International Commission for the Northwest Atlantic Fisheries

Serial No. 5145
(D.c.11)

ICNAF Res.Doc. 77/XI/68
(Revised)

SPECIAL MEETING OF STACRES - NOVEMBER 1977

# New estimates of harp seal production on the Front and in the Gulf of St. Lawrence and their impact on herd management[1]

by

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## Introduction

Estimation of the number of harp seals has proved to be somewhat of an enigma. Two approaches have been developing in parallel, a direct method using aerial sensing techniques (Lavigne, 1976) and indirect methods such as survivorship indices (Sergeant, 1969; Benjaminen and Øritsland, MS 1976) and sequential population analysis (Lett and Benjaminsen, 1977). Other visual estimates have been made which also rely on a systematic, fixed method of estimation (see p. 1175, Lett and Benjaminsen, 1977).

The aerial sensing method using ultraviolet photography produced a mean estimate of 125,958 pups in 1975 (Lavigne, 1975), or 14,671 pups less than the actual catch. This cursory appraisal was due to an unrealistic low estimate of the Front[2] herd (Lavigne, 1975) in addition to a number of other confounding factors. The 1977 aerial sensing produced a mean estimate, after correction factors were applied of 249,975. This value was contingent upon the use of the 1975 value for pup production in the Gulf of 46,300 animals, since the 1977 survey in this area was deemed incomplete (Lavigne et al., 1977). However, it is our opinion that this estimate is particularly suspect, since the catch of pups in the Gulf in 1971 was 74,182 seals. In 1972 the

[1] Following the Special Meeting of STACRES, 15-18 November 1977, this paper was revised at the request of the *ad hoc* Working Group on Seals. It contains important changes which could not be discussed at the Meeting.

[2] Front refers to the area where harp seals are present between February and May, off the east coast of Labrador and Newfoundland.

Gulf was closed to hunting, thus the stock should have started to build up by now, not to decline as the 46,300-estimate implies. The average catch of Gulf seal pups in the Gulf between 1964 and 1971 was 77,129.

Survivorship indices, projected ahead to 1977 using a numerical model, imply that pup production is now between 315,000 and 330,000 animals (Benjaminsen and Øritsland, MS 1976). Sequential population methods suggest that pup production between 1975 and 1977 has increased from 307,000 to 320,000 although these estimates are considered to be conservative (Lett and Benjaminsen, 1977).

Each year through the auspices of the International Commission for the Northwest Atlantic Fisheries (ICNAF) the status of the herd is re-evaluated, and new sources of data are brought a forward for analysis. This paper presents a new method for separating the Gulf and Front herds, in addition to fine tuning some of the parameter values and submodels associated with the Lett and Benjaminsen model (L-B model). Furthermore, new levels of maximum sustainable yield (MSY) and sustainable yield are calculated considering the Front and Gulf herds as separate breeding stocks which intermix at the juvenile stage.

Lastly, this paper will discuss the suppositions related to whether the Northwest Atlantic population is indeed one or two herds and the impact of each hypothesis on management. In the past, it has been too easy to select the hypothesis which most conveniently solved the problem at hand, without proper consideration being given to the impact on herd management.

Data Sources

The assessment of an animal population requires the estimation of certain vital rates. Estimation of these rates depends mostly on the analysis of age frequencies and data related to the productive potential of the animal.

The main problem associated with the population modelling of harp seals has been the estimation of natural mortality. To estimate this parameter, the population structure as derived from Benjaminsen and Øritsland (MS 1975) and Lett and Benjaminsen

(1977) is required. Further data on the age frequency in the large vessel and landsmen hunt for 1977 are presented by Sergeant (1977) and the weighted age frequencies are presented in Table 1.

Lett and Benjaminsen (1977) have already discussed the fact that only a sample of moulting males will represent the seal population structure. Unfortunately, in 1977 the sample taken was not sexed, thus the adjustment factors shown in Lett and Benjaminsen (1977, Fig. 1) were applied to the sample so that it would approximate the real population structure.

No new data were collected concerning maturity other than that already presented by Benjaminsen and Øritsland (MS 1975), Lett and Benjaminsen (1977) and Sergeant (1966, 1976). However, this information was revaluated to calculate new estimates of natural mortality and population numbers.

Catch and effort information not previously used in the analysis of the population dynamics of harp seals came from a number of Sources (Anon. 1968, 1975, 1977; G. Burke, Grand Falls, Newfoundland, pers. Comm.; Curran, MS 1977). This data was used to calculate pup production in the Gulf as well as check on aerial census estimates for the Front.

Estimating the Production of Harp Seal Pups in the Gulf of St. Lawrence

The escapement of pups from the Gulf of St. Lawrence in any one year depends on the level of hunting within the Gulf, and the original pup production. After "break-up" the pups move out of ICNAF Div. 4T into ICNAF Subdiv. 4Vn and 3Pn. They then "beat" their way north along the west coast of Newfoundland, where they are caught by landsmen in small power boats and by longliners. In Subdiv. 3Pn beaters are also taken by landsmen walking out from shore or in small power boats.

The method employed to analyze the data relies on hunting pressure occurring randomly, not staying constant from year to year or tending toward higher or lower levels. With the closing of the Gulf to hunting by all individuals except landsmen and inceased surveillance in the area, the consistency of the statistics was altered (G. Burke, pers. comm.) For these reasons the analysis was restricted to the data for the years 1964 to 1971. The data are as follows:

| Year | Men | Landsmen 4R, 3Pn catch | Catch/Man 4R, 3Pn | Catch in 4T | Escapement 4T | Pup Production | Smoothed Pup Production |
|---|---|---|---|---|---|---|---|
| 1964 | 716 | 3,490 | 4.87 | 91,927 | 38,545 | 130,471 | 119,997 |
| 1965 | 1,918 | 19,635 | 10.24 | 18,011 | 81,047 | 99,058 | 106,852 |
| 1966 | 615 | 7,415 | 12.06[1] | 60,484 | 38,344 | 98,818 | 98,697 |
| 1967 | 274 | 334 | 1.22 | 88,921 | 9,644 | 98,577 | 94,356 |
| 1968 | 191 | 646 | 3.38 | 54,698 | 26,732 | 81,450 | 90,564 |
| 1969 | 732 | 6,057 | 8.26 | 35,402 | 65,375 | 100,777 | 94,982 |
| 1970 | 803 | 4,775 | 5.95 | 49,830 | 47,092 | 96,922 | 92,659 |
| 1971 | 406 | 526 | 1.30 | 65,726 | 10,289 | 76,015 | 89,952 |

[1] Not included in analysis, explanation is within the text.

The catch in Div. 4T includes pups caught by the Madeleinot, Canadian, and Norwegian large vessels, and aircraft. These catches were plotted against the catch per man in the 4R, 3Pn fishery (Fig. 1) and produced an inverse correlation. The 1966 point was not used because of its inconsistency with the remaining data. In this year, the catch per man of landsmen was particularly high because of abnormally loose ice conditions (Curran, per. comm.), thus a large catch of beaters resulted during early April north of 50°N (Sergeant, per. Comm.). The year 1965 was also exceptional since the so-called Mecatina patch drifted close to the western Newfoundland shore and resulted in a large kill. However, since ice conditions were normal in that year, power-boat operators still had the same degree of difficulty in hunting these animals, and thus the catch per man was usable in the analysis. These two situations certainly indicate that the separate Gulf sub-herds which seem to have distinct whelping periods and locations, and the activity of the herd and hunters, depends heavily on environmental conditions.

A GM regression (Ricker, 1973) was applied to the ordered pairs of 4T catch, and catch per man (r=-0.791), since there is a sizable variance in both the estimation of the independent and dependent variables. The intercept on the independent axis should represent the average production in the Gulf between 1964 and 1971. Thus the average production for the period is estimated at 97,611 pups. It should be noted that the inclusion on the 1966 point alters this estimate by less than 1%, even though the correlation coefficient drops significantly. The average catch in 4T for the period was 57,789, leaving an average escapement of 39,423 pups.

The relationship between escapement and the catch per man in the 3Pn, 4R fishery should be positive, linear, and go through the origin. Since the average catch per man is 5.03,

$$\text{Escapement} = 7{,}917.1 \times \text{CUE}$$

Thus, by knowing the catch per man, the escapement is predictable, as is the overall production when this is summed with the catch.

As illustrated in the foregoing table, pup productions predicated in this way are variable, but not so much that the trends cannot be detected. Therefore, we decided to use a running average, to produce values more consistent with the actual biological trend in Gulf production, by taking half the value on either side of the year of interest, and summing this with the mean year value and dividing by two. On end years, two-thirds of the 1964 and 1971 values were presented in the last column of the foregoing table.

Gulf seals have been known to whelp on the Front when the ice conditions were unfavourable (Lett and Benajminsen 1977), but the smoothing is justified since these seals can still be designated as Gulf breeding stocks.

Using a method devised by Ricker (1972) and suggested by Winters (pers. comm.), the escapements between 1964 and 1971 were projected ahead to 1978. It was necessary to make the following assumptions.

(1) The maturity ogive gradually shifts (linearly ) from that presenting in Lett and Benjaminsen (1977) to that presented in Sergeant (1976). No animals under 4 years of age will produce a pup.

(2) The mixing of Gulf bedlamers was in accordance with Sergeant's (1977) tag returns in the Front.

(3) The pregnancy rate was 0.95 (Lett and Benjaminsen, 1977).

(4) One-third of the total catch of bedlamers were Gulf animals times the fraction presented in Sergeant's tag returns, since previous estimates indicate that one-third of the total stock stock resides in the Gulf, while two-thirds on the Front.

(5) Fraction female bedlamers was assumed to be 0.50 in 1971 (Lett and Benjaminsen, 1977).

By substracting the catch, using assumption (4) and catch data from Lett and Benjaminsen (1977), the 1964 to 1970 pup productions were brought forward to 1971 to represent the population aged 7 to 1, respectively. After applying the maturity ogive, fraction female, and pregnancy rate to these 1- to 7-year-old animals, the remaining animals required to make up the breeding stock were calculated by subtracting the sum of the breeding females aged 1 to 7 from the 1971 pup production. These remaining seals were designated as 8+. For this reason it should be noted that the estimation of the number of seals in the Gulf in 1971 is fairly critical in projection made beyond this point, and that variations in this estimate could have substantial influence on further conclusions.

According to the calculations presented here, pup production reached a minimum in 1974 of 87,622 seals. There was a continual decline from 1964 to 1974. The upsurge in 1975 was not due to the closing of the Gulf, but more a result of the entry of the 1969 year-class into the breeding stock. Since this time the Gulf herd has been increasing at about 8%/year, or at the same rate as the 1+ stock. Lavigne (1977) has criticized Canadian Government management policy on the basis that we have no idea that the harp seal herd will increase if protected. These figures would contradict his statement (see Lavigne, 1977, p.11). Furthermore, Lavigne et al. (1977) state that the best figure for Gulf production is 46,300 seals in 1975, however our calculations would indicate that slightly less than half of the seals were actually photographed.

It has become apparent that it is quite difficult to photograph pups in the Gulf due to (1) the time over which whelping occurs, and (2) the spatial distribution of seals. Whelping in 1977 has been recorded as early as 25 February and as late as 21 March (S. Dudka, pers. comm.). Moreover, whelping occurs along leads and cracks in the ice which go for tens of miles. This statement is supported by the results from the 1977 aerial census where 1.07 times as much area was flown in the Gulf than on the Front, but only 14% as many seals were counted.

Sequential Population Analysis

The sequential population analysis of the harp seal herd was based upon the catch-at-age data in Table 1 and assumptions on starting population sizes and final catch rates. Since the hunt is mainly concentrated at one time of the year, the appropriate form of the catch equation to use is:

$$N_{t+1} = (N_t - C_t) \text{ EXP } ( -M)$$

There is no instantaneous rate of fishing mortality, $F_t$, in this equation and the appropriate indicator of fishing mortality is the exploitation rate, $C_t/N_t$.

Natural mortality, M, was calulated using unpublished estimates of pup production (Winters MS 1978) from survivorship indices between 1966 and 1977. This method of estimating pup production (Benjaminsen and Øritsland, MS 1975) is independent of estimates of M and catch-at-age data (Lett and Benjaminsen, 1977). In addition, information on maturity, sex ratio, and the pregnancy rates are needed to estimate M.

The population structure was determined from large vessel catch in the moulting patches as given in Lett and Benjaminsen (1977) and Sergeant (1977). These catches were multiplied by the fraction males at different ages (see Fig. 1, Lett and Benjaminsen, 1977) to then give the true representation of the population structure of 2+ animals. However, partial recruitments do annually vary to some degree among the younger age-groups, therefore, only animals aged 5 to 22 were used to calculate natural mortality. The maturity ogive was assumed to vary linearly between 1966 and 1977.

By knowing the maturity, sex ratio, pregnancy rate and population structure, the pup production could be broken out over the appropriate age-groups to give estimates of numbers at age. We assumed, as Lett and Benjaminsen (1977), that 6% of the breeding females are over the age of 25. Thus, M can be simply calculated for each age-group using the formula

$$M = \ln \left[ \frac{{}_aN_t - {}_aC_t}{{}_{a+1}N_{t+1}} \right]$$

This gave an estimate of M = 0.1 with an SE of 0.03 between 1966 and 1977 for age-groups 5 to 22. Sampling for ages over 22 was erratic and produced results in which we could have no confidence.

To obtain starting population estimates in 1977, a number of assumptions were made. First, four levels of pup production were assumed, 250, 300, 330, and 350 thousand animals. Justification for these values will be presented in later discussion. The population structure was that of moulting males, determined from a sample of both males and females. There is no available maturity data for 1977, so the latest maturity ogive is that in Table 20 in Sergeant (1976) for 1976. The age structure of breeding females was determined after applying the sex ratios given in Lett and Benjaminsen (1977, Table 6).

Assuming a pregnancy rate of 0.94, this age structure is used to estimate the number of breeding females-at-age needed to produce the given number of pups. From this, number-at-age for the population are derived, except of 1-year-olds.

This initial population in 1977 was projected back to 1952 using the catch data and catch equation, assuming hunting occurs during a relatively short period. The 1976 pup production was estimated during sex ratios from Lett and Benjaminsen (1977) and Sergeant's (1976) maturity ogive. Since pup production likely varies less than the errors in numbers-at-age derived from the moulting patch samples, the pup production was smoothed and projected back to 1977 to re-estimate the starting numbers.

For a complete analysis, all that is now required are starting exploitation rates for the 25-year-olds. Sergeant (1976) has maturity data for 1976 and 1968-1970, and data for several years in the 1950's and early 1960's and in Sergeant (1966). Balancing between the changes in the proportion of the adult population caught and the adult population size needed to yield the obtained pup productions, starting exploitation rates were derived. The final results for numbers-at-age using a 1977 pup production of 330,000 are shown in Table 2 and the exploitation rates in Table 3.

One interesting question that could be answered using the method outlined above was, how low could pup production be in 1977 to produce consistent results. By consistent results, we mean that the maturity ogive in any given year would produce a pup production similar to that determined by an assumed starting population in 1977. It was found that the lowest pup production in 1977 that would give realistic results was 250,000. Values below 250,000 produced results that were impossible, unless there are serious errors associated with the catch-at-age and maturity information, which is generally felt to be our best data.

Density-Dependent Whelping at Age

Sergeant (1966,1973) first proposed that the mean age of maturity was a density-dependent function relying on population size. Indeed, this phenomenon is well noted for other marine mammal (Gambell, 1973) and terrestrial mammal stocks (Markgren, 1969). Lett and Benjaminsen (1977) first showed the mathematical structure of such a relationship, relating maturity to the coincident population size. However, Lett and Benjaminsen (1977) go on to say that it is more likely that maturity is related to the growth rate of juvenile seals which is itself related to the population density. This would imply some lag between population size and mean age of maturity.

Sergeant's (1966, 1973, 1976) maturity data were used to find the best fit between mean age of maturity and population size using different lags. The lag producing the highest correlation was five years. Different pup productions in 1977, of course, gave different answers, but the lag period remained consistent. Thus, the equation that was developed to describe shifts in the mean age of whelping, $\Omega$ , was

$$\Omega = \beta_o + \beta_1 \, pop_{t-5}$$

where $\beta_o$ is a fitted constant, $\beta_1$ is that rate at which changes with the 1+ population size lagged five years, $pop_{t-5}$. For different starting populations, the following results were obtained.

| Pup Production 1977 | $\beta_0$ | $\beta_1$ | $\Omega_{78}$ |
|---|---|---|---|
| 350,000 | 3.011 | 1.609 | 4.87 |
| 330,000 | 3.169 | 1.517 | 4.83 |
| 300,000 | 3.351 | 1.454 | 4.82 |
| 250,000 | 3.663 | 1.281 | 4.76 |

By amalgamating Sergeant's data for various years, it was possible to test for significant shifts in the standard deviation of the maturity ogive. No significant changes were noted, thus, it was possible to fit a cumulative normal or Arc sine transformation to linearize the data. It was found, in accordance with Lett and Benjaminsen (1977) that the Arc sine transformation, using a range of 0° to 90°, gave the best fit to the data. Thus the equation developed was

$$_tE_a = \text{Sine } (31.34 + 19.91 \times \gamma)$$

where $_tE_a$ is the fraction whelping at age a in year t, and $\gamma$

where $_tE_a$ is the fraction whelping at age a in year t, and

is the difference between the mean age of whelping and t. The expression in brackets is constrained within 0° and 90°.

<u>Estimation of Production on the Front</u>

A number of estimates for Front production were determined by subtracting estimates for the Gulf from those determined by virtual population analysis and maturity ogives.

| Year | Gulf pup production | Front pup production based upon different total pup production in 1977: 250,000 | 300,000 | 330,000 | 350,000 |
|---|---|---|---|---|---|
| 1965 | 106,852 | 211,923 | 227,093 | 239,533 | 243,225 |
| 66 | 98,697 | 214,178 | 238,699 | 247,504 | 253,109 |
| 67 | 94,356 | 211,881 | 244,398 | 248,477 | 261,298 |
| 68 | 90,564 | 222,667 | 246,141 | 258,094 | 266,220 |
| 69 | 94,982 | 207,617 | 242,323 | 249,049 | 262,418 |
| 1970 | 92,659 | 208,517 | 243,187 | 252,673 | 265,460 |
| 71 | 89,952 | 203,095 | 237,921 | 248,222 | 263,575 |
| 72 | 89,951 | 201,074 | 222,365 | 243,206 | 253,931 |
| 73 | 88,793 | 195,984 | 216,445 | 243,876 | 253,684 |
| 74 | 87,622 | 180,466 | 204,931 | 234,424 | 248,170 |
| 1975 | 89,384 | 165,620 | 194,800 | 225,625 | 243,566 |
| 76 | 91,631 | 171,101 | 198,512 | 238,493 | 252,634 |
| 77 | 93,324 | 156,676 | 206,676 | 236,676 | 256,676 |

No matter which estimate of total pup production is used, the 1+ population size has been increasing since 1972 when the strict quota of 150,000 seals was introduced (Fig.2). Lett and Benjaminsen (1977) show pup production increasing slightly since 1972, however, in this most recent analysis pup production does not begin to increase until 1975. In the case of 250,000 pups, production is still declining. The upsurge in pup production is due to the entry of the 1968 year-class in addition to the reduced killing of adults. The real effect of the quota on the breeding stock should not be seen until 1978. Pup production in the Gulf began to also increase in 1975 but this was not true for the Front (Fig.3). In the cases of the 300,000 and 330,000 pup production estimates, indeed the most likely estimates, the abundance of pups is still short of the 1972 level, although both lines are beginning to trend toward recovery. The failure of the Front to recover in the same manner as calculated for the Gulf is a result of most of the quota being moved onto the Front when the Gulf was closed to hunting. For a total production of 300,000 pups, the Front sustainable yield is about 130,000 animals; and for 330,000 pups, is about 140,000 animals, assuming the present kill ratio. The total kill on the Front in the past three years has been in excess of about 135,000 seals or close to the sustainable yield. Thus, based upon these calculations, it would be prudent to consider moving some of the quota into the Gulf of St. Lawrence.

Other estimates of total and partial production on the Front are available. Using the daily catch rates and cumulative catches, the DeLury (1947) method was used to estimate the number of seals in the eastern portion of the herd which was thoroughly hunted. This method gives an estimate of 106,000 seals. Lavigne et al. (1977) give an estimate of 115,818 for this portion of the herd using their simple random method.

The DeLury method was also used to estimate the escapement from the whitecoat hunt on the Front. To use this procedure, it was first necessary to intercalibrate the longliners and large vessels by comparing their catch rates when hunting in a similar area. The intercalibration factor determined by the ratio of the CUE's was 8.9 for the period 28 March to 10 April. In other words, the daily effort of one large vessel was equivalent to 8.9 longliners. Unfortunately, the results from this method are inconclusive since the relationship between CUE and catch becomes discontinuous between 10 April and 14 April when the large vessels move out of the fishery. Two estimates were attempted, however, 0 138,000 pups using the data before 10 April and 140,000 using the data after 10 April. The total catch of whitecoats and beaters before 28 March was 59,851, giving a mean estimate of total Front production of 198,851, not much different from the Lavigne et al. estimate of 203,675 pups. However, it should be noted that this t represents a minimum estimate since it only applies to animals in the area of hunting. Animals outside this area are not accounted for.

<u>Update of the Lett-Benjaminsen Model</u>

In order to make estimates of MSY, sustainable yields (SY), and population projections, the model described in Lett and Benjaminsen (1977) was modified to incorporate recent findings. The primary modification was the splitting of the herd into two sub-herds, Front and Gulf. Generally, animals were assumed to remain with the sub-herd into which they were born with the exception of ages 1 to 3. Gulf animals in these age-groups were assumed to be found on the Front with the respective probabilities of 0.79, 0.69, and 0.11 based upon Sergeant's (1977) tag return data. The total herd was split on the basis of 68:32, Front to Gulf. This ratio was determined from the foregoing analysis. The age distribution of the catch on the Front was taken to be the same as that for the total herd published in Lett and Benjaminsen (1977). The distribution for the Gulf, however, was compiled from data from the LaTabatière region. The Greenland and high Arctic catches were subtracted from each herd proportionally to its size.

The whelping ogives differed somewhat from those of the published model. The mean age of whelping was determined in the manner already described with the mean age being a function of the 1+ herd size lagged by five years. Furthermore, this mean age was constrained to be greater than 4.5 years. The pregnancy rate determination is unchanged from the published model.

The MSY and SY estimates were found by taking averages over 10 stochastic runs. Natural mortalities were drawn from a distribution having a mean of 0.1 and an SD of 0.015. The landsmen catch was modelled to have a coefficient of variation of 0.4. Also, the normal distributions were drawn using the Box-Muller transformation instead of summing 12 draws from a uniform distribution as listed in Lett and Benajaminsen (1977). The five-year projections were found was using only the mean values of these parameters.

<u>Catch projections and Calculation of MSY and SY</u>

The TAC for 1978 has been set at 180,000 seals based upon the advice from the <u>ad hoc</u> Working Group on Seals (ICNAF, 1977). This management option was projected ahead using the modified L-B model and the following breakdown of catch, which, in part, was based on the 1976 distribution of effort and an 80:20 pup to adult ratio.

| Fishery | Total | Pups | 1+ Seals |
|---|---|---|---|
| Greenland and high Arctic | 10,000 | 5,000 | 5,000 |
| Norwegian large vessels | 35,000 | 34,000 | 1,000 |
| Gulf of St. Lawrence | 35,000 | 27,000 | 8,000 |
| Landsmen | (15,000) | (8,000) | (7,000) |
| Large Vessels | (20,000) | (19,000) | (1,000) |
| Front Canadian | 100,000 | 78,000 | 22,000 |
| Landsmen | (50,000) | (29,000) | (21,000) |
| Large Vessels | (50,000) | (49,000) | (1,000) |
| All areas | 180,000 | 144,000 | 36,000 |

The catch projections, using a TAC of 180,000 and the above breakdown of catch, are as follows.

| Pups | Year | Front 1+ | Gulf 1+ | Total 1+ |
|---|---|---|---|---|
| $350 \times 10^3$ | 1979 | $920 \times 10^3$ | $456 \times 10^3$ | $1,376 \times 10^3$ |
| | 1980 | 918 | 477 | 1,395 |
| | 1981 | 921 | 497 | 1,418 |
| | 1982 | 932 | 520 | 1,452 |
| | 1983 | 941 | 541 | 1,482 |
| $330 \times 10^3$ | 1979 | 838 | 417 | 1,255 |
| | 1980 | 831 | 436 | 1,267 |
| | 1981 | 829 | 453 | 1,282 |
| | 1982 | 834 | 473 | 1,307 |
| | 1983 | 837 | 492 | 1,329 |
| $300 \times 10^3$ | 1979 | 710 | 357 | 1,068 |
| | 1980 | 696 | 372 | 1,068 |
| | 1981 | 684 | 385 | 1,069 |
| | 1982 | 678 | 399 | 1,077 |
| | 1983 | 669 | 412 | 1,081 |
| $250 \times 10^3$ | 1979 | 545 | 280 | 824 |
| | 1980 | 516 | 287 | 802 |
| | 1981 | 489 | 292 | 781 |
| | 1982 | 467 | 299 | 765 |
| | 1983 | 440 | 303 | 743 |

The sustainable yield calculations were made using a pup production figure of 330,000 for 1977. The rationale behind the use of this figure is as follows. A minimum estimate of pup production that is in keeping with the catch-effort data is about 300,000 seals. Maximum estimates of pup production are as high as 350,000. The figure of 330,000 was calculated for 1977, using sequential population methods and maturity data (Lett and Benjaminsen, 1977) and survivorship indices (Benjaminsen and Øritsland, MS 1976). Thus, the majority of evidence indicates that the 1977 pup production is at or near this value.

The sustainable yield for this pup production is 204,000 seals or 24,000 seals above the present TAC. Lett and Benjaminsen (1977) estimated the sustainable yield for 330,000 seals at 190,000, however, our new estimates of M are 12% lower, thus decreasing the loss of seals by this amount, due to natural causes. In addition, the total catch in 1977 fell short of the quota by 5,000 seals. It should be noted at this point that the sustainable yields calculated b. khe ad hoc Working Group on Seals (ICNAF, 1977) are optimistic in relation to the pup productions. The reasons for this are twofold. First, the new maturity information was not incorporated into the model when these runs were made, and the projections to calculate SY were only brought forward 20 years as opposed to 50 years used in this study. Thus, the good recruitment, resulting from much lower catches due to the installation of the quota, were still having an effect. Furthermore in the L-B model, the Gulf is separate from the Front, but the density-dependent effects occur while stock is mixed in the Arctic. Thus, increases in the Gulf herd causes the maturity ogive to shift to a position which does not compensate as well for the over-exploitation of the Front as would be the case if there are less than 300,000 seals born in 1978 (see foregoing table).

Lett and Benjaminsen (1977) first determined the MSY population level as a reference point for harp seal management at 1.6 million 1+ seals. New data and analysis have allowed us to refine this estimate to 1.5 million, basically due to a 12% drop in our estimation of M (Fig. 4). The maximum sustainable yield is 220,000 seals, assuming 20% 1+ seals and 80% pups in the catch. A previous estimate by Lett and Benjaminsen (1977) was 240,000. However, with the drop of M, the maximum sustainable yield must also drop proportionately.

## Conclusions

Evidence has been presented showing the pup production in the Gulf of St. Lawrence is presently about 100,000 seals. Production in the Gulf has been increasing at 4%/year since 1975 because of s the large escapement in 1969 and the Gulf closure in 1972. It is expected that the rate of recovery of the Gulf of St. Lawrence herd will be greater when the full impact of the 1972 closure is felt.

Based upon numerical methods, the minimum possible total pup production is 250,000. However, biological evidence indicates that a minimum estimate of pup production is 300,000 while the maximum estimate is 350,000; thus a realistic estimate of pup production probably lies between 300,000-350,000 pups in 1977.

The fact that the Gulf pup production increases, while the Front declines, at pup productions less than 300,000 suggests that there is some degree of separation of the breeding stocks. Therefore, maybe TAC's should be assigned separately to these components. Failure to manage these two separate stock components properly may lead to a local overexploitation.

The maximum sustainable yield is 220,000 seals, assuming a kill ratio of 80% pups to 20% 1+ seals, for a 1+ population size of about 1.5 million seals. Under the present TAC of 180,000 animals, this level of population may be achieved in four to eight years.

## Acknowledgement

We would like to thank B. Beck, T. Benjaminsen, P. F. Brodie, F. Kapel, D. M. Lavigne, A. W. Mansfield, M. C. Mercer, H. Rossell, D. E. Sergeant, and G. H. Winters for helpful comments and discussion. We also appreciated the help of T. Curran and D. E. Sergeant in providing unpublished information concerning the landsmen hunt.

References

Anon. 1968. Canadian Atlantic coast harp and hood seal catch statistics. An historical series by regions, methods of capture, types of pelts, area of catch, 1946-1967. Economic Service, Dept. Fish. Can., 26 p.

1975. Canadian sealing statistics, 1968-1974. Intelligence Service Division, Marketing Services Branch, Dept. Envir., 21 p.

1977. Canadian sealing statistics, 1975-1981. Intelligence Services Division, Marketing Services Branch, Dept. Envir., 21 p.

Benjaminsen, T., and T. Øritsland. MS 1975. Adjusted estimates of year-class survival and production with estimates of mortality for northwestern Atlantic harp seals. (Unpublished manuscript).

MS 1976. Age-group frequencies, mortality and production estimates for Northwest Atlantic harp seals updated from samples collected off Newfoundland-Labrador in 1976. (Unpublished manuscript).

Curran, T. MS 1977. Sealing report: 1977 season Newfoundland region 45 p.

DeLury, D. B. 1947. On the estimation of biological populations. Biom., 3: 147-167.

Gambell, R. 1973. Some effects of over-exploitation on reproduction in whales. J. Reprod. Fertil. Suppl., 19: 533-553.

ICNAF. 1977. Report of the *ad hoc* Working Group on Seals. Standing Committee on Research and Statistics (STACRES), International Commission for the Northwest Atlantic Fisheries (ICNAF), 15-18 November, 1977, Dartmouth, N.S., Canada. 13 p.

Lavigne, D. M. 1975. Harp seal, *Pagophilus groenlandicus*, production in the western Atlantic during March 1975. ICNAF Res. Doc. 75/XII/150, Serial No. 3728. (mimeographed).

1976. Counting harp seals using ultraviolet photography. Polar Rec., 18: 269-277.

1977. Stock assessment and management of western Atlantic harp seals. The 2nd Symposium on Endangered N. Amer. Wild. and Hab., St. Louis, MO, 1-5 June. 16 p.

Lavigne, D. M., S. Innes, W. Barchard, and W. G. Doubleday. 1977 The 1977 census of western Atlantic harp seals, Pagophilus groenlandicus. ICNAF Res. Doc. 77/X11/62 (Revised), Serial No. 5139. (mimeographed).

Lett, P. F. and T. Benjaminsen. 1977. A stochastic model for the management of the northwestern Atlantic harp seal (Pagophilus groenlandicus) population. J. Fish. Res. Bd. Canada, Vol. 34: 1155-1187.

Markgren, G. 1969. Reproduction of moose in Sweden. Viltrevy (Stockholm), 6 (3): 125-299.

Ricker, W. E. 1972. Comments on the western Atlantic harp seal herd and proposals for the 1972 harvest. ICNAF Res. Doc. 75/X11/143 (Appendix), Serial No. 3716. (mimeographed).

1973. Linear regressions in fishery research. J. Fish. Res. Bd. Canada, Vol. 30: 409-434.

Sergeant, D. E. 1966. Reproductive rates of harp seals, Pagophilus groenlandicus (Erxleben), in the Northwest Atlantic. J. Fish. Res. Bd. Canada, Vol. 22: 433-464.

1969. On the population dynamics and size of stocks of harp seals in the northwestern Atlantic. ICNAF Res. Doc. 69/31, Serial 2171. (mimeographed).

1973. Environment and reproduction in seals. J. Reprod. Fertil. Suppl., 19: 555-561.

1976. Studies on harp seals of the western North Atlantic population in 1976. ICNAF Res. Doc. 76/X/124 (Revised), Serial No. 4010. (mimeographed).

1977. Studies on harp seals of the western North Atlantic population in 1977. ICNAF Res. Doc. 77/X1/58, Serial No. 5133. (mimeographed).

Winters, G. H. 1978 MS. Surplus production and sustainable yield of the Northwest Atlantic Harp Seal. 47 p.

Table 1. Catch-at-age.

| Age | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 198063 | 197975 | 184491 | 260020 | 346846 | 171909 | 149350 | 243255 | 164158 | 174762 | 211285 | 285994 | 270952 |
| 1 | 4679 | 20685 | 35353 | 26005 | 14664 | 25488 | 44871 | 25180 | 37848 | 6586 | 27588 | 6780 | 2502 |
| 2 | 11520 | 6527 | 14119 | 12499 | 7175 | 11796 | 20701 | 11796 | 18220 | 2597 | 34154 | 8785 | 4418 |
| 3 | 7589 | 5888 | 4257 | 7526 | 4215 | 6631 | 12830 | 6675 | 10108 | 2566 | 9672 | 8044 | 6364 |
| 4 | 5983 | 3913 | 6444 | 5467 | 3355 | 5280 | 11387 | 5194 | 9486 | 3155 | 9549 | 4980 | 7429 |
| 5 | 6875 | 3988 | 3590 | 4738 | 2660 | 4248 | 9163 | 4360 | 6478 | 1067 | 7108 | 4215 | 5364 |
| 6 | 12029 | 3207 | 4207 | 3889 | 2310 | 3647 | 8247 | 3838 | 5783 | 1335 | 2932 | 4572 | 7702 |
| 7 | 8451 | 2843 | 3879 | 3367 | 3208 | 3256 | 6812 | 3365 | 4877 | 1326 | 2978 | 4308 | 4117 |
| 8 | 8302 | 2790 | 3351 | 3171 | 2045 | 2908 | 6268 | 3021 | 4200 | 811 | 3081 | 4349 | 3419 |
| 9 | 5889 | 2732 | 2246 | 2588 | 1804 | 2618 | 5347 | 2731 | 3737 | 771 | 2963 | 3993 | 3289 |
| 10 | 6711 | 2263 | 3271 | 2414 | 1588 | 2493 | 5231 | 2485 | 3506 | 1192 | 1350 | 4582 | 4751 |
| 11 | 5889 | 2741 | 1350 | 2159 | 1378 | 2285 | 4754 | 2168 | 3145 | 712 | 2462 | 4440 | 2597 |
| 12 | 1740 | 1664 | 2841 | 1031 | 1349 | 2088 | 4129 | 1961 | 2896 | 409 | 2075 | 3272 | 2544 |
| 13 | 1532 | 1267 | 2806 | 1763 | 1169 | 1877 | 3792 | 1792 | 2627 | 411 | 1160 | 3440 | 2023 |
| 14 | 2325 | 996 | 1430 | 1659 | 1112 | 1809 | 3419 | 1741 | 2488 | 403 | 1550 | 3562 | 1988 |
| 15 | 4208 | 1909 | 1882 | 1567 | 964 | 1670 | 3141 | 1595 | 2284 | 204 | 2319 | 2828 | 2799 |
| 16 | 1443 | 1901 | 2415 | 1485 | 1006 | 1541 | 2774 | 1479 | 2172 | 325 | 810 | 2240 | 2314 |
| 17 | 2355 | 1395 | 1092 | 1311 | 867 | 1367 | 2566 | 1319 | 1912 | 248 | 1829 | 2355 | 2887 |
| 18 | 1844 | 879 | 391 | 1161 | 865 | 1205 | 2188 | 1128 | 1673 | 130 | 914 | 1522 | 4290 |
| 19 | 962 | 640 | 1243 | 1068 | 734 | 1112 | 1916 | 1075 | 1538 | 157 | 652 | 1242 | 2331 |
| 20 | 4971 | 2786 | 746 | 859 | 624 | 964 | 1741 | 854 | 1273 | 193 | 1470 | 1306 | 142 |
| 21 | 1383 | 1630 | 356 | 674 | 450 | 696 | 1150 | 617 | 923 | 53 | 183 | 1107 | 2189 |
| 22 | 60 | 909 | 338 | 592 | 392 | 615 | 1028 | 548 | 831 | 105 | 715 | 865 | 1130 |
| 23 | 481 | 649 | 773 | 418 | 321 | 417 | 842 | 427 | 616 | 78 | 199 | 717 | 1130 |
| 24 | 1344 | 468 | 151 | 348 | 263 | 371 | 702 | 343 | 513 | 65 | 183 | 566 | 1616 |
| 25 | 481 | 254 | 320 | 47 | 54 | 83 | 157 | 62 | 69 | 103 | 215 | 267 | 628 |
| No.1+ animals | 109055 | 74924 | 98851 | 88806 | 53472 | 86465 | 165156 | 85736 | 129183 | 25002 | 117111 | 84377 | 79863 |

TABLE 1.B

| AGE | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 187384 | 225250 | 279858 | 159971 | 236532 | 220520 | 213349 | 119658 | 102744 | 118036 | 140629 | 132085 | 124932 |
| 1 | 7413 | 11558 | 10877 | 5980 | 20985 | 7844 | 7315 | 990 | 1949 | 9604 | 9629 | 10928 | 5458 |
| 2 | 3693 | 10383 | 5100 | 4521 | 2993 | 7535 | 2483 | 1289 | 2874 | 5629 | 5719 | 6241 | 4898 |
| 3 | 4898 | 5183 | 1959 | 3069 | 3088 | 2714 | 2591 | 2272 | 2511 | 2123 | 3275 | 3976 | 4271 |
| 4 | 6408 | 5414 | 2090 | 1823 | 2512 | 2644 | 1163 | 1573 | 3087 | 1752 | 1999 | 2874 | 3154 |
| 5 | 7889 | 5880 | 3587 | 1682 | 2966 | 2387 | 1250 | 1604 | 3367 | 1945 | 2072 | 1567 | 1677 |
| 6 | 7349 | 6086 | 4760 | 1711 | 2125 | 1687 | 764 | 1041 | 1248 | 3144 | 1867 | 1264 | 1163 |
| 7 | 3121 | 5373 | 4341 | 2437 | 2479 | 1776 | 606 | 820 | 1299 | 985 | 1832 | 1073 | 921 |
| 8 | 1826 | 3543 | 3059 | 2498 | 2983 | 1637 | 542 | 752 | 1380 | 1200 | 1186 | 1027 | 743 |
| 9 | 1081 | 2018 | 2227 | 1705 | 2325 | 2045 | 776 | 659 | 1245 | 1283 | 740 | 481 | 357 |
| 10 | 1524 | 1928 | 1830 | 1757 | 1831 | 1958 | 837 | 842 | 1038 | 954 | 693 | 757 | 236 |
| 11 | 655 | 2522 | 2282 | 1310 | 1666 | 1286 | 554 | 592 | 1392 | 732 | 672 | 523 | 259 |
| 12 | 2088 | 1756 | 1570 | 1031 | 1153 | 1332 | 606 | 593 | 1360 | 891 | 605 | 369 | 161 |
| 13 | 660 | 1639 | 1316 | 976 | 1295 | 1175 | 490 | 552 | 1224 | 825 | 646 | 306 | 266 |
| 14 | 1553 | 1825 | 1852 | 1233 | 1333 | 844 | 277 | 355 | 1064 | 685 | 529 | 309 | 368 |
| 15 | 1415 | 1546 | 1810 | 1082 | 1393 | 1211 | 335 | 410 | 1067 | 674 | 353 | 517 | 335 |
| 16 | 794 | 1580 | 1289 | 1037 | 991 | 914 | 297 | 304 | 909 | 686 | 350 | 191 | 64 |
| 17 | 512 | 1104 | 1964 | 903 | 1248 | 847 | 284 | 264 | 682 | 594 | 247 | 221 | 35 |
| 18 | 846 | 1619 | 1592 | 1237 | 1039 | 780 | 357 | 224 | 623 | 447 | 323 | 145 | 131 |
| 19 | 961 | 1035 | 1608 | 1073 | 1042 | 703 | 251 | 158 | 526 | 377 | 159 | 135 | 29 |
| 20 | 340 | 1094 | 1143 | 742 | 927 | 676 | 322 | 252 | 566 | 306 | 127 | 155 | 128 |
| 21 | 593 | 780 | 684 | 485 | 680 | 389 | 203 | 132 | 288 | 282 | 88 | 40 | 50 |
| 22 | 282 | 349 | 491 | 684 | 554 | 312 | 286 | 94 | 690 | 287 | 106 | 46 | 35 |
| 23 | 58 | 687 | 552 | 379 | 491 | 185 | 229 | 67 | 201 | 201 | 59 | 53 | 29 |
| 24 | 87 | 373 | 400 | 267 | 267 | 195 | 129 | 54 | 151 | 219 | 97 | 31 | 27 |
| 25 | 87 | 256 | 342 | 139 | 310 | 91 | 222 | 40 | 171 | 210 | 74 | 30 | 22 |
| NO.1+ ANIMALS | 56133 | 75531 | 58725 | 39761 | 58676 | 43167 | 23169 | 15933 | 29917 | 36035 | 33447 | 33259 | 24817 |

Table 2. Numbers-at-age from sequential population analysis with M = 0.1

| AGE | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 505086 | 469630 | 450983 | 490673 | 498106 | 424164 | 389247 | 431054 | 463599 | 443656 | 437658 | 463630 | 435599 |
| 1 | 153858 | 277806 | 245803 | 241121 | 208704 | 136866 | 228250 | 217068 | 169928 | 179045 | 243306 | 204831 | 160732 |
| 2 | 184879 | 134983 | 232653 | 190423 | 194655 | 175574 | 100779 | 165928 | 173628 | 119511 | 239202 | 195189 | 179204 |
| 3 | 232645 | 156854 | 116232 | 197738 | 160993 | 169639 | 148193 | 72458 | 239481 | 140619 | 105788 | 185355 | 169668 |
| 4 | 195796 | 203639 | 136600 | 101319 | 172111 | 141858 | 147496 | 122481 | 59523 | 117062 | 124915 | 86969 | 160061 |
| 5 | 125092 | 171750 | 180720 | 117770 | 86731 | 152697 | 152697 | 123581 | 106126 | 45275 | 103067 | 104388 | 74187 |
| 6 | 222802 | 106968 | 151798 | 160274 | 102275 | 76070 | 134322 | 103530 | 107491 | 90165 | 40001 | 86827 | 90640 |
| 7 | 94047 | 190715 | 93887 | 133546 | 141503 | 90452 | 65531 | 114077 | 90205 | 92030 | 80377 | 33542 | 74428 |
| 8 | 120176 | 77451 | 169994 | 81441 | 117790 | 126130 | 78899 | 53131 | 100177 | 77208 | 82072 | 70034 | 26452 |
| 9 | 87609 | 101228 | 67556 | 150785 | 70823 | 104731 | 114496 | 65729 | 45342 | 86843 | 69127 | 71474 | 59434 |
| 10 | 111262 | 73944 | 89123 | 59095 | 134094 | 62451 | 92396 | 96047 | 56994 | 37646 | 77882 | 59868 | 61059 |
| 11 | 73835 | 94602 | 64859 | 77682 | 51287 | 119897 | 54252 | 78870 | 84679 | 48398 | 32985 | 69249 | 50025 |
| 12 | 46137 | 61480 | 83119 | 57466 | 68336 | 45160 | 106419 | 44788 | 69403 | 73757 | 43148 | 28523 | 58641 |
| 13 | 103383 | 40172 | 54124 | 72639 | 50159 | 60612 | 38973 | 92556 | 38751 | 60178 | 66368 | 37164 | 22848 |
| 14 | 51316 | 92158 | 35203 | 46434 | 64131 | 44328 | 53146 | 31833 | 82187 | 32687 | 54079 | 59003 | 30515 |
| 15 | 34888 | 44329 | 82487 | 30559 | 40514 | 57022 | 38473 | 44995 | 27229 | 72060 | 19212 | 47531 | 50166 |
| 16 | 47049 | 27760 | 38384 | 72935 | 26233 | 35787 | 50085 | 31970 | 72060 | 22589 | 65018 | 24333 | 40440 |
| 17 | 14302 | 41266 | 23399 | 32546 | 64650 | 22826 | 20987 | 42809 | 27589 | 33568 | 20145 | 58098 | 19991 |
| 18 | 12599 | 10811 | 36077 | 20184 | 28262 | 57714 | 19417 | 25716 | 37541 | 23234 | 30149 | 16573 | 50439 |
| 19 | 13518 | 9732 | 8986 | 32290 | 17213 | 24790 | 51131 | 15590 | 22249 | 32455 | 20905 | 26453 | 13619 |
| 20 | 14985 | 11361 | 8227 | 7007 | 28251 | 14911 | 21425 | 44532 | 13133 | 18740 | 29225 | 18326 | 22812 |
| 21 | 10515 | 9061 | 7759 | 6769 | 5563 | 24998 | 12619 | 17811 | 39521 | 10732 | 16782 | 25113 | 25400 |
| 22 | 4487 | 8263 | 6724 | 6699 | 5515 | 4626 | 21989 | 10378 | 15558 | 34925 | 9663 | 15019 | 21722 |
| 23 | 21570 | 4006 | 6654 | 5778 | 5526 | 4635 | 3629 | 18967 | 8895 | 13325 | 31507 | 8096 | 12807 |
| 24 | 21395 | 19082 | 3037 | 5322 | 4850 | 4709 | 3817 | 2522 | 16775 | 7491 | 11987 | 28328 | 6677 |
| 25 | 24050 | 18143 | 16843 | 2612 | 4500 | 4150 | 3925 | 2819 | 1972 | 14715 | 6719 | 10680 | 25120 |
| No.1+ animals | 2022185 | 1987552 | 1960233 | 1910430 | 1854657 | 1762622 | 1741219 | 1639739 | 1573553 | 1576144 | 1633615 | 1571136 | 1496620 |

Table 2 B

| AGE | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 346385 | 346201 | 342833 | 348658 | 344031 | 345332 | 338174 | 333157 | 332672 | 322046 | 315009 | 330124 | 330000 |
| 1 | 148978 | 143870 | 109441 | 56983 | 170731 | 97269 | 112935 | 112947 | 193182 | 208047 | 194596 | 157786 | 179193 |
| 2 | 143172 | 128094 | 119721 | 89185 | 46149 | 135496 | 80915 | 95569 | 101303 | 173035 | 179559 | 158316 | 132882 |
| 3 | 158153 | 126206 | 106509 | 103714 | 76607 | 39049 | 115784 | 70960 | 85308 | 89062 | 151475 | 157297 | 137603 |
| 4 | 146857 | 138671 | 109506 | 94601 | 91067 | 66523 | 32878 | 102421 | 62159 | 74918 | 78666 | 134097 | 138730 |
| 5 | 138596 | 127083 | 120576 | 97194 | 83949 | 80128 | 57800 | 28697 | 91251 | 54356 | 66203 | 69371 | 118735 |
| 6 | 62274 | 118268 | 109669 | 105856 | 86423 | 73277 | 70343 | 51168 | 24514 | 79521 | 47423 | 58028 | 61351 |
| 7 | 75046 | 49698 | 101507 | 94926 | 94234 | 76276 | 64777 | 62958 | 45357 | 21057 | 69109 | 41221 | 51362 |
| 8 | 63620 | 65080 | 40107 | 87919 | 83688 | 83024 | 67411 | 58064 | 56225 | 39866 | 18161 | 60875 | 36327 |
| 9 | 20841 | 55913 | 55681 | 33522 | 77292 | 73025 | 73642 | 60505 | 51858 | 49625 | 34986 | 15360 | 54152 |
| 10 | 50893 | 27880 | 48767 | 48367 | 28790 | 67833 | 64225 | 65932 | 54151 | 45797 | 43742 | 30987 | 13463 |
| 11 | 50950 | 44671 | 14434 | 42470 | 42175 | 24393 | 59607 | 57356 | 58896 | 48059 | 40576 | 38953 | 27353 |
| 12 | 42914 | 45509 | 38138 | 10995 | 37243 | 36654 | 20908 | 53433 | 51362 | 52032 | 42823 | 36106 | 34772 |
| 13 | 50759 | 36941 | 39589 | 33088 | 9016 | 32656 | 31961 | 18370 | 47812 | 45244 | 46274 | 38201 | 32336 |
| 14 | 18843 | 45332 | 31943 | 34631 | 29056 | 6986 | 28485 | 28476 | 16123 | 42154 | 40192 | 41286 | 34288 |
| 15 | 25813 | 15645 | 39366 | 27227 | 30220 | 25085 | 5558 | 25524 | 25445 | 13626 | 37523 | 35888 | 37077 |
| 16 | 42858 | 22076 | 12757 | 33982 | 23657 | 26084 | 21602 | 4726 | 22724 | 22058 | 11719 | 33633 | 32005 |
| 17 | 34506 | 38061 | 18545 | 10377 | 29810 | 20509 | 22775 | 19278 | 4001 | 19739 | 19338 | 10287 | 30259 |
| 18 | 15476 | 30759 | 33440 | 15004 | 8573 | 25844 | 17791 | 20350 | 17204 | 3003 | 17323 | 17275 | 9108 |
| 19 | 41757 | 13238 | 26367 | 28818 | 12457 | 6817 | 22679 | 15775 | 18211 | 15003 | 2313 | 15382 | 15499 |
| 20 | 10214 | 36914 | 11042 | 22403 | 25105 | 10328 | 5532 | 20294 | 14131 | 16002 | 13235 | 1949 | 13796 |
| 21 | 20512 | 8934 | 32411 | 8957 | 19599 | 21877 | 8734 | 4714 | 18135 | 12274 | 14203 | 11860 | 1623 |
| 22 | 11954 | 18024 | 7378 | 28708 | 7666 | 17119 | 19443 | 7719 | 4146 | 16139 | 10851 | 12771 | 10695 |
| 23 | 18632 | 10562 | 15993 | 6232 | 25357 | 6435 | 15208 | 17334 | 6900 | 3127 | 14244 | 9723 | 11514 |
| 24 | 10566 | 16807 | 8935 | 13972 | 5296 | 22500 | 5655 | 13553 | 15624 | 6061 | 2648 | 12926 | 8749 |
| 25 | 4579 | 9482 | 14870 | 7723 | 12400 | 4550 | 20182 | 5000 | 12215 | 14000 | 5286 | 2308 | 1166 |
| No.1+ animals | 1408752 | 1363706 | 1266682 | 1136841 | 1156549 | 1079726 | 1046817 | 1021120 | 1098225 | 1163794 | 1192556 | 1201875 | 1234539 |

Table 3 Exploitation rate ($C_t/N_t$)

| AGE | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .392 | .422 | .409 | .530 | .696 | .405 | .384 | .564 | .354 | .394 | .483 | .617 | .622 |
| 1 | .030 | .074 | .144 | .108 | .070 | .186 | .197 | .116 | .223 | .024 | .113 | .033 | .016 |
| 2 | .062 | .048 | .061 | .066 | .037 | .067 | .205 | .071 | .105 | .022 | .143 | .045 | .025 |
| 3 | .033 | .038 | .037 | .038 | .026 | .039 | .087 | .092 | .072 | .018 | .091 | .043 | .038 |
| 4 | .031 | .019 | .047 | .054 | .019 | .037 | .077 | .042 | .159 | .027 | .076 | .057 | .046 |
| 5 | .055 | .023 | .020 | .040 | .031 | .028 | .074 | .035 | .061 | .024 | .069 | .040 | .072 |
| 6 | .054 | .030 | .028 | .024 | .023 | .048 | .061 | .037 | .054 | .015 | .073 | .053 | .085 |
| 7 | .090 | .015 | .041 | .025 | .015 | .036 | .104 | .029 | .054 | .014 | .037 | .128 | .055 |
| 8 | .069 | .036 | .020 | .039 | .017 | .023 | .079 | .057 | .042 | .011 | .038 | .062 | .128 |
| 9 | .067 | .027 | .033 | .017 | .025 | .025 | .048 | .042 | .082 | .009 | .043 | .056 | .054 |
| 10 | .060 | .031 | .037 | .041 | .012 | .040 | .057 | .026 | .062 | .032 | .017 | .077 | .078 |
| 11 | .080 | .029 | .021 | .028 | .027 | .019 | .088 | .027 | .037 | .015 | .044 | .064 | .052 |
| 12 | .038 | .027 | .034 | .035 | .020 | .046 | .039 | .044 | .042 | .006 | .048 | .115 | .043 |
| 13 | .015 | .032 | .052 | .024 | .023 | .031 | .097 | .019 | .068 | .007 | .017 | .093 | .089 |
| 14 | .045 | .011 | .041 | .036 | .017 | .041 | .064 | .055 | .030 | .012 | .029 | .060 | .065 |
| 15 | .121 | .043 | .023 | .051 | .024 | .029 | .082 | .035 | .083 | .003 | .079 | .059 | .056 |
| 16 | .031 | .068 | .063 | .020 | .038 | .043 | .055 | .046 | .055 | .014 | .012 | .092 | .057 |
| 17 | .165 | .034 | .047 | .040 | .013 | .060 | .083 | .031 | .069 | .007 | .091 | .041 | .144 |
| 18 | .146 | .081 | .011 | .058 | .031 | .021 | .113 | .044 | .045 | .006 | .030 | .092 | .085 |
| 19 | .071 | .066 | .138 | .033 | .043 | .045 | .037 | .069 | .069 | .005 | .031 | .047 | .171 |
| 20 | .332 | .245 | .091 | .123 | .022 | .065 | .081 | .019 | .097 | .010 | .050 | .071 | .006 |
| 21 | .132 | .180 | .046 | .100 | .081 | .028 | .091 | .035 | .023 | .005 | .011 | .044 | .142 |
| 22 | .013 | .110 | .050 | .088 | .071 | .133 | .047 | .053 | .053 | .003 | .074 | .058 | .052 |
| 23 | .022 | .162 | .116 | .072 | .058 | .090 | .232 | .023 | .069 | .008 | .006 | .089 | .088 |
| 24 | .063 | .025 | .050 | .065 | .054 | .079 | .184 | .136 | .031 | .009 | .015 | .020 | .242 |
| 25 | .020 | .014 | .019 | .018 | .012 | .020 | .040 | .022 | .035 | .007 | .032 | .025 | .025 |
| $F_{1-25}$ | .074 | .059 | .051 | .050 | .032 | .051 | .093 | .048 | .069 | .012 | .051 | .063 | .077 |

Table 3b

| Age | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .541 | .651 | .815 | .459 | .688 | .639 | .631 | .359 | .309 | .367 | .446 | .400 | .379 |
| 1 | .050 | .080 | .099 | .105 | .123 | .081 | .065 | .009 | .010 | .046 | .052 | .069 | .030 |
| 2 | .026 | .081 | .043 | .051 | .065 | .056 | .031 | .013 | .028 | .033 | .032 | .039 | .037 |
| 3 | .031 | .041 | .018 | .030 | .040 | .070 | .022 | .032 | .029 | .024 | .022 | .025 | .031 |
| 4 | .044 | .039 | .019 | .019 | .028 | .040 | .035 | .015 | .034 | .023 | .025 | .021 | .023 |
| 5 | .057 | .046 | .030 | .017 | .035 | .030 | .022 | .056 | .037 | .036 | .031 | .023 | .014 |
| 6 | .118 | .051 | .043 | .016 | .025 | .023 | .011 | .020 | .051 | .040 | .039 | .022 | .019 |
| 7 | .042 | .108 | .043 | .026 | .026 | .023 | .009 | .013 | .029 | .047 | .027 | .026 | .018 |
| 8 | .029 | .054 | .076 | .028 | .036 | .020 | .008 | .013 | .025 | .030 | .065 | .017 | .020 |
| 9 | .052 | .036 | .040 | .051 | .030 | .028 | .011 | .011 | .024 | .026 | .021 | .031 | .007 |
| 10 | .030 | .108 | .038 | .036 | .064 | .029 | .013 | .013 | .019 | .021 | .016 | .024 | .018 |
| 11 | .013 | .056 | .158 | .031 | .040 | .053 | .009 | .010 | .024 | .015 | .017 | .013 | .009 |
| 12 | .049 | .039 | .041 | .094 | .031 | .036 | .029 | .011 | .026 | .017 | .014 | .010 | .005 |
| 13 | .013 | .044 | .033 | .029 | .144 | .036 | .015 | .030 | .026 | .018 | .014 | .008 | .008 |
| 14 | .082 | .040 | .058 | .036 | .046 | .121 | .010 | .012 | .066 | .016 | .013 | .007 | .011 |
| 15 | .055 | .099 | .046 | .040 | .046 | .048 | .060 | .016 | .042 | .049 | .009 | .014 | .009 |
| 16 | .019 | .072 | .101 | .031 | .042 | .035 | .014 | .064 | .040 | .031 | .030 | .006 | .002 |
| 17 | .015 | .029 | .106 | .087 | .042 | .041 | .012 | .014 | .170 | .030 | .013 | .021 | .001 |
| 18 | .055 | .053 | .048 | .082 | .121 | .030 | .020 | .011 | .036 | .149 | .019 | .008 | .014 |
| 19 | .023 | .078 | .061 | .037 | .084 | .103 | .011 | .010 | .029 | .025 | .069 | .009 | .002 |
| 20 | .033 | .030 | .104 | .033 | .037 | .065 | .058 | .012 | .040 | .019 | .010 | .080 | .009 |
| 21 | .029 | .087 | .021 | .054 | .035 | .018 | .023 | .028 | .016 | .023 | .006 | .003 | .031 |
| 22 | .024 | .019 | .067 | .024 | .072 | .018 | .015 | .012 | .166 | .018 | .010 | .004 | .003 |
| 23 | .003 | .065 | .035 | .061 | .019 | .029 | .0154 | .004 | .029 | .064 | .004 | .005 | .003 |
| 24 | .008 | .022 | .045 | .019 | .050 | .009 | .023 | .004 | .010 | .036 | .037 | .002 | .003 |
| 25 | .019 | .027 | .023 | .018 | .025 | .020 | .011 | .008 | .014 | .015 | .014 | .013 | .002 |
| $F_{1-25}$ | .037 | .056 | .056 | .042 | .052 | .042 | .022 | .018 | .041 | .034 | .024 | .020 | .013 |

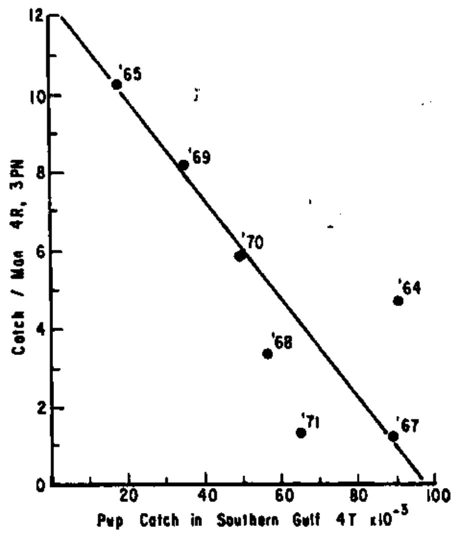


Fig. 1 Geometric mean regression between catch in 4T and catch/man in 4R, 3Pn.

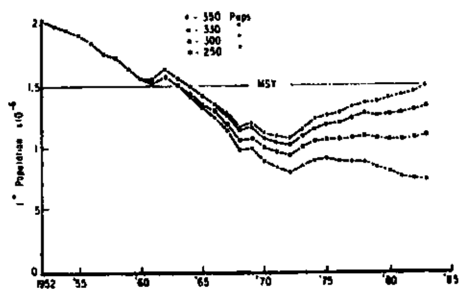


Fig. 2 Population estimates and projections from 1952 to 1983.

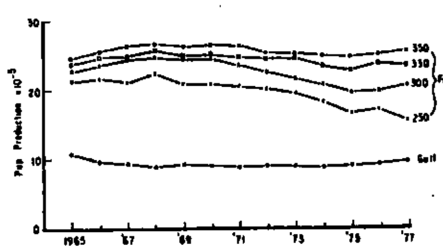


Fig. 3 Estimates of Gulf and Front productions from 1965 to 1977 varying estimates of total production for 1977.

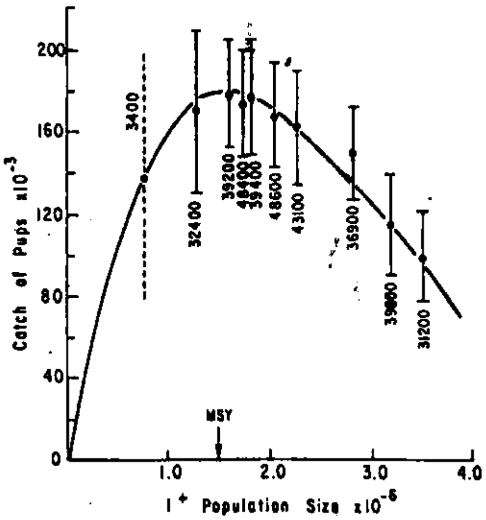


Fig. 4 Graham-Schaefer plot, for 20-80 adult to pup ratio in catch and 350,000 production for 1977. Bars indicate two stand deviations and numbers are associated adult catch.