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The mortality rates of Antarctic fin whale stocks

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In 1820, William Scoresby, Jr., advanced the theory that the transverse striations occurring at regular intervals on the surface of the baleen plates of a whalebone whale afford an intimation of the age of the whale. Eschricht and Reinhardt (1866) did not agree with this proposal, although they did agree that the striations were due to a periodicity in the growth of the plate.

Stimulated by the need for a method of making individual and direct age determinations of whales, we have studied the surface structure of the baleen plates and their possible application to age analyses since 1939. At the same time and quite independently, A. G. Tomilin (1945) examined baleen plates in the collections of Russian museums.

In a series of papers (Ruud, 1940, 1945; Ruud and Jonsgård, 1950), we have shown that the transverse striations of the baleen plates are due to variations in the thickness of the cortical layer or enamel. We have also described how records made of these variations reveal growth periods which we have assumed to be annual. On this assumption we have developed a method for age analyses. The method has limited applicability because the baleen plates are subject to wear at their distal ends and therefore growth periods are gradually worn away.

We believe, however, that the age of fin whales in their first, second, third and fourth years (age groups O, I, II and III) can be determined with great exactitude, because of the presence of structures on the distal portion of their baleen plates, which indicate that this part was formed during the suckling period or during the first krill-feeding season. We assume further that our analyses of records from baleen plates of whales in age groups IV and V give fairly accurate results. Admittedly we can give only minimum estimates of the ages of older animals, because at some undetermined age the annual growth increment of the baleen plates is balanced by the annual wear at the tip; from then on we find a maximum number of 4 to 7 growth periods in the plates. Hence, our age groups above V should more correctly be VI+, VII+, and VIII+, meaning that older animals are telescoped into our three highest baleen-record groups.

For some years we have engaged in age studies of Antarctic fin whales. The material consists of baleen samples from catches of Norwegian pelagic expeditions in post-war seasons. Details concerning the material, analyses and results will be published shortly in *Hvalradets Skrifter* by Hylen, Pike, Jonsgård and Ruud. The histogram (Fig. 1) shows the percentage age distribution of the Antarctic fin whales taken during this period. In 1945/46 and 1946/47 our samples were small. It is therefore questionable whether they were representative of the catches, but since 1947/48 we have determined the ages of 850 to 1250 fin whales each season. Chi-square tests on length distributions show that our samples from the last six seasons are fairly representative of the catches from which they are drawn.

In the history of whaling there is ample evidence that whale stocks are easily over-fished and depleted, if not to extinction, at least to such a degree that whaling is rendered unprofitable. It is only natural, therefore, that we, who have witnessed the gigantic expansion of modern pelagic whaling operations in the Antarctic, are on the alert for signs of over-fishing of the stocks of blue and fin whales. Such signs are now evident: (1) increasing numbers of small and sexually immature whales in the catches which result in a decrease in the mean length, indicate a corresponding decrease in the average age and (2) decreasing catches per unit of effort threaten the

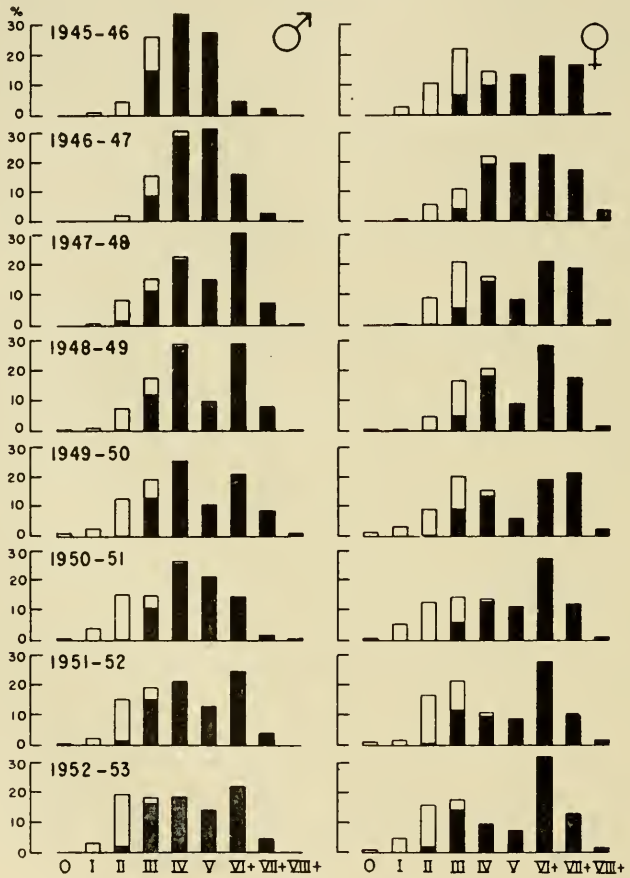

Fig. 1

economy of the industry. This trend is influenced to some extent by the changes in the varying regulations imposed on the industry. Hence, although the trend seems to be unmistakable, the extent of the depletion may well be disputed.

It is agreed that carefully planned and extensive marking experiments may produce conclusive evidence of over-fishing, because the rates of fishing can be estimated from the rates of recovered marks. However, extensive whale marking is costly and there are great losses in the recoveries. Many marks are probably shed before recapture, and marks are easily overlooked when the whales are worked up. It would be better therefore, if the age composition of the catches were known, because, as

shown by BARANOV (1918) and others, the right limb of the curves representing the age frequencies of the catches enables us to calculate the total mortality rates, provided that the following conditions are satisfied:

1. For the age groups in question, the mortality rate, or its complement, the survival rate, is uniform.

2. In these age groups, the samples used for age analyses are representative of the stocks.

3. The recruitment is uniform over a period of years; that is, each age group in question was initially of the same numerical strength as each of the others under study.

The first condition is satisfied as a rule in all stocks subject to high rates of fishing. As mentioned above, the second condition is satisfied fairly well for the last six seasons in our series. For the third condition, we can safely rule out the possibility that the recruitment to the stocks is increasing from year to year. The best we can hope for is a constant recruitment, or a recruitment fluctuating from year to year around a constant average sufficiently high to balance the losses from natural causes and from whaling operations. On the other hand, if the recruitment is decreasing, as it well may be, then the mortality rates calculated from the age distributions will be too low.

From the age distributions in Fig. 1, it can be seen that only groups IV and V of males and possibly groups III, IV and V of the females can be used in a direct calculation of survival or mortality rates. Thus, the ratios of Vs to IVs calculated for the period 1947/48 through 1952/53 give annual mortality rates which vary considerably from season to season, from a minimum of 0·17 (females, 1951/52) to a maximum of 0·65 (males, 1948/49). The means for the period are 0·42 and 0·40 for males and females respectively. Great seasonal variations might be expected if there were great fluctuations in the numerical strength of the year classes. This seems unlikely in a mammal such as a whale.

Systematic errors in our interpretation of the baleen records may, however, result in over-emphasis of age group V, because some older animals may be placed in that group. Such mistakes might vary in number from season to season. If this is the case, the calculated mortality rates will be lower than the actual ones.

Consequently, it is desirable to develop a formula which enables us to consider the total material contained in the right limb of the age-distribution curve. This is possible if we assume that the older animals telescoped into our age groups VI+, VII+, and VIII+ should in reality be spread in a regular way over a number of older age groups.

Thus such a formula for the annual mortality rate is: $a = 1 - \sqrt{\frac{A+B}{B}}$, where A is the sum of two age groups supposed to be fully represented in the catches, and B the sum of all higher age groups: hence, $A + B$ is the sum of all age groups considered.

We have formed the sum A from age groups III and IV of the females, and IV and V of the males, and used it in calculating the mortality rate for the individual seasons. These results show much less seasonal variation; namely a minimum of 0·19 and a maximum of 0·34 for females, and a minimum of 0·29 and a maximum of 0·49 for

males. The mean mortality rate for the period 1947/48 through 1952/53 is 0·22 for females and 0·34 for males, with 0·28 *as an average for both sexes.* It should be borne in mind that this is either the true mortality rate, or, what is more likely, it is too low.

It is assumed that the female fin whale has her first pregnancy at an age of 3 or 4 years, and that she gives birth to one calf every second year. The maximum rate of increase for the stocks of fin whales should thus be 0·25 per adult per year. We know nothing about the annual mortality rates of immature age groups, but most likely they are considerable, because some will be taken in whaling operations (compare the left limb of the age distribution curves). It must be assumed, therefore, that the real rate of increase for the whole stock of fin whales must be significantly lower than 0·25 per year.

Since the annual mortality rate calculated above was 0·28 or more, the inevitable conclusion is that the Antarctic stocks of fin whales were overfished in the period 1946/47 through 1952/53. In that period the annual catches were about 21 thousand fin whales. In subsequent seasons they have increased to more than 27 thousand fin whales per year. Unless the stocks have increased, this means increased mortality rates also, and the stocks are being heavily overfished.

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