International Commission for the Northwest Atlantic Fisheries

Serial No. 3727
(D.c.11)

ICNAF Res.Doc. 75/XII/149

SPECIAL MEETING OF PANEL A (SEALS) - DECEMBER 1975

Comments on an attempt by P.F. Lett and D.M. Lavigne to estimate mortality for Northwestern Atlantic harp seals from catch and effort data

by

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In ICNAF Res. Doc. 75/XII/148 Lett and Lavigne (MS 1975 b) claim to have estimated mortalities for harp seals from catch per unit of effort data. Their basic assumption is that the catchability coefficient (q) is proportional to $\frac{1}{N}$ where N is the stock size. The main conclusion in the present paper is that Lett and Lavigne's basic assumption implies that the effort data can not give any information about mortalities in addition to the information one has from the catch data alone.

If, as assumed by Lett and Lavigne,

(1) $q = k \cdot \frac{1}{N}$,

then

(2) $F = q \cdot E = k \cdot \frac{E}{N}$

where F is the hunting mortality and E the hunting effort.

Setting $C = F\overline{N}$ $\left[\overline{N} = \frac{N}{F+M}(1-e^{-(F+M)})\right.$ is the mean population size in the year in question as defined by Beverton and Holt (1957)] , equation (2) implies that

$\frac{C}{\overline{N}} = k\frac{E}{N}$ or $C = k \cdot \frac{\overline{N}}{N} \cdot E$

Assuming that $\frac{\overline{N}}{N}$ is approximately constant from year to year (or that N in equation (1) is actually equal to $\overline{N}$) this gives

(3) $C = kE$ or $C/E = k$

which means that catch and catch per unit of effort is independent of stock size. It seems evident that if this is the case, the effort data can not give any information about stock size or mortality. Even so, Lett and Lavigne (MS 1975 b) apparantly have used effort data to estimate mortality by calculating "effective effort" (E/N) and analysing data on catch per unit of "effective effort". It therefore is necessary to go through

their paper in some detail to discover what actully has happened through all the manipulations Lett and Lavigne have carried out.

One problem in doing this is that gross errors occur in their basic input data. (This is documented in Working Documents by T. BENJAMINSEN, Ø. ULLTANG and T. ØRITSLAND presented to the Special meeting of Scientific Advisers to Panel A (Seals), Ottawa, November 1975 and Bergen, December 1975), and it is difficult to judge what effect these errors have had on the results without repeating all the calculations with corrected data. This problem, however, may be disregarded for the purpose of the present paper by assuming that the data used by Lett and Lavigne represent a hypothetical harp seal population.

The first suspecious feature of the method used by Lett and Lavigne is that a population size (or population index) had to be assumed for each of the different years in the period studied in order to use the effort data. The assumed population sizes, shown in Fig. 8 of their first paper (Lett and Lavigne, 1975 a) are mainly based on aerial surveys. Lett and Lavigne's "effective effort" is given by $E/N_{assumed}$ where $N_{assumed}$ denotes the assumed population size. Equation (3) then gives

(4) $\quad C/(E/N_{assumed}) = k\, N_{assumed}$

The catch per unit of "effective effort" therefore simply is proportional to the assumed stock size.

In Fig. 4 of their paper (Lett and Lavigne, MS 1975 b) mortalities are estimated for the yearclasses 1951-1962 by regression of the logarithm of catch per unit of "effective effort" against age.

Equation (4) gives

$$\frac{\text{catch per unit "effective effort" in year } t}{\text{catch per unit "effective effort" in year } t+1} = \frac{N_{assumed} \text{ in year } t}{N_{assumed} \text{ in year } t+1}$$

If the catch and effort data had fitted the basic assumption in equation (1) the regressions in their Fig. 4 therefore simply would have given the mortalities inherent in the assumed stock sizes.

This, however, is not what their Fig. 4 gives because a series of manipulations were made with the "effective effort" data before the regressions were calculated. In order to discover what the regressions in their Fig. 4 really give the different steps in the manipulations must be looked at.

In Fig. 1 in Lett and Lavigne's paper (MS 1975 b) fishing mortalities from cohort analysis (Lett and Lavigne, MS 1975 a) are plotted against "effective effort". Lett and Lavigne concluded from this figure that catchability had changed from 1966 onwards and they explained this as result of the introduction of catch quotas. The possibility of a change in catchability from 1966 onwards (a change in k in equation (1)) can not be disregarded, but the reason for the change can not be catch quota regulations because overall quotas

limiting the ship's catches were not enforced until 1971. Further, to plot fishing mortalities from cohort analysis against "effective effort" is not the best way to study possible changes. The results of the cohort analysis depend completely on the assumed natural mortality (M = 0.21), and "effective effort" depends completely on the assumed stock sizes which are based mainly on incomplete aerial surveys. The simplest and safest way to check whether catchability changed in 1966 is to plot catch per unit of effort (not "effective effort") against time, and it is rather surprising that Lett and Lavigne have not done this. Such a plot would both give an idea of the validity of their basic assumption ($q = k \cdot \frac{1}{N}$ or $C/E = k$) and show any spesial change in 1966 or any other year.

In Fig. 1 in this paper C/E are plotted against year for the period 1952-1970, the period covered in Lett and Lavigne's Fig. 1, using Lett and Lavigne's catch and effort data. From this figure it may be concluded that perhaps C/E varies around a constant value, but the variations are rather wide. The figure further shows that there is no basis to distinguish the 1966-1970 data from data for earlier years.

In order to discover what Lett and Lavigne's Fig. 1 really means the expected relation between effective effort ($E/N_{assumed}$) and fishing mortality from cohort analysis (F_{cohort}) if $C/E = k$ must be studied. When

(5) $F_{cohort} = \frac{C}{N_{cohort}}$

and

(6) $E/N_{assumed} = \frac{C}{k \cdot N_{assumed}}$ (using equation (5)

we have

(7) $F_{cohort} = k \frac{N_{assumed}}{N_{cohort}} \cdot E/N_{assumed}$

Therefore, if $\frac{N_{assumed}}{N_{cohort}}$ and k were constant during the period studied one should expect a linear relation between F_{cohort} and $E/N_{assumed}$ ("effective effort").[1] Lett and Lavigne's Fig. 1 (MS 1975 b) shows that the data for the years 1966-1970 does not fit in with the data from earlier years in a linear regression. As explained above, there is no reason to suppose that k changed significantly in 1966 (see Fig. 1 in this paper) which

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1) To be exact, N_{cohort} and $N_{assumed}$ on the right side of equations (4) and (5) should be substituted by $\bar{N}_{cohort}$ and $\bar{N}_{assumed}$ where $\bar{N} = \frac{N}{F+M}(1-e^{-(F+M)})$. However, $\frac{\bar{N}_{assumed}}{\bar{N}_{cohort}}$ may be set equal to $\frac{N_{assumed}}{N_{cohort}}$

really is what Lett and Lavigne have suggested. The lack of fit in their Fig. 1, however, may easily be explained by a change in $\frac{N_{assumed}}{N_{cohort}}$.

Lett and Lavigne have not given data for $N_{assumed}$ or population indexes in any of their papers, but these may easily be calculated from their Table 1, column a(effort) and column b(effective effort) (MS 1975 b). The calculated population indexes are given in Table 1, column a, in this paper.
In column b, are given Lett and Lavigne's stock sizes of seals aged 1 and older from cohort analysis (MS 1975 a) and column c gives their population indexes ($N_{assumed}$) divided by N_{cohort}. Column c shows that there is a systematic increase with time in $\frac{N_{assumed}}{N_{cohort}}$. There is a particularly abrupt change in this ratio around 1965, the values for 1967-1970 lying on a much higher level than in earlier years. Equation (4) shows that this will make F_{cohort} too high, or "effective effort" too low in later years as compared with earlier years.
By changing either $N_{assumed}$ or N_{cohort} so that the ratio $\frac{N_{assumed}}{N_{cohort}}$ is constant for the whole period, the points in Lett and Lavigne's Fig. 1 (MS 1975 b) will show a much better fit to a straight line. This is illustrated in Fig. 2 in the present paper where $N_{assumed}$ and thereby Lett and Lavigne's "effective effort", has not been changed, but the N_{cohort}, and thereby F_{cohort}, have been adjusted to make $\frac{N_{assumed}}{N_{cohort}}$ constant (= 2) for the whole period. The figure shows that when this adjustment has been made, there is no sign of a change in catchability in 1966.

The conclusion of the above discussion must be that the relation between Lett and Lavigne's F_{cohort} and their "effective effort" ($E/N_{assumed}$) depends completely upon the ratio $N_{assumed}/N_{cohort}$ where $N_{assumed}$ is based mainly on aerial surveys and N_{cohort} on the assumption that M= 0.21.

On the basis of Fig. 1 in their paper Lett and Lavigne (MS 1975 b) have adjusted the "effective effort" for the period 1966-1970. On the basis of the discussion above and equation (7) it is easily seen that this is equivalent to an adjustment of the $N_{assumed}$, thus making $\frac{N_{assumed}}{N_{cohort}}$ for these later years more directly comparable to the ratios for earlier years.

In Table 1 in this paper is also given the ratios $\frac{N_{assumed}}{N_{cohort}}$ for 1966-1970

resulting from Lett and Lavignes adjustment of "effective effort". By this adjustment and the later "adjustment for ice condition's" 1) their "effective effort" is made approximately proportional to

F_{cohort} (effective effort $= k \cdot F_{cohort}$)

Therefore

$$(8) \qquad \frac{C}{\text{"effective effort"}} = \frac{1}{k} \cdot \frac{C}{F_{cohort}} \approx \frac{1}{k} \; N_{cohort} \qquad 2)$$

which means that catch per unit of "effective effort" is proportional to stock size from cohort analysis. Lett and Lavignes Fig. 2 (MS 1975 b) is therefore only their Fig. 1 in another form after adjustment of the 1966-1970 data and "adjustment for ice conditions" which have the effect of reducing the variance about the line. But given equation (8) it follows that

(C/"effective effort") year i/ (C/ "effective effort") year i + 1 =

$$\frac{N_{cohort,\ year\ i}}{N_{cohort,\ year\ i+1}}$$

The mortalities estimated by Lett and Lavigne (MS 1975 b) from the regression lines in their Fig. 4, based on catch per unit of "effective effort" of a yearclass in successive years, therefore simply are the mortalities in the cohort analysis with more or less random fluctuations generated by fluctuations in C/E around the constant k in equation (3) and fluctuations in the ratio $N_{assumed} / N_{cohort}$.

The discussion above may be summarized as follows:

From Lett and Lavigne's basic relation, $q \doteq k \cdot \frac{1}{N}$ or $C = kE$,

$$F_{cohort} = k \frac{E}{N_{cohort}}$$

whatever values are chosen for starting stock size and natural mortality in the cohort analysis. The equation above is identical to

$$F_{cohort} = k \cdot \frac{N}{N_{cohort}} \cdot \frac{E}{N}, \quad \text{where N is a "dummy" variable}$$

(Lett and Lavigne's population index). $\frac{k \cdot N}{N_{cohort}}$ is constant if k is constant (variations in C/E around k were partly adjusted for by Lett and Lavigne's "adjustment for ice conditions") and if N is made proportional

1) While the need for "adjustment for quotas" mainly reflects that $N_{assumed}$ N_{cohort} changed during the period, the need for "adjustment for ice conditions" mainly reflects that C/E is not constant but have a lot of variance. Whether this variance reflects ice conditions or not is immaterial in the context of the present paper, and the latter adjustment will not be discussed in any further detail here.

2) Again, to be exact, N_{cohort} should be substituted by $\overline{N}_{cohort}$. However, assuming $N_{cohort}/\overline{N}_{cohort}$ to be approximately constant from year to year, this will only change the value of k.

to N_{cohort} (this was partly the effect of Lett and Lavigne's "adjustment for quotas"). Then $C/(E/N)$ will be proportional to N_{cohort} (E/N is their "effective effort", which is also a "dummy" variable), and the mortalities from analysis of the $C/(E/N)$-data will be the mortalities from the cohort analysis. These are completely dependent on the value for natural mortality used in the cohort analysis. It is therefore not at all surprising that Lett and Lavigne from analysis of their catch per unit of "effective effort" arrived at a value of M around 0.21 the value they assumed in cohort analysis.

Summary

1. The catch and effort data used by Lett and Lavigne indicate that their basic assumption, $q = k \cdot \frac{1}{N}$ or $C/E = k$ (catch per unit of effort independent of stock size), to some extent may be valid, but there are considerable variations in their catch per unit of effort.

2. Given their basic assumption, Lett and Lavigne's effort data can not give any new information on mortalities and stock sizes.

3. Their population indexes ($N_{assumed}$ in this paper) and thereby their "effective effort" are only "dummy" variables. Through "adjustment for quota regulations" and "adjustment for ice conditions" the "effective effort" is made approximately proportional to stock size from cohort analysis. The mortalities estimated by Lett and Lavigne from analysis of their data on catch per unit of "effective effort" therefore fluctuate around the mortalities given by the cohort analysis. These mortalities are completely dependent on the value of natural mortality assumed in the analysis.

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Table 1. The relation between assumed stock sizes (population indexes) and stock sizes from cohort analysis given by Lett and Lavigne (MS 1975 a).

Year	$N_{assumed}$	N_{cohort}	$\frac{N_{assumed}}{N_{cohort}}$ [1]
1952	5.60	4.21	1.33
1953	5.40	3.92	1.38
1954	5.30	3.73	1.42
1955	5.08.	3.49	1.46
1956	4.90	3.13	1.57
1957	4.70	2.89	1.63
1958	4.60	2.76	1.67
1959	4.40	2.42	1.82
1960	4.21	2.22	1.90
1961	4.00	1.99	2.01
1962	3.90	1.92	2.03
1963	3.70	1.72	2.15
1964	3.50	1.52	2.30
1965	3.30	1.32	2.50
1966	3.20	1.21	2.64 (1.13)
1967	3.00	1.02	2.94 (1.25)
1968	2.80	0.92	3.04 (1.20)
1969	2.60	0.92	2.83 (1.06)
1970	2.40	0.82	2.93 (1.34)

1) Figures in brackets give $N_{assumed} / N_{cohort}$ resulting from "adjustment for quota" (taken as an adjustment of $N_{assumed}$).

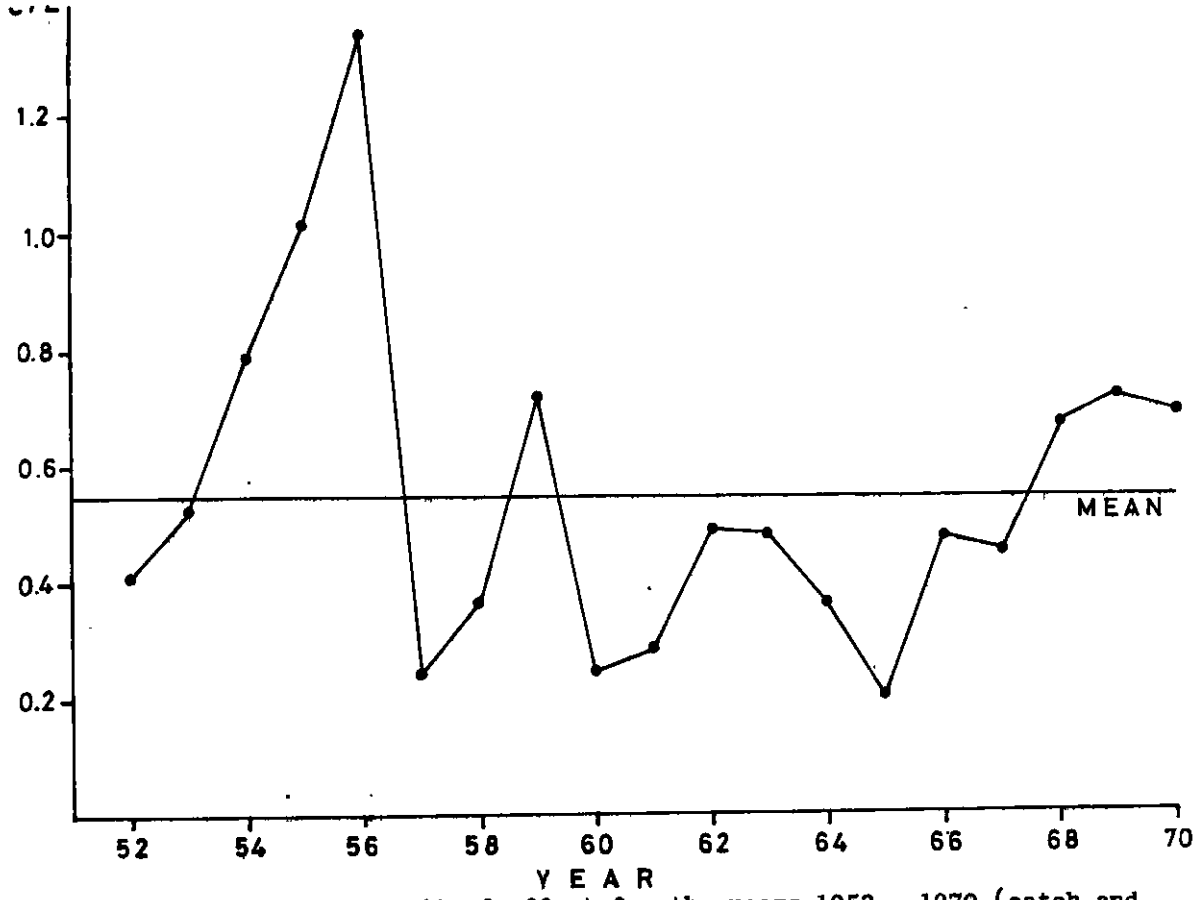

Figure 1. Catch per unit of effort for the years 1952 - 1970 (catch and effort data from Lett and Lavigne (MS 1975a, MS 1975b))

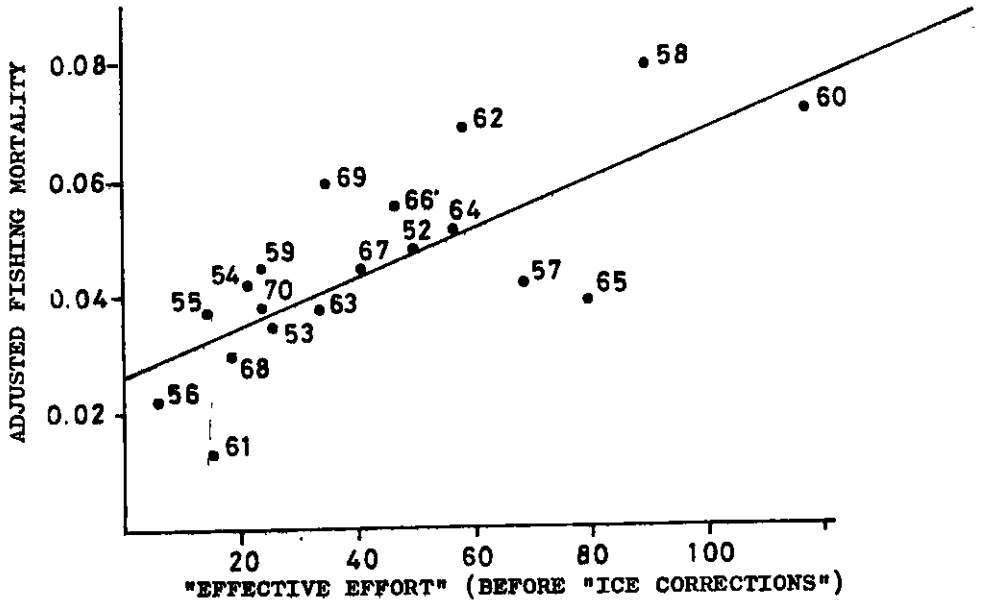

Figure 2. Adjusted fishing mortalities against Lett and Lavigne's (MS 1975b) "effective effort" (for further explanation see text)