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Investigation of the ear plug of the southern sei whale, *Balaenoptera borealis*, as a valid means of determining age

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A method of bleaching the longitudinally bisected ear plugs of sei whales with hydrogen peroxide (1·02 g/ml), has facilitated the counting of laminae in the ear plug core. Indirect evidence from several sources suggests that one pale and one adjacent dark lamina together comprise an annual growth layer. The growth layers can generally be used for determining age, although much evidence points to unreliable age estimates from ear plug growth layer counts of older mature whales. In older mature females, ovarian corpora number is a more reliable means of determining age, with an average ovulation rate of 0·68 per annum. The lamination patterning in the sei whale ear plug core closely resembles that of fin whales, and the transition phase, associated with sexual maturity, described in ear plugs of the latter species is generally apparent for mature sei whales. From an examination of the gonads the mean age at sexual maturity for catches in the 1960's averages 7·5 years in males and 8·4 years in females. However, from an analysis of the transition phase in the ear plugs, there is an indication that the age at sexual maturity has declined to these ages from original values of 11 to 11·5 years in the pre-1935 year classes. The body lengths at sexual maturity average 13·6 m (44·5 ft) in males and 14·0 m (45·7 ft) in females taken off Durban.

Introduction

The ear plug from the external auditory meatus of the southern fin whale has been shown by Roe (1967) and other workers to contain a core of keratinised epithelium laminated into annual growth layers (each consisting of one pale and one dark lamina), which have proved very satisfactory in age determination. The ear plug is a common feature of all rorquals and in the sei whale it appears to have a similar laminated structure to that of the fin whale when the plug is cut longitudinally down to the mid-line. The ear plug of the sei whale has therefore been considered as a possible means of determining age in this species. However, there are difficulties in the interpretation of the growth layers. This is partly because the laminations are very unevenly layed down; some plugs contain large areas of amorphous gelatinous material, the cause of which is uncertain; many plugs are very small and fragile and break up with handling; and the majority of all plugs examined here are darkly pigmented thus partially obscuring the layering pattern. All these features are atypical of the fin whale ear plug. Roe (1968) commented on the difficulties encountered in examining sei whale ear plugs, and found that neither sectioning and staining nor bleaching with potassium permanganate and concentrated sulphuric acid aided interpretation, and he came to no conclusion about the rate of lamination deposition. Masaki (1968) found that readability of the sei whale ear plug was improved by a technique of X-ray photography, but since then there has been little progress.

Material and methods

The Institute of Oceanographic Sciences has several collections of ear plugs of sei whales. Information about date and position of capture, body length and sexual status and maturity for these whales is also available. The ear plug collections have been taken between 1960 and 1965 at South Georgia, from Antarctic Area II (0°–60°W) and at Durban, South Africa, and amount to a total usable sample of 1127 ear plugs.

A technique of X-ray photography has been tried out on a sample of both sei and fin whale ear plugs. Generally poor pictures were obtained for sei whale plugs (whether whole, bisected, or sectioned) at a power input of 20 kV with a current of 10 mA for 50 seconds, although results were good for fin whale plugs. This technique was abandoned as it was relatively expensive and laborious for the amount of extra information gained over and above that obtained simply by counting layers by eye. The method is worth mentioning because good clear pictures were obtained for fin whale ear plugs at a power input of 25 kV and current of 15 mA for 45 seconds, and this X-ray technique may be helpful in examining ear plugs of other rorqual species, such as *Balaenoptera acutorostrata*, where small size and fragility may render the plugs useless for cutting and handling.

The chief problem in examining many sei whale ear plugs is that the laminae in the core are masked by dark pigmentation. A method of bleaching this pigment has been devised in order to lighten the core. The ear plugs are initially cut down to the mid-line along the longitudinal axis with a sharp razor and then ground and smoothed down on wet stone to expose all the laminae, the foetal cap at the distal end of the core and the neonatal line which defines and separates the foetal and post-natal zones of the core. Each ear plug is placed in a labelled, partly sealed polyethylene bag, for purposes of identification. The ear plugs, which are normally preserved in 10% neutral formaldehyde solution, are then rinsed well and soaked overnight in water. They are then placed in 20 volumes per cent hydrogen peroxide, (that is, a solution of 1·02 g per ml) a mild organic bleach for 18 to 24 h depending on the intensity of the core pigmentation. The plugs are then well rinsed and stored in water until required within the following three days.

The main disadvantage of this bleaching method is that the ear plug tissue is softened, and the bleaching process should be regarded as somewhat destructive; an important consideration in some analyses.

Results

An examination of the bleached ear plugs, using a magnifying lens when necessary, enabled satisfactory laminae counts to be made for 93% of the sample, compared with only 50% before bleaching. Counting only the dark laminae, a satisfactory count constitutes agreement within $\pm$ 1 lamina for ear plugs containing less than 20 laminae, and $\pm$ 2 laminae for ear plugs containing more than 20 laminae, when three persons are independently making counts. The agreed count is then the average of the three values.

Having established that the laminae present in the sei whale ear plug can be counted, there remains the uncertainty as to the time period represented by a growth layer (a paired light and dark lamination), whether the period is a year and even whether the numbers of laminae per growth layer are consistent. These problems will be discussed below.

Rate of growth layer formation

Roe (1968) attempted an examination of the germinal epithelium of the sei whale ear plug in a similar manner to that of the fin whale (Roe, 1967) in order to assess the nature of the epithelial cells developing, hence the lamination type forming and the growth rate of the laminae. He found that only 17% of his sample of ear plugs still retained this epithelium, and he was unable to say more than that the histological structure of the sei whale plug closely resembled that of the fin whale. He suggested that because sei and fin whales were so closely related, it seemed probable that one dark and one pale lamination in the sei plug would constitute an annual growth layer.

Since Roe used samples from the same collections worked on here, and it has not been possible for us to collect further material, a study on the germinal epithelium has not been possible. However, there are several ways of indirectly assessing the validity of sei whale ear plug laminae counts for age determination and at what rate laminae are formed.

Direct examination of the lamina type at the base of the ear plug core

Samples of 98 cut, bleached plugs taken in the 1964/65 season, November to February inclusive, at Leith Harbour, South Georgia, and 100 cut, bleached plugs taken in the 1965 season, July to September inclusive, at Durban, South Africa, were examined under a magnifying lens to determine the type of lamination at the base of the core, adjacent to the germinal epithelium. In many plugs this epithelium was absent and/or the base lamina damaged, so that ultimately only 50% plugs of the entire sample could be analysed. Overall, the base lamina could be more successfully interpreted in younger plugs containing less than 15 pale and 15 dark alternating laminae. Of all the younger plugs, 62·5% were classifiable compared with 39·4% of older plugs. This is because the germinal epithelium is more frequently lost and damaged in older plugs and also the bottom laminae are too compressed for visual differentiation.

The results of the edge type lamina analysis are shown in Table 1. The main observation is that the type of base lamina present in the South Georgia plugs is opposite to that in the Durban plugs. Geographically these two locations are comparable, and although there are few mark returns from sei

Table 1. Edge type lamination of ear plugs from South Georgia and Durban.

Edge type lamination	South Georgia $n = 50$	Durban $n = 52$
Dark	14%	81%
Pale	86%	19%

whales in this region, there are enough which show indisputably that sei whales do migrate between these latitudes (most probably seasonally) and also disperse laterally between Areas II (60°W–0°) and III (0°–70°E). Table 2 shows these important mark return data for southern sei whales.

Although it is probable that the base lamina observed is the newly forming one, there is no certainty without confirmation from microscopical histological studies of the germinal epithelium. This is no longer feasible with the present material which is perhaps in poor condition for reliable results, but the analysis here serves to show that further work using freshly collected material from younger animals where the germinal epithelium is intact could be worthwhile.

The evidence therefore, suggests that for southern hemisphere sei whales, dark laminae form in lower latitudes in the winter months when diminished feeding is occuring, and pale laminae form in higher latitudes in the summer months when feeding activity is high. Feeding activity and migration between low and high latitudes occur in an annual cycle (Gambell, 1968), and it is very probable that one pale and one dark lamina form each year.

Ear plug laminae counts for recovered marked whales

Unfortunately, there is no directly useful information on the ages of marked sei whales, the marks being recovered within too short a time period.

Relationship between numbers of ovarian corpora and ear plug lamina counts

A total of 270 mature female sei whales from both South Georgia and Durban, were examined for both corpora and ear plug laminae. In Figure 1 the individual corpora numbers at each ear plug lamination count are shown. The regression coefficient and standard error for these data have been calculated using the laminae counts as the independent variable. All the data below and including 7 laminae have been deleted in order to eliminate any bias from precocious whales. The regression coefficient from least-squares analysis is $0{\cdot}68 \pm 0{\cdot}02$ corpus per lamina. Gambell (1968) gave an ovulation rate of 0·68 corpus per annum, but recently has revised his estimate at 0·61 corpus per annum (Gambell, 1973) from an age-independent analysis of ovulations. Lockyer (1972) gave a comparable value of 0·69 corpus per annual growth layer for southern fin whales.

The conclusion therefore, is that for sei whales, as for fin whales, one dark and one pale lamina together constitute an annual growth layer.

Table 2. Data for sei whales from which marks have been recovered

Mark number	Sex	Estimated body length when marked m	Measured body length on recovery m	Date when marked	Position when marked	Date when recovered	Position when recovered	Growth layers in the ear plug	Comments
13894	♀	15·3	15·9	18 Feb 1965	50°03′S 40°15′W	19 Feb 1966	44°11′S 11°19′E	19	dispersal east from Area II to III
18285	♂		12·6	22 Aug 1969	30°03′S 32°31′E	11 Feb 1970	44°04′S 50°54′E		seasonal migration south
18290				22 Aug 1969	29°31′S 32°20′E	ca 24 Feb 1970	ca 45°30′S 71°25′E		seasonal migration south; dispersal east to Area IV
18935	♂		13·8	18 Jan 1964	54°20′S 22°51′W	14 Dec 1968	41°21′S 06°23′E		movement north; dispersal east from Area II to III
25739	♂	15·3	14·4	16 Nov 1962	35°36′S 80°50′E	15 Feb 1968	51°02′S 72°47′E	15	movement south
28145				28 Dec 1969	40°09′S 38°38′W	ca 6 Jan 1970	ca 41°50′S 12°49′E		dispersal east from Area II to III

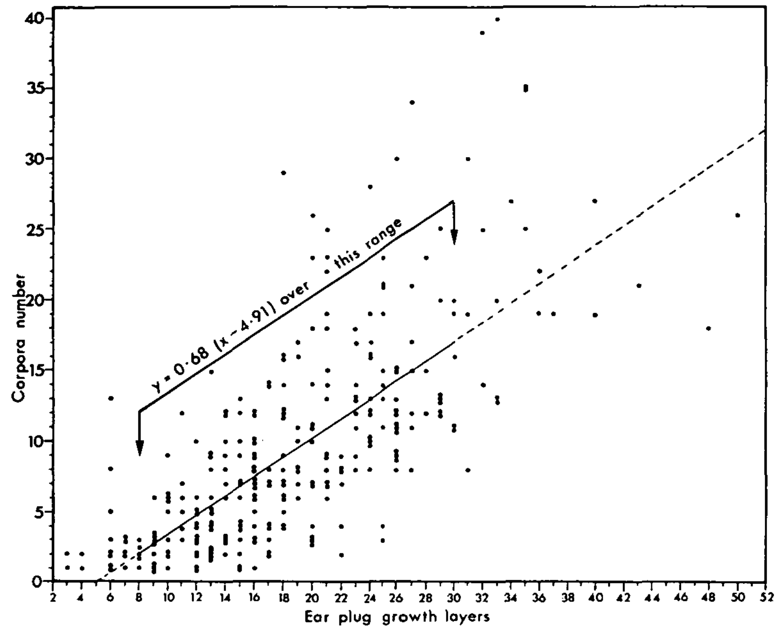

Figure 1. Ovarian corpora number at each ear plug growth layer count.

Anomalies in age data of older mature females

Referring to the individual points in Figure 1, it is evident that the numbers of ovulations in several older females (exceeding 25 ear plug laminations, but especially over 30 laminations) relative to age determined from ear plug laminae counts are generally higher than the extrapolated mean line. It is possible that in older physically mature adults the ear plug core grows imperceptably slowly and some growth layers become squashed out. In fin whales, (Lockyer, 1972), the layering becomes very compressed with advance of age, and in small plugs such as those of the sei whale the newer growth layers may become virtually invisible. This cannot be proven, but it is both interesting and puzzling to note from Figure 2 that in a comparison with a random sample of about 80 older female fin whales from a well-exploited stock, there is a similar distribution of corpora numbers in the whales with 15 and more corpora, yet the age distribution in whales of 30 years and more is rather different with relatively fewer old female sei whales than would be expected from the corpus number distribution represented. Furthermore, comparing the means of the corpora counts from Figure 2, and then the observed and predicted mean ages in Table 3, it is apparent that the observed mean ages estimated from ear plugs are too low in sei whales, if all the assumptions made are correct. Ear plug growth layers therefore may be unreliable for age determination after 30 years in sei whales, and visible growth layers may only be directly related to age up to about 30 growth layers.

Another important possibility is that some older females actually ovulate more frequently than the younger adults. Gambell (1968) mentions that of sei, fin, blue and humpback whales, the sei have the highest incidence of multiple births. Kimura (1957) and Laws (1961) both give evidence of increased twinning and multiple ovulations with advance of age in female fin whales and Gambell (1968) gives data for pregnant and ovulating sei whale females where more than two corpora lutea were observed. Of the sample of 13 females, 2 bore three corpora lutea. The total corpora albicantia were also given and of these, 5 females had between 5 and 14 corpora and 8 females including the couple bearing three corpora lutea had between 15 and 37 corpora. This indicates certainly that the multiple ovulations are not characteristic of newly mature females and possibly increase with age. However, these females form only 2·6% of a sample of 493 ovulating and pregnant females. In samples of ovaries used here, females with more than 14 ovulations form approximately 21·5% of the total (that is 106 whales out of 493) so that polyovulation incidences in this group are as follows:

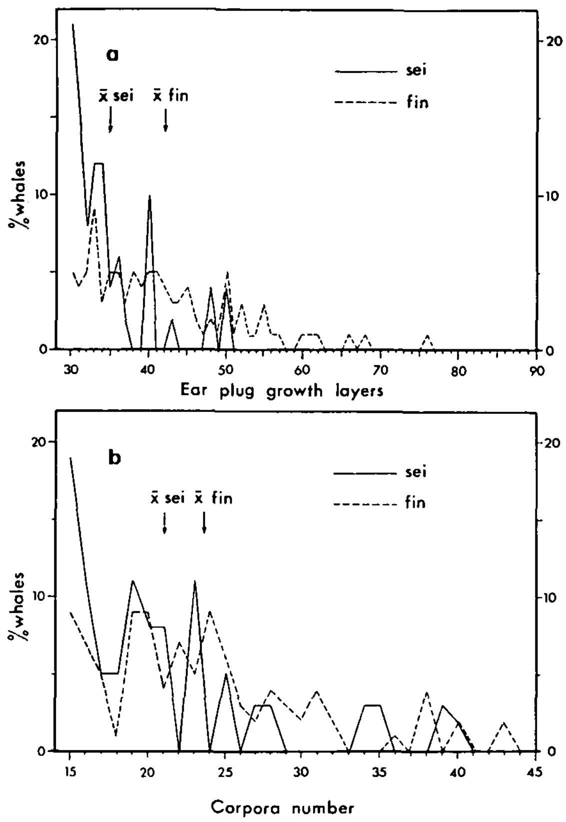

Figure 2. Comparative age distribution of older female sei and fin whales, using (a) ear plug growth layers and (b) corpora number, as the means of determining age.

all multiple ovulations $(8 \times 100)/106 \simeq 7{\cdot}5\%$
double ovulations only $(6 \times 100)/106 \simeq 5{\cdot}6\%$
triple ovulations only $(2 \times 100)/106 \simeq 1{\cdot}9\%$

In the younger females, multiple ovulations are $(5 \times 100)/387 \simeq 1{\cdot}3\%$.

It is likely then that multiple ovulations are more frequent in older females. If during each ovulation cycle (mean 1·47 years) 7·5% of the older females polyovulate, every individual has a probability of a multiple ovulation once in $(100 \times 1{\cdot}47)/7{\cdot}5 \simeq 20$ years. It is immediately obvious that this rate is not going to affect the expected number of corpora in the ovaries for a whale of a particular age, unless the same 7·5% persist in polyovulating.

Analysis of ovulations reveals that only two females from the entire sample, one of 16·2 m (53 ft) with 22 ear plug growth layers and 15 corpora, the other of 16·8 m (55 ft) with 26 growth layers and 30 corpora can actually be traced from the diameter of the corpora as ovulating more frequently (not multiple ovulations) than the main population. Other anomalous females appear to bear no unusual ovarian scars.

Conclusion on the validity of using ear plugs for age determination

Ear plug growth layers represent periodic growth of the ear plug tissue, a pair of pale and dark laminae forming in a year. The number of growth layers produced therefore constitute a record of the actual age of the sei whale at the time of capture. However, ear plug growth layer counts must be applied with considerable caution in age analyses for sei whales and it would seem most likely that growth layers become so densely packed in the ear plug in later age that they are usually either squashed out or completely unidentifiable.

The only plausible reason for ear plug layers becoming squashed out would be that the core could no longer grow normally in length because of actual physical restraint. We have seen that all the anomalies connected with age determination concern older mature animals. This is almost certainly significant if attainment of physical maturity is considered as a possible cause of disruption of regular structural growth processes.

Dr Peter Best has kindly provided me with his own data on fusion of epiphyses in the vertebral column

Table 3. Comparison of the observed mean age of the catch of older females with the predicted mean age. Data marked * from Lockyer (1972)

Species	Mean age of catch (30 years +) (from Figure 2)	Mean corpora number of catch (15 corpora +) (from Figure 2)	Apparent ovulation rate/year for catch	Approximate mean age at sexual maturity for catch (30 years +) (see Figure 6)	Predicted mean age of catch (30 years +)
Fin	41·8	23·6	0·69*	9·5*	43·7
Sei.......................	35·0	21·1	0·68	11·4	42·4

of sei whales taken at Donkergat, South Africa, during 1963 and 1964. The epiphyses were examined in three places: the anterior thoracic, the lumbar and the caudal regions. The state of fusion of the epiphyses was described in four progressive stages:

1. unfused with thick cartilage;
2. unfused with thin cartilage;
3. fused with join visible;
4. fused with join invisible.

Physical maturity is normally assessed from progressive fusion of the epiphyses, when further growth is no longer possible.

In Table 4 the sequence of fusion is shown relative to age in terms of ovulations in the female, for all three vertebral regions. The relative age at which fusion occurs in the caudal region is not before 5 corpora, but is usually in the range 7 to 12 corpora. In the lumbar region, fusion generally occurs between 14 and 18 corpora, but not before 10 corpora; and in the anterior region, fusion does not usually occur before 14 corpora but may take place at any age up to about 28 corpora (although samples are too small to say more than this). These ranges are indicated by vertical bars in Table 4 and represent the most likely ages at which the mature fully fused state is attained.

Clearly most females are on the brink of physical maturity and cessation of structural growth after 14 ovulations, and this may be reflected in the stunted growth of the ear plug from this age onwards. Probably corpora number gives a more reliable estimate of relative age in older females than the ear plug growth layers. However, any similar anomalies in ear plug growth in males cannot be resolved.

Application of ear plug growth layer counts in age determination

Age at sexual maturity

Durban data for 82 females and 110 males from age one year upwards have been examined for gonad maturity (ovulation activity in females, and semini-

Table 4. The numbers of female sei whales examined for fusion of the vertebral epiphyses in the anterior thoracic, lumbar, and caudal regions. For further explanation see text. Data collected by Dr P. B. Best at Donkergat, South Africa during 1963 and 1964.

Corpora number	State of fusion in vertebral region											
	Anterior thoracic				Lumbar				Caudal			
	1	2	3	4	1	2	3	4	1	2	3	4
0	–	–	–	–	–	–	–	–	5	–	–	–
1	–	–	–	–	1	–	–	–	4	–	–	–
2	2	–	–	–	9	1	–	–	11	1	–	–
3	8	–	–	–	12	1	–	–	13	5	–	–
4	8	–	–	–	11	3	–	–	9	7	1	–
5	2	2	–	–	7	2	–	–	3	4	1	2
6	2	1	–	–	1	2	–	–	4	1	–	1
7	4	–	–	–	4	–	–	–	3	2	–	2
8	4	–	–	–	5	1	–	–	1	2	–	2
9	1	–	–	–	1	1	1	–	–	1	–	3
10	2	1	–	–	3	1	–	1	3	1	–	2
11	4	–	–	–	1	3	–	–	–	–	–	5
12	2	–	–	–	2	4	–	–	–	1	1	2
13	5	1	–	–	–	4	3	–	–	–	–	5
14	–	1	1	–	–	1	1	1	–	1	–	–
15	1	2	–	–	–	1	–	1	–	–	–	1
16	2	–	–	–	–	1	–	1	–	–	–	1
17	1	1	–	–	–	2	2	–	–	–	–	3
18	1	–	–	–	–	1	–	–	–	–	–	1
19	1	–	1	–	–	–	–	1	–	–	–	–
20	1	–	–	1	–	–	1	1	–	–	–	–
21	–	–	–	–	–	–	–	–	–	–	–	–
22	–	1	–	–	–	–	–	1	–	–	–	–
23	–	–	–	–	–	1	–	–	–	–	–	1
24	–	–	–	1	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	1	–	–	–	–	1	–	–	–	–
28	–	1	–	–	–	1	–	–	–	–	–	1

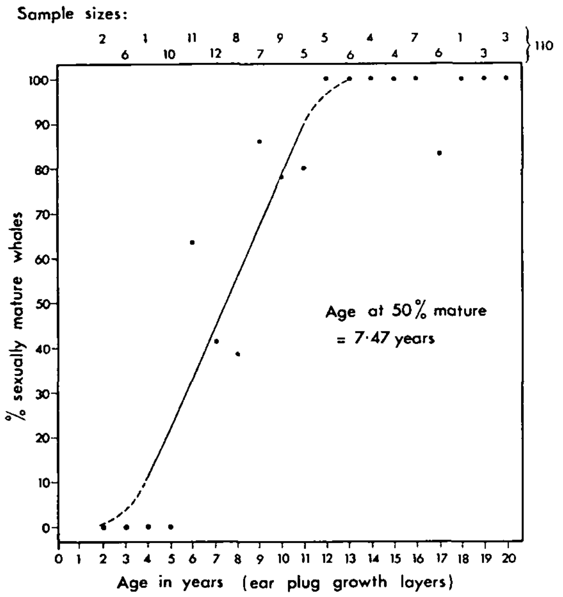

Figure 3. Percentage of sexually mature male Durban sei whales at each ear plug growth layer count.

ferous tubule size, sperm activity and testes weight exceeding 3 kg (Gambell, 1968) in males). The proportion of sexually mature individuals in each age group is plotted for males in Figure 3 and for females in Figure 4. Mean curves have been fitted

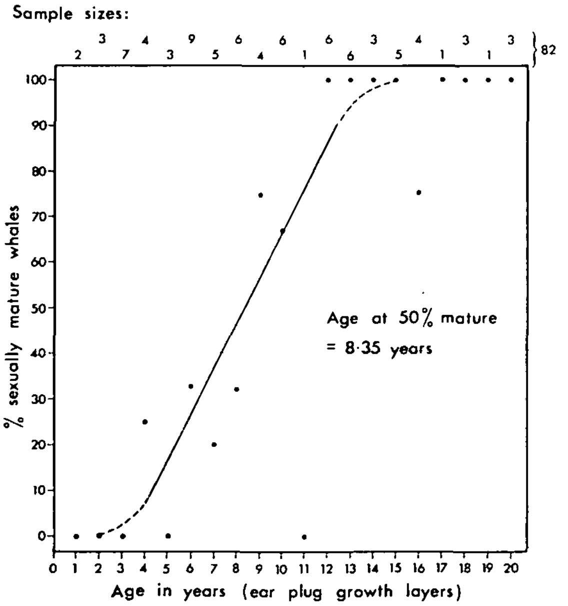

Figure 4. Percentage of sexually mature female Durban sei whales at each ear plug growth layer count.

both by eye and from a least-squares analysis of the data between 4 and 12 years. The resulting mean curves in Figures 3 and 4 are considered to be the best fit. At the 50% levels of maturity the 1965 mean ages are indicated at about 7·5 years in males and 8·4 years in females.

Presence of a transition phase in the ear plug growth layer pattern

In all ear plugs, the region of active growth is at the base germinal epithelium. This tissue gives rise to successive layers in time so that the newest growth layers are near the base of the core and the oldest ones, formed during the pre-pubertal years, are situated distally below the foetal cap and neonatal line. An examination of sei whale ear plugs from Antarctic Area II and Durban shows that a noticeable change in growth layer patterning occurs in the majority at around the middle of the core where the growth layers become subsequently more compressed. This phenomenon seems in appearance to be similar to the transition phase described by Lockyer (1972) in the ear plugs of sexually mature southern fin whales.

An analysis of the presence of the transition phase in sei whales of different classes of maturity is summarized in Table 5. It is clear that there is a correlation between maturity and the presence of a transition phase. However, the results are not as definite as in the case of immature fin whales where no transition was found. The explanation of the anomaly in sei whales is probably that the plugs are more difficult to interpret than those of fin whales. However, this is not significant for practical application of this finding when other information on sexual condition is available.

If the rate of growth layer deposition is regular throughout most of the whale's life (and it would appear likely from the annual migratory and feeding behaviour, and ovulation rate), then the numbers of growth layers up to and including the transition

Table 5. Presence of a transition phase in the ear plug of sei whales from the Antarctic (Area II) and Durban.

Sexual maturity classification	Plugs showing a transition phase: Males %	Males Total sample	Females %	Females Total sample
Immature	5	41	4	43
Pubertal	38	21	(20)	5
Mature..........	89	429	89	398

layer should be a direct record of the age at which the whale became sexually mature.

Transition phase as an indication of age at sexual maturity in different year classes

If total ear plug growth layer counts are assumed to be representative of total age, and one growth layer represents one year's growth, then the year class of a whale can be calculated from this information and the date of capture. The plotting of individual and mean transition counts for each year class by sex shows that for males in Figure 5, the mean transition is fairly stable up to 1935 and averages at 11·0. The females in Figure 6 appear more erratic, although the data are rather patchy up until 1930 probably

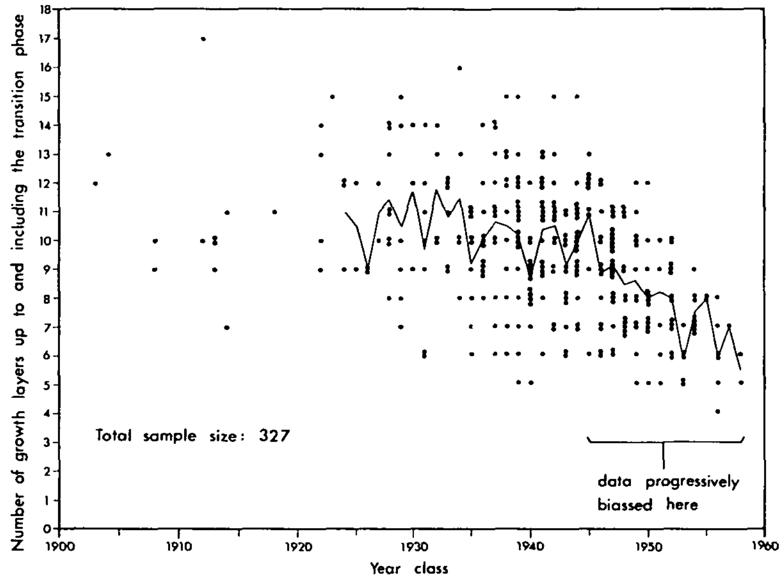

Figure 5. Ear plug transition phase by year class in male sei whales from South Georgia and Durban.

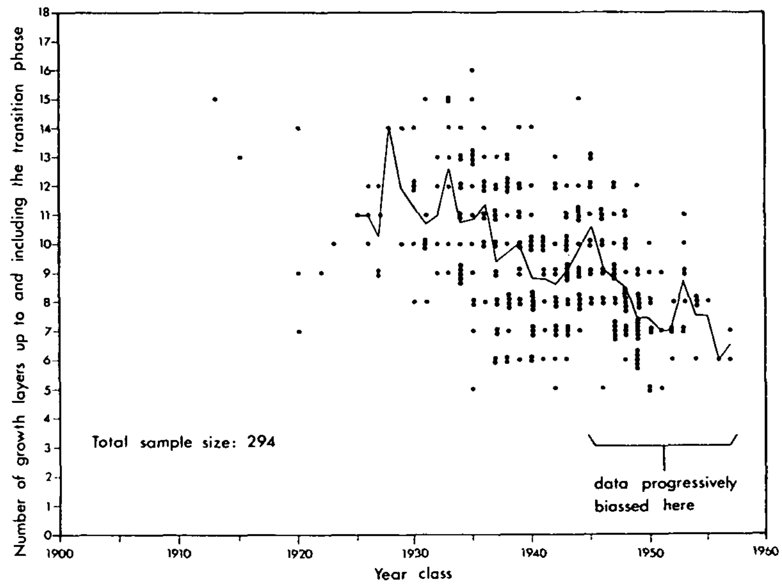

Figure 6. Ear plug transition phase by year class in female sei whales from South Georgia and Durban.

because of the anomalies in the ear plug growth layers of these old animals. The mean transition up to 1935 however averages at 11·4, and for both males and females there is a small drop in mean transition between 1935 and 1945 to 10·0 in males and 9·7 in females. After 1945, the mean transition declines rapidly in both sexes, and the higher individual transition counts are absent. This is chiefly because if one assumes that the latest maturing whale becomes mature at about 15 years of age (see Figs 3 and 4), and the catches are taken between 1960 and 1965, the year classes since 1945 will have biased representation in these seasons since only the early maturing whales can be recorded by the method of transition phase.

As we have seen in Figures 3 and 4 the 1965 mean age at sexual maturity in the Durban catches is 7·5 years in males and 8·4 years in females. These estimates follow on well from the post-1935 period when there is an indication that whales are maturing earlier, and also into the post-1945 period when the mean transition falls off too rapidly to be the result of biased sampling only.

In Figures 7 and 8 the 1925–1935 year classes inclusive and the 1940–1944 year classes inclusive are compared by sex for changes in the rate of maturity. The percentage of whales having a transition phase present by a certain age have been plotted for these year class groups. Figures 7 and 8 again show that the age at sexual maturity has declined in both males and females. The mean age at sexual maturity has fallen from 10·2 to 9·3 years in males and from 10·6 to 8·4 years in females. The upper limits of maturity are still similar, although now there are some whales maturing at 5 years whereas there are

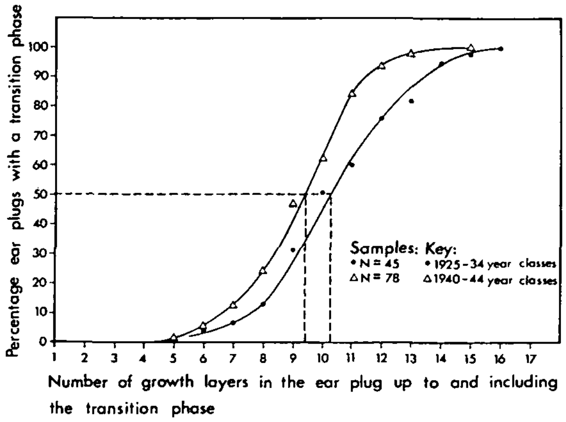

Figure 7. Proportion of male sei whales with an ear plug transition phase at each ear plug growth layer count, in year classes 1925–34 inclusive and 1940–44 inclusive, from South Georgia and Durban.

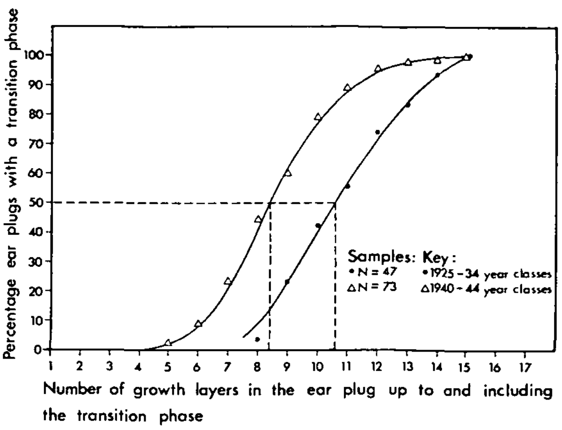

Figure 8. Proportion of female sei whales with an ear plug transition phase at each ear plug growth layer count, in year classes 1925–34 inclusive and 1940–44 inclusive, from South Georgia and Durban.

none previously in either sex. This is especially noticeable in females. The age of maturity has advanced, and by the former mean age at sexual maturity, approximately 70–85% of the population are now mature.

Both ecological and genetical factors may be controlling the physiological change in the rate of growth and maturation. The sei whale did not become an important element in the Antarctic whale fisheries until 1960, so that these changes in age at sexual maturity cannot be ascribed to exploitation of this species since the effects of this, if it was occurring, would not yet be evident from these analyses. However, the apparent change in maturity is not as marked as in fin whales where exposure to the direct effects of fishing has been prolonged. It might be expected, however, that the gross reduction in the fin (and also the blue and humpback) whale populations since 1930 could affect neighbouring related groups such as sei whales which have a similar biology of migration and feeding habits. Indeed, both Matthews (1938) and Brown (1968) found that the summer food of sei whales off South Georgia consisted, with rare exceptions, entirely of the krill, *Euphausia superba*, the food of other balaenopterid whales in the area at this time. Furthermore, the sizes of krill ingested generally ranged from 30–55 mm in body length, the sizes taken by blue and fin whales. Nemoto (1962) and Bannister and Gambell (1965) report evidence of real changes in abundance, distribution and habits of the sei whales since the decline in other whale stocks. Gambell (1973) has found evidence of improved fecundity during this period from increases in pregnancy rates in sei whales, so that it may be possible that the sei whales are indeed in competition for food and space with other rorquals, and the effects of fishing and altering the balance of different populations may have far-reaching and even permanent results.

Mean body length at age

Gambell (1968) has mentioned in his estimations of body length at sexual maturity in sei whales of the lesser reliability of the Antarctic material from high latitudes compared with that from South Africa for this particular analysis, especially in the case of males. He ascribes this to the fact that the data from the Antarctic is biased to the larger whales since the smaller and immature animals are generally not represented in this region, owing to differences in migratory habits. This fact has been borne in mind when attempting to construct mean body length at age curves, and in order to retain some uniformity, only the Durban data have been used for this purpose.

The mean body lengths at each age are shown separately for males and females in Figures 9 and 10 respectively, with the mean curves and formulae best describing them. Unfortunately the data are too sparse after about 25 growth layers to be considered reliable; however, Antarctic data alone would suggest that some males could attain 15·0 m (49 ft) and females 16·2 m (53 ft).

If the current ages at sexual maturity are approximately 7·5 years in males and 8·4 years in females, then the corresponding mean lengths at maturity are approximately 13·6 m (44·5 ft) and 14·0 m (45·7 ft). for males and females respectively. These values are in agreement with the estimates of Gambell (1968)

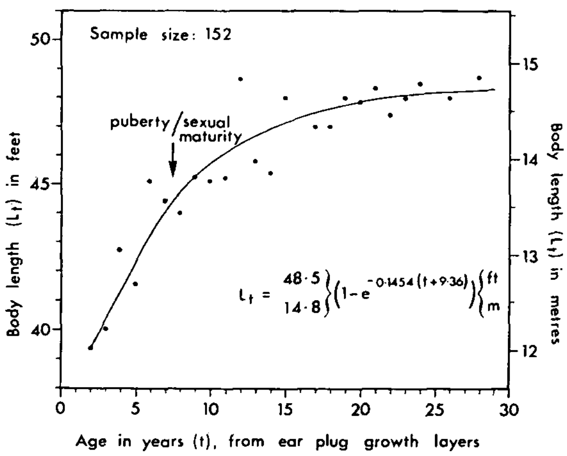

Figure 9. Observed mean body length at age curve for male sei whales from Durban.

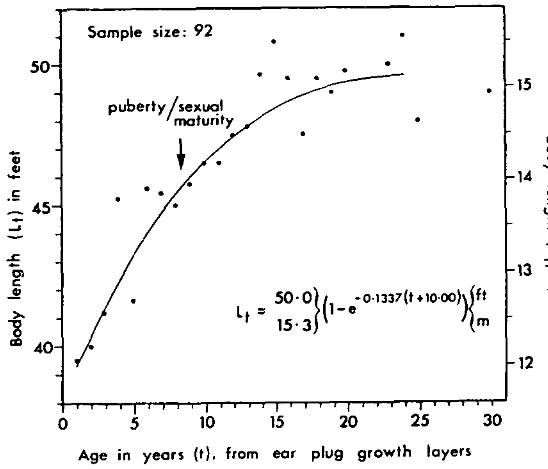

Figure 10. Observed mean body length at age curve for female sei whales from Durban.

of 13·6 m and 14·0 m for males and females respectively from South Africa, for which he plotted the percentage of sexually mature whales at each body length. Because in Figures 7 and 8 samples total less than 160, the estimates of body length at sexual maturity are intended to corroborate Gambell's findings and Figures 9 and 10 are not to be regarded as growth curves. This is because the International Whaling Commission (1950) forbade the taking of calves accompanied by nursing females in all whale species, and set body size limits on the sei whale catch. Small young whales are thus absent from the catches and the data for early years is biased.

General conclusion and summary

Using the method of bleaching with hydrogen peroxide, the laminae in the core of the sei whale ear plug can more easily be counted by eye, using a magnifying lens if necessary. This is because the lightening of the overall dark pigment reveals the differentiation into pale and dark laminae.

The absence through loss of the germinal epithelium in the majority of ear plugs has meant that the actual rate of lamina deposition cannot be histologically determined and other indirect means of estimating the rate of lamina formation have been used. An analysis of the type of base lamina in samples of South Georgia and Durban plugs suggests that one pale and one dark lamina form annually and so represent one year's growth layer, in a similar manner to that in fin whales.

Comparative evidence of rates of accumulation of ovarian corpora through methods both independent of and dependent on ear plug growth layer counts also suggests that one pale and one dark lamina in the ear plug form each year. However, conflicting results from true and apparent ovulation rates in old females, expected and observed distributions of age and proportions of old animals in the catches using both corpora number and ear plug growth layer counts as age-equivalents, show that ear plug growth layer counts are reliable indicators of age only up to about 30 growth layers.

The ear plugs of sei whales may, with some discretion, also be used for estimating the age at which the whale became sexually mature from transition phase counts, similar to the method used in fin whales (Lockyer, 1972). This method and direct estimates of mean age at sexual maturity indicate a decline in the mean age at sexual maturity from about 11 years or so in both sexes to about 7·5 years in males and 8·4 years in females in recent years. The reason implicated is the rapid diminution of other whale species such as blue, humpback and especially fin whales through commercial whaling operations, and the subsequent reduction of interspecific competition.

The mean body lengths at sexual maturity of sei whales off Durban are 13·6 m in males and 14·0 m in females.

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