear function (6.M) regression of survival indexes on pup catch.

PERIOD	MID-YEAR	PRODUCTION	r
1961 - 66	1963	32.9	0.79
1961 - 67	1964	33.8	0.78
1961 - 68	1964	31.5	0.80
1962 - 68	1965	31.3	0.80
1961 - 71	1966	32.8	0.78
1962 - 71	1967	32.3	0.78
1963 - 71	1967	31.2	0.77
1964 - 71	1968	33.3	0.79
1965 - 71	1968	33.1	0.79
1966 - 71	1969	32.2	0.95
1967 - 71	1969	31.5	0.89
1968 - 71	1970	30.9	0.88

TABLE 4

Catch at age data for 1+ females and female pups caught of Newfoundland.

AGE	1971	1972	1973	1974	1975	1976
0						
1						
2						
3	60	18	0	18	76	34
4	576	622	134	336	853	711
5	408	463	236	414	840	642
6	731	311	145	509	740	512
7	684	305	108	255	627	406
8	396	288	113	168	502	456
9	360	276	70	177	126	276
10	252	200	97	121	113	147
11	228	159	59	82	126	120
12	144	106	33	91	88	140
13	120	94	17	69	63	103
14	108	83	11	82	51	34
15	60	71	11	48	26	30
16	36	71	6	22	76	50
17	24	59	6	31	101	17
18	12	53	6	13	26	17
19	36	18	6	13	26	27
20	36	53	6	13	26	27
21	12	42	6	5	13	4
22	12	30	6	13	13	7
23	12	18	6	5	13	4
24	36	12	6	5	13	7
25	12	6	6	5	13	7

Table 5. Number of female hood seals at age based on catch at age and a 1971 calculated population size. Pup productions are males and females and were calculated with a maturity ogive assuming 100% pregnancy.

AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	33497	26827	29336	29162	30981	31651	30930	32244	34762
1	12023	11244	8789	10925	10235	10305	10042	9627	10036
2	10117	10621	9933	7764	9651	9041	9096	8871	8505
3	12012	8938	9383	8774	6859	8526	7838	8036	7837
4	8139	10559	7880	8289	7735	5992	7342	6921	7095
5	4352	6682	8778	6842	7025	6080	5055	6420	6051
6	4195	3485	5493	7546	5679	5464	5129	4404	5593
7	4373	3061	2804	4725	6216	4363	4609	4419	3795
8	3231	3259	2434	2381	3948	4937	3681	3971	3808
9	1656	2505	2625	2051	1955	3045	4165	3172	3422
10	1320	1145	1969	2257	1655	1616	2569	3589	2733
11	1562	944	835	1654	1887	1362	1364	2214	3092
12	838	1179	693	686	1389	1556	1149	1176	1907
13	800	614	948	584	525	1149	1313	990	1013
14	831	601	459	822	455	409	970	1132	853
15	748	639	458	396	654	357	345	836	975
16	256	608	502	395	307	555	302	298	721
17	276	195	475	438	329	204	469	261	257
18	139	223	120	414	360	202	173	405	225
19	290	113	150	101	354	295	171	150	349
20	260	225	84	128	78	290	249	148	129
21	181	198	152	69	101	46	245	215	127
22	125	150	138	129	56	78	39	212	185
23	188	100	106	117	102	38	66	34	182
24	80	156	73	88	99	79	33	57	29
25	106	39	127	59	74	76	67	29	49
TOTAL NUMBER 1+ FEMALES	68098	67470	65395	67621	67718	66051	66546	67575	
						Catch pups		9134	9522
						Catch adults ♂		819	848

Mean age of maturity

1971	1972	1973	1974	1975	1976
3.68	4.70	4.54	4.99	4.91	4.65

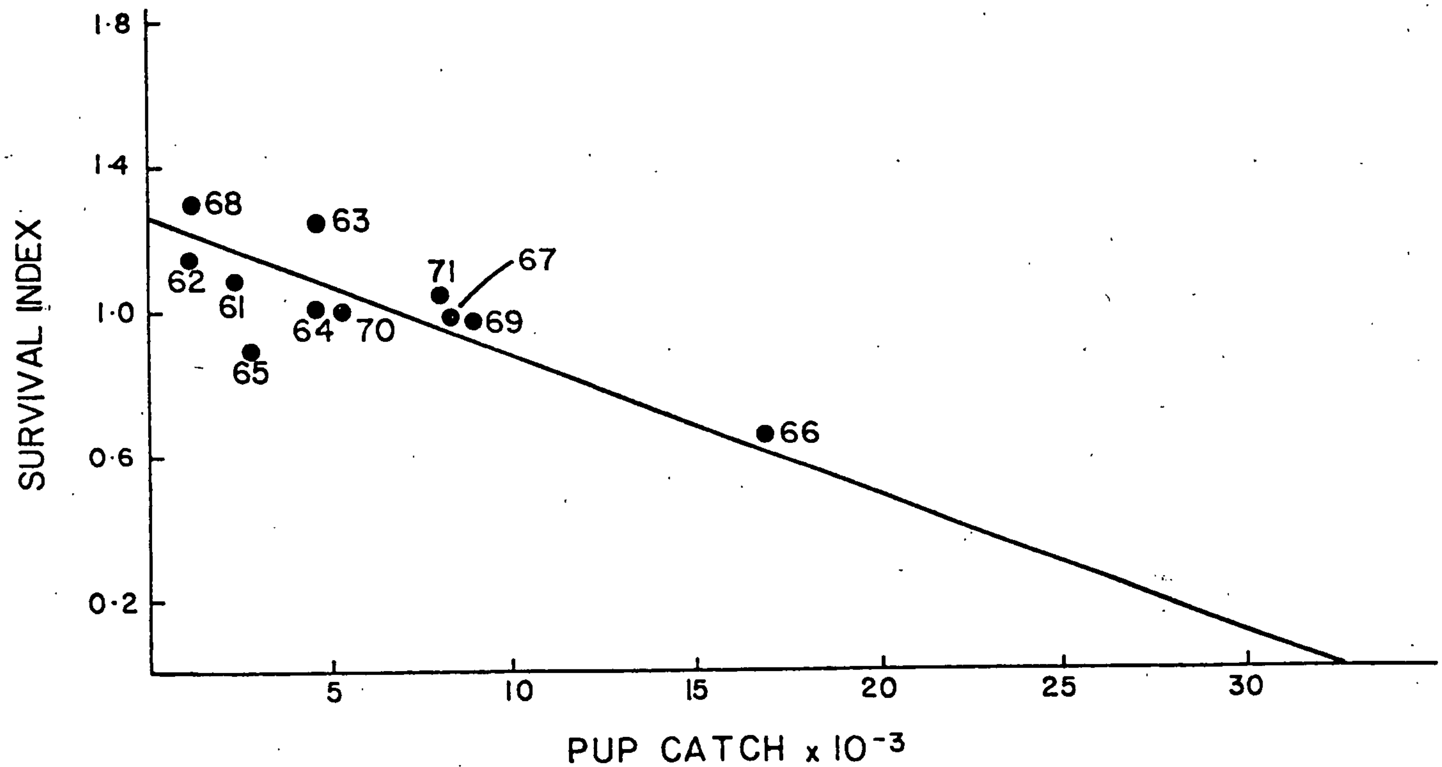

Figure 1. Relationship between survival index and pup catch between 1961 and 1971. Average production for the period is about 33,000 pups.

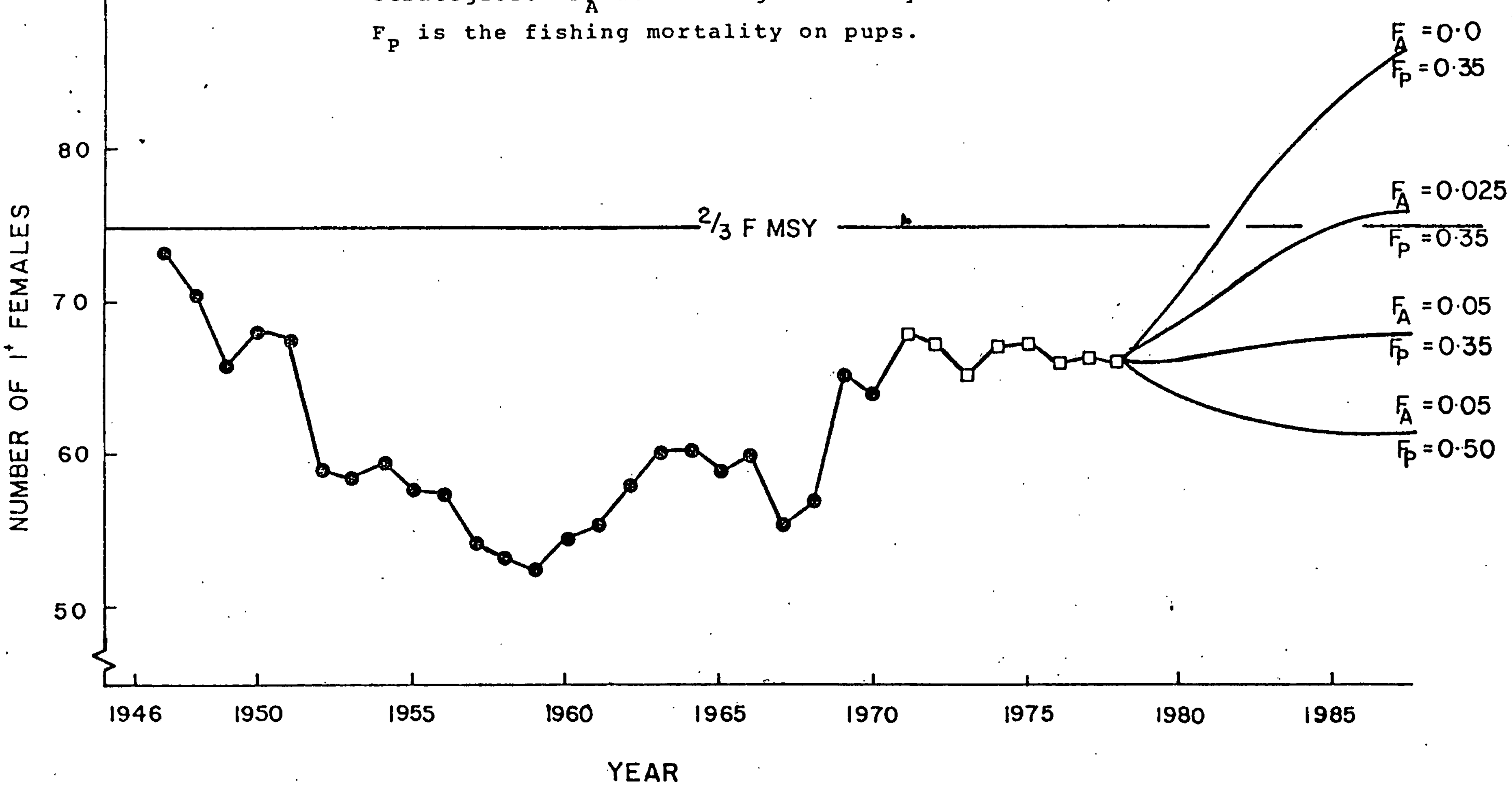

Figure 2. Time series of population numbers of 1+ females from 1947 to 1977. Round dots are from back projection program, squares are from forward projection using catch-at-age data, and solid lines from simulation using different management strategies. F_A is fishing mortality on 1+ seals, F_P is the fishing mortality on pups.

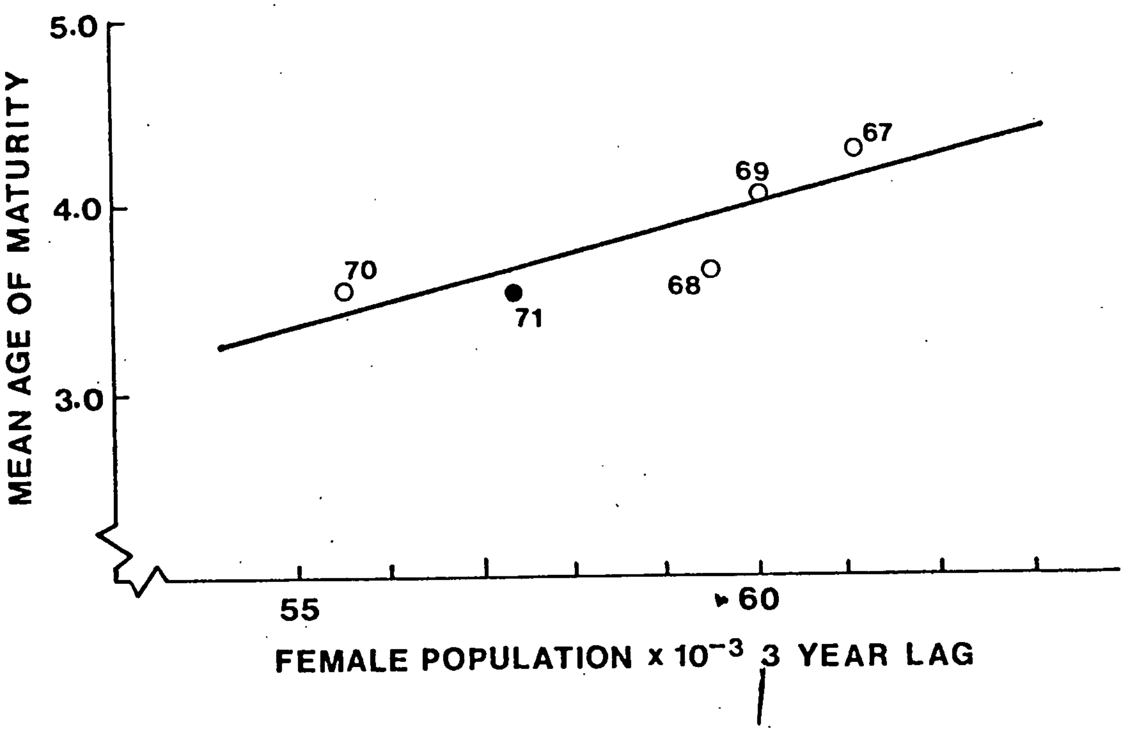

Figure 3. Relationship between mean age of maturity and 1+ female population size lagged by 3 years. Dark dot is a measured value while open circles are values determined using numerical techniques.

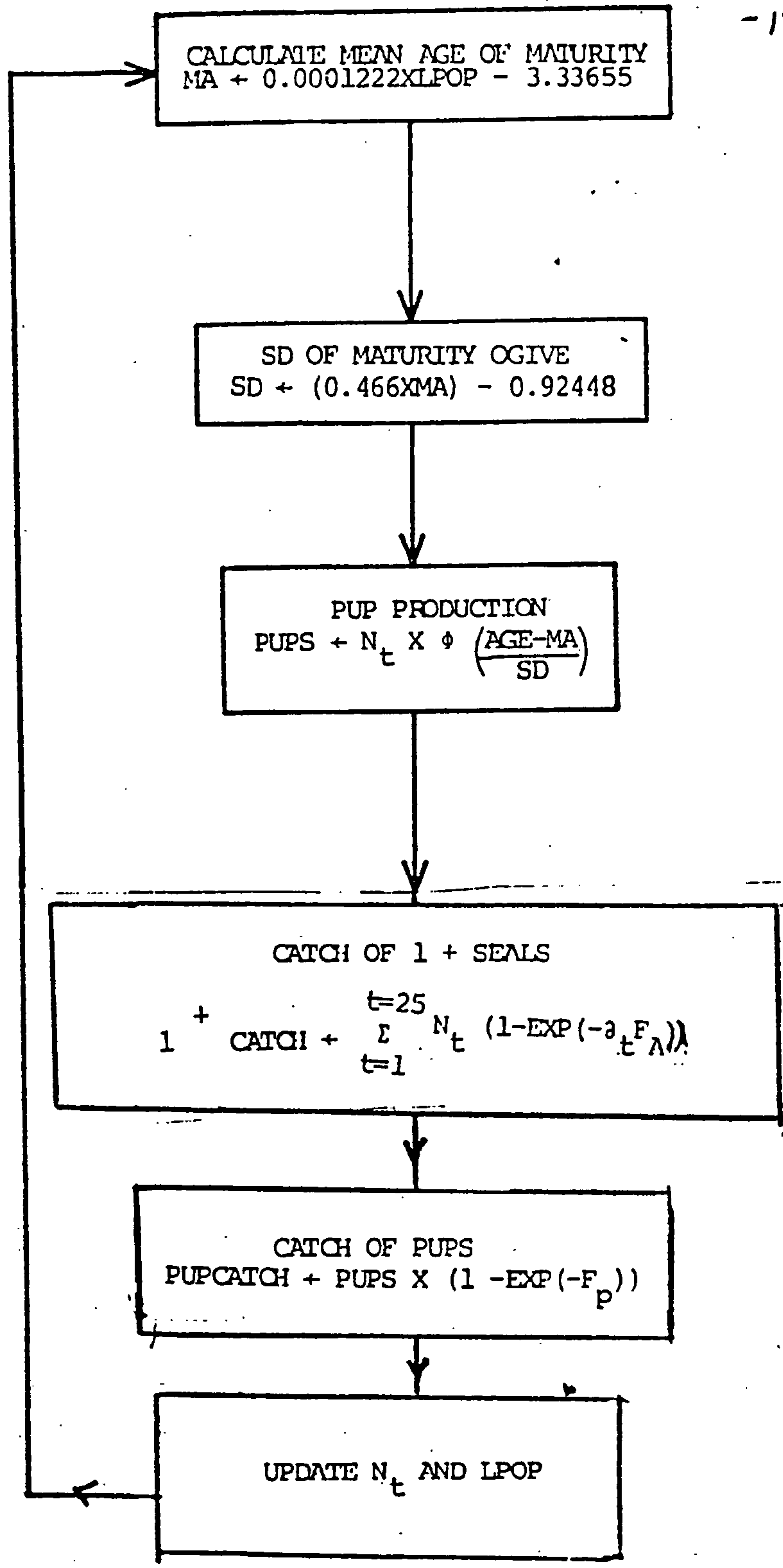

Figure 4. Flow chart of APL program simulating hooded seal population dynamics.

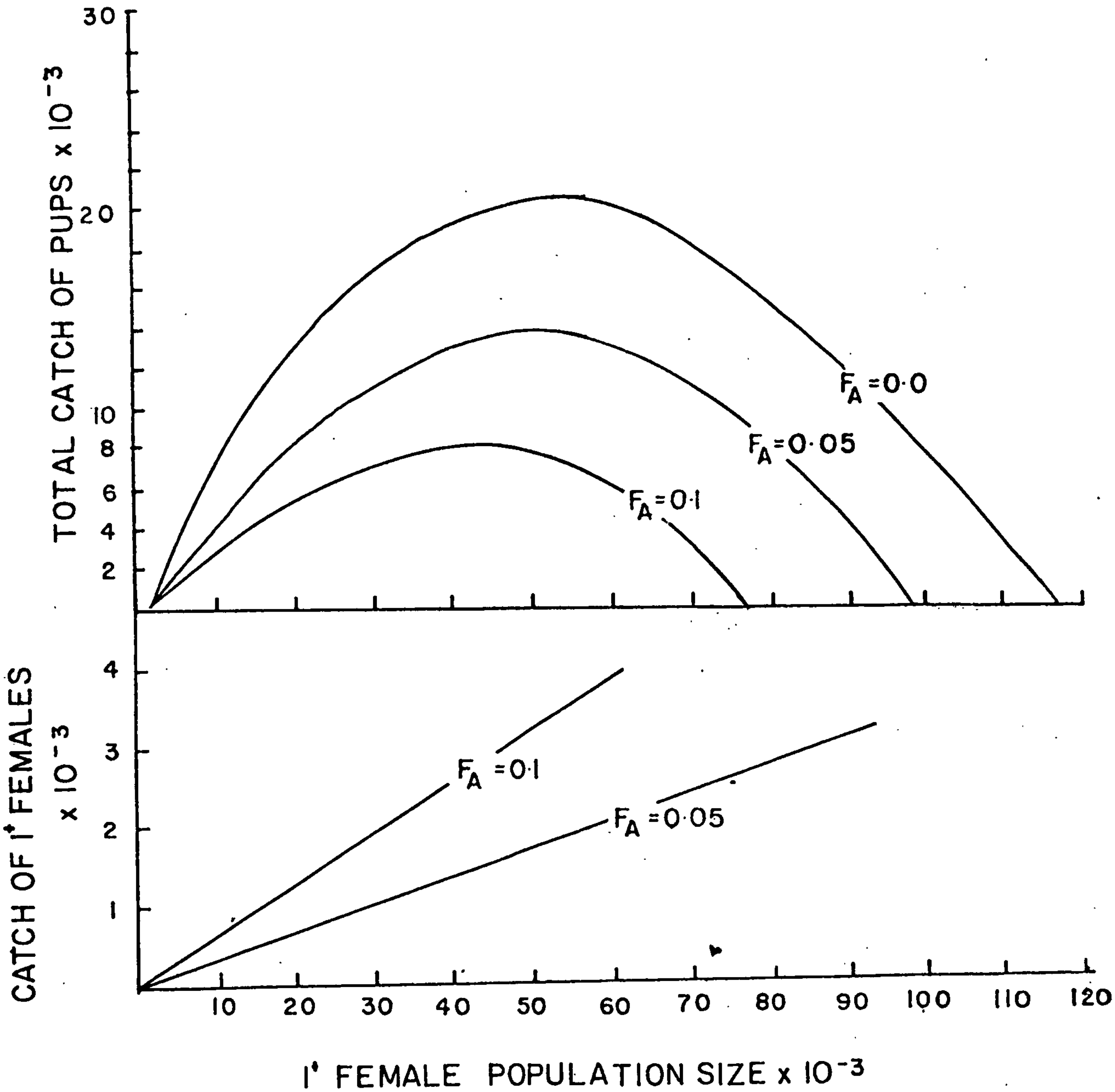

Figure 5. Top figures are simulated Graham-Shaeffer type curves for different levels of hunt, while bottom figure is relation between stock size and catch of females for different levels of hunt.

F_A = Fishing mortality adults.