On the Sexual Maturity of the Sei Whale of the Bonin Waters

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Introduction

Since 1923 Japanese whalers have been operating in the Bonin Islands waters, and the land stations on Chichi-jima was the base of the operation prior to the World War II. As this land station has been lost as the result of the war, the whaling has been conducted under the floating factory system since the 1946 season, taking 300 to 400 whales per season (Fig. 1). The catch in those postwar seasons consists mainly of sei and sperm whales, and the former species amounts to more than 50% of the catch in very season. Since the 1950 season this species have been accounting for even more than 80% of the catch, because of the change of operating season due to the amendment of the International Whaling Regulations and the favorable price of this whale. In recent years, the relative importance of the whaling in the Bonin waters to the Japanese coastal whaling have increased, partly because the productivity of the former operation has been augmented by the adoption of the floating factory system and the efficient catcher boats, and partly because the productive whaling grounds in the Kuril and Korean waters was lost because of the war (Table 1).

In keeping with the increasing importance of the sei whale of the Bonin waters as the fishery resource, the biology of this whale is investigated actively. With the progress of the study, it has become more probable that this whale is not the true sei whale, *Baraenoptera borealis*, but the Bryde whale or it very close relative.

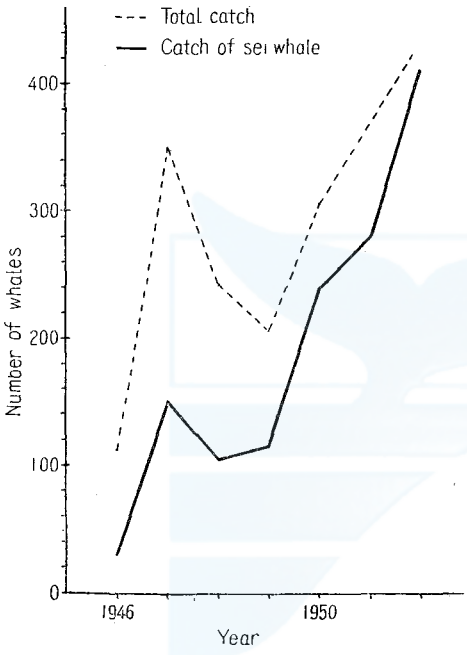

Fig. 1. Number of Catch by year

Table 1. Whale Catch by the Japanese Coastal Whaling and its Part Taken in the Bonin Waters

Season	Japanese Coastal Whaling (Number)	Bonin Waters	
		(Number)	(Percentage)
1937	2050	160	8.2
1951	2300	340	14.8

Several authors have hitherto investigated in the sexual maturity of the sei whales of the adjacent waters of Japan. Andrews (1916) reported a pregnant female of 25 ft. in length. This individual, however, should be regarded as an exceptional case, if it was not a mink, but really a sei whale. Hayashi (1927) concluded, on the basis of his anatomical study of the ovary, that the female attain sexual maturity at lengths greater than 12 m. (40 ft.). According to Matsuura (1935), however, the length of the female at sexual maturity is not more than 40 ft., because pregnant females range between 40 and 43 ft. in length. Kasahara (1950) studied the sexual maturity of the male as well as of the female, and also distinguished the individuals caught in the Bonin waters from those caught off the pacific coasts of Sanriku (northern Honshu) and Hokkaido. Based on the graph in which the length of the male is plotted against the weight of the testes and on the presence or absence of corpus luteum, he approximately estimated the lengths of the two sexes at sexual maturity as follows (male : female): 41 ft.: 41 ft. for the Bonin group and 43–44 ft. for the Sanriku-Hokkaido group. He ascribed this regional difference in the length at sexual maturity to the fact that the whaling is operated in the Bonin waters about a half year earlier than in the Japanese coastal waters, and con-

sidered that the whales grow by that length while they are migrating from the former region to the latter. Along the same line of reasoning, he estimated the growth rate of the sei whale at 2–3 ft. in 5–6 months.

Omura (1950) determined the length of both sexes at sexual maturity for the three different whaling grounds, namely Bonin Islands, Sanriku (Ayukawa to Kamaishi) and Hokkaido (Kushiro to Kiritappu). His result follows:

	Bonin Islands	Sanriku	Hakkaido
Male	40 ft.	42 ft.	43 ft.
Female	41 ft.	44 ft.	45 ft.

On the basis of the herein indicated geographic differences in the length at sexual maturity, he presumed that the sei whales of the Hokkaido waters and those of the Bonin Islands waters belong to different populations, and that the two populations mix in the Sanriku waters. In his study, females with any corpus luteum and males with a testis weighing 1.0 kg. or more are regarded as sexually mature.

Since Omura published this study, a group of Japanese biologists have collected, under his leadership, the various evidences which support his theory and distinguished the sei whales in the adjacent waters of Japan into the northern and southern types. The northern type is considered as preponderant in the Hokkaido waters, and the southern type, in the Bonin waters. The most notable characteristic distinguishing the two types are the colour and structure of the baleen plates.

Chapter I. Material and Methods

The material for this study consists of the 694 sei whales taken in the whaling area round the Bonin Islands in the 1951 and 1952 seasons by the whaling fleet of the Kyokuyo Whaling Co., Ltd. accompanied by the floating factory Baikal Maru. The operating period was May 1—June 10, 1951 in the former season, and May 1—June 20, 1952 in the latter. In the two seasons the whaling fleet operated in the nearly same area (Fig. 2). The sex composition and average lengths of different sexes of these whales are shown in Table 2. Length frequency distribution of these whales is illustrated in Fig. 3.

That all these whales belong to the aforementioned "southern type" has been ascertained from the characteristics of the baleen plates. Sample baleen plates were collected from all individuals and are preserved.

Of course, it is nearly impossible to sample a whale stock according

to a well-defined plan. In order to compensate for this disadvantage, the sample size, i. e. the number of the whales to be examined, as large as possible is desired. From this standpoint, the catches of the two seasons are combined and subjected to analysis, because they consisted exclusively of the southern type, and were taken in the nearly same area and in the nearly same season of the year during a relatively short period of time, (i. e. one and a half months). The difference in the length composition between the catches of the two seasons has also been taken into account.

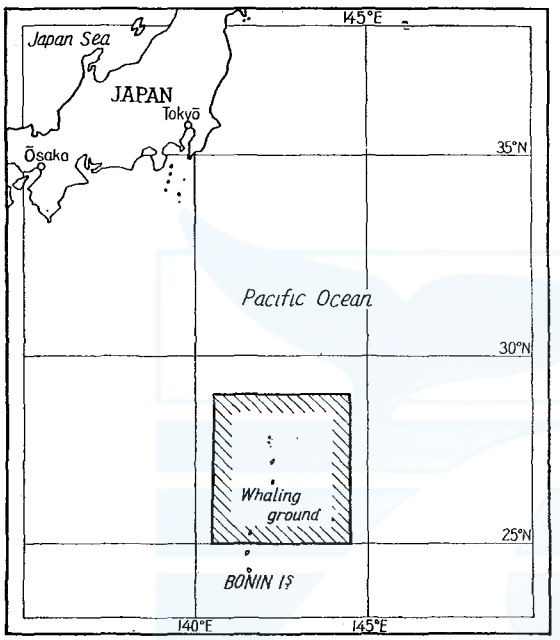

Fig. 2. Whaling Ground of Bonin Area

Sexual maturity of the male is determined by the histological method. Immediately after the carcass of a male is dismembered, a sample piece of about 1 cm. cube is taken from the gland tissue about 1 cm. underneath the free surface of the central part of each testis, and fixed in the alcohol-formalin solution (1 part of 10% formalin solution in 9 parts of 60% alcohol). At the same, each testis is weighed. In the laboratory, the sample piece is sectioned,

Table 2. Sex Composition and Mean Length of the Sei Whales used as the Material

Season Caught	Male			Female			Sex Ratio
	Number	Length (ft.)		Number	Length (ft.)		Male : Female
		Mean	Standard Deviation		Mean	Standard Deviation	
1951	157	41.7	1.56	126 (1)	42.3	1.39	57.6 : 42.1
1952	270 (3)	41.7	1.25	141 (7)	42.5	1.52	65.7 : 34.3
Total	427 (3)	41.7	1.56	267 (8)	42.4	1.41	61.7 : 38.3

double-stained by haematoxylin and eosin and examined under the microscope for the presence of spermatozoa. If completely metamorphosed spermatozoa is found in the sample piece, the testis, hence the whale, from which the sample piece is taken is regarded as mature.

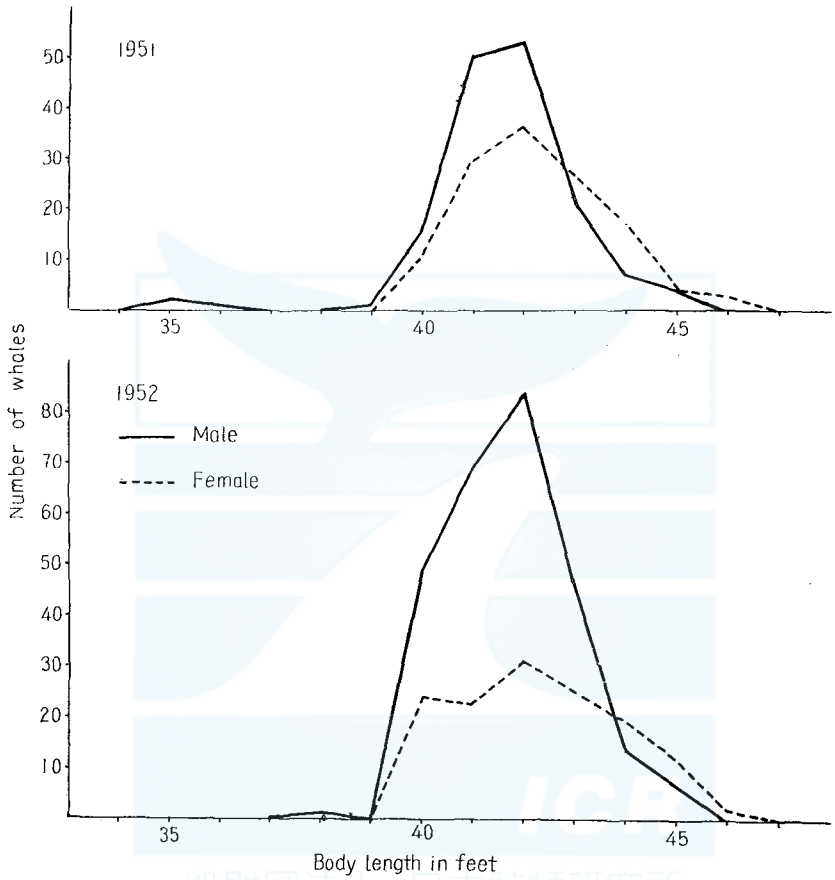

Fig. 3. Frequency Curve of Body Length.

It may happen that the testis which is determined as immature by this method is actually mature, containing metamorphosed spermatozoa in its other part than the sample piece. This possibility limits, to some extent, the applicability of the result of the determination. For practical purposes, however, the result of this method can be applied with little, if any disadvantage, because neither the length of the whale at sexual maturity nor the weight of the testis at its maturity can be estimated smaller than the truth.

In the female, sexual maturity is determined on the basis of the female, sexual maturity is determined on the basis of the corpus luteum evidence.

In the female, sexual maturity is determined on the basis of the corpus luteum evidence.

The collection of the material, i.e. weighing the testis, taking and fixing the testis sample, and examining the ovaries for the presence of corpus luteum, is carried out by the government inspectors and the biologists on board the floating factory.

Chapter II. Sexual Maturity of the Male

Based on the results of the examination of all the testis samples, the percentage maturity of the testes is calculated for each testis weight class, and graphed in Fig. 4.

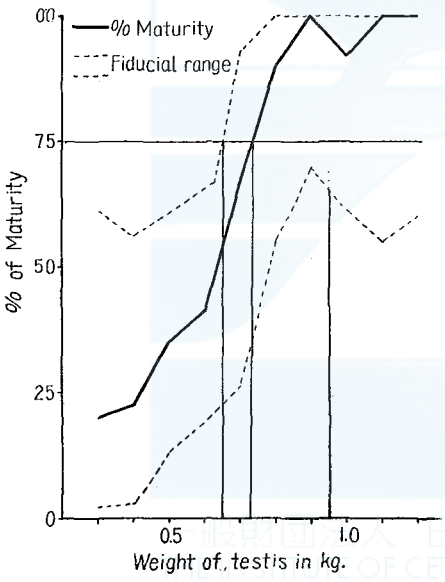

Fig. 4. Maturity of Testis.

In the graph, the testis weight corresponding to the percentage maturity of 75% is 0.74 kg, its fiducial range being 0.63–0.95 kg. at the significance level of 5%. Hence, statistically the testis of the sei whale of the "southern type" becomes mature at the weight between 0.63 and 0.95 kg, and in average at 0.74 kg.

In Fig. 5 the weight of the testis is plotted against the length of the whale, and discrimination is made between mature and immature testes. The general trend suggested by the graph, though not very distinct because the dots are not sufficiently many, is that the relative frequency of the mature testes is more closely correlated to the weight of testis than to the length of the whale. And the relatively extensive scattering of dots in the direction of the length of the whale probably represents the considerable variation of the length within each age-class.

In Table 3 the male whales are classified in respect to the relative weights of their right and left testes. The statistical analysis of the

result shown in Table 3 indicates that there is no such tendency that heavier testis occurs on the definite side of the body. This fact suggests that there is little sense in segregating the right testis from the left for the purpose of making comparison between right or left testis only, and that the combined weight of the right and left testes is a more suitable measure for comparison than the weight of the testis of one definite side.

In Fig. 6, the combined weight of the pair of testes is plotted against the length of the whale. Only a few whales are smaller than 40 ft., because this is the minimum length limit provided by the regulations. In Fig. 6, in contrast with the similar graphs for other whales, it is difficult to define such a whale length above which sexually mature individuals predominate and below which immature whales are dominant. (This fact may be interpreted to indicate that the present length limit is stringent enough to protect the immature male.) Although the weight of the testis is positively correlated to the length of the whale, the relationship between the two factors is much obscured by the considerable dispersion of the dots, particularly in the lower length classes.

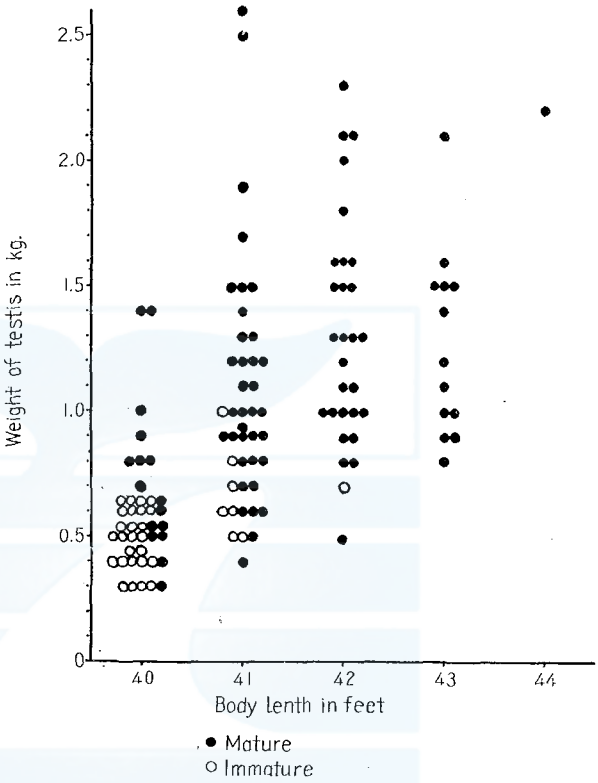

Fig. 5. Weight of Testis and Body Length, stained as the Maturity of Testis.

Table 3. Number of the Male as Classified According to the Relative Weights of the Right and the Left Testis.

Season Caught	Left Testis Heavier	Both Testes Equal in Weight	Right Testis Heavier
1951	44	31	82
1952	93	116	58
Total	137	147	140

Therefore, it may well be said that the length at which the male sei whales of the Bonin waters attain sexual maturity can hardly be estimated correctly by the simple observation of the graph in which the weight of the testes is plotted against the length of the whale.

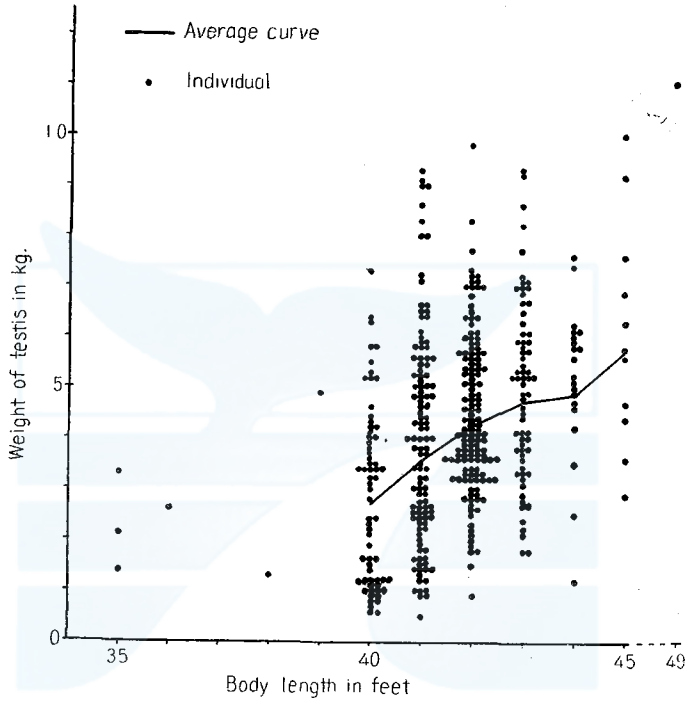

Fig. 6. Weight of Testes and Body Length.

With the view of overcoming these limitations of Fig. 6, the percentage maturity is calculated for each length class, and used for the determination of the length at sexual maturity. Since it has been statistically shown that a testis weighs an average of 0.74 kg. at its maturity, a whale is regarded as sexually mature if its pair of testes weighs more than twice as much, i.e. 1.5 kg or more. The result is illustrated in Fig. 7.

Statistical computation shows that the length of the whale corresponding to the 75% maturity in Fig. 7 is 40.4 ft. and its fiducial range is 39.8–40.9 ft. at the level of significance of 5%.

To sum up, the length of the male sei whale of the Bonin waters at sexual maturity is estimated at 40.4 ft. on the basis of the measurements taken in May and June.

Of the males examined in this study, i.e. those taken in the 1951 and 1952 seasons, about 90% were sexually mature. Accordingly, one may consider that the majority of the male sei whales taken in the Bonin waters are mature, as far as the present regulations are operative.

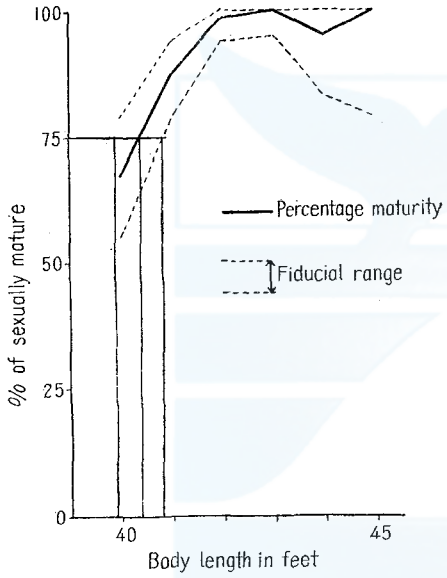

Fig. 7. Sexual Maturity of Male

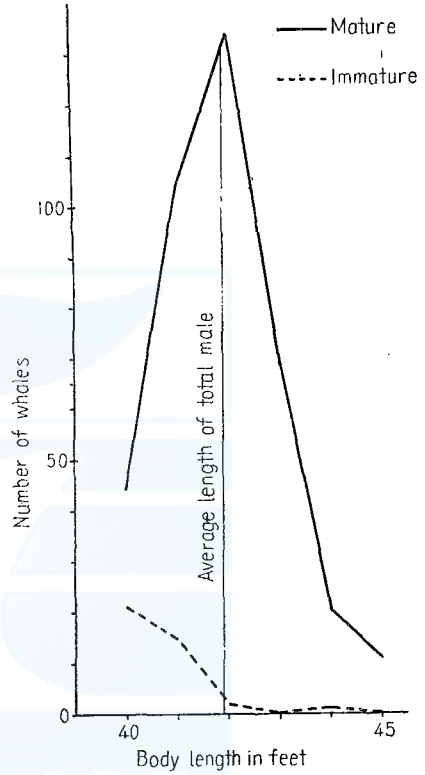

Fig. 8. Frequency Curve of Mature and Immature Male

Fig. 8 shows the length composition of the sexually mature and immature groups of the males taken in the 1951 and 1952 seasons. The modal and the mean length of the mature group are 42 and 41.9 ft., respectively.

Chapter III. Sexual Maturity of the Female.

Fig. 9 shows the relation between the length of the female and the number of the corpora lutea in its both ovaries.

A female is regarded as sexually mature if any corpus luteum is found in its ovaries. And the percentage of the sexually mature in-

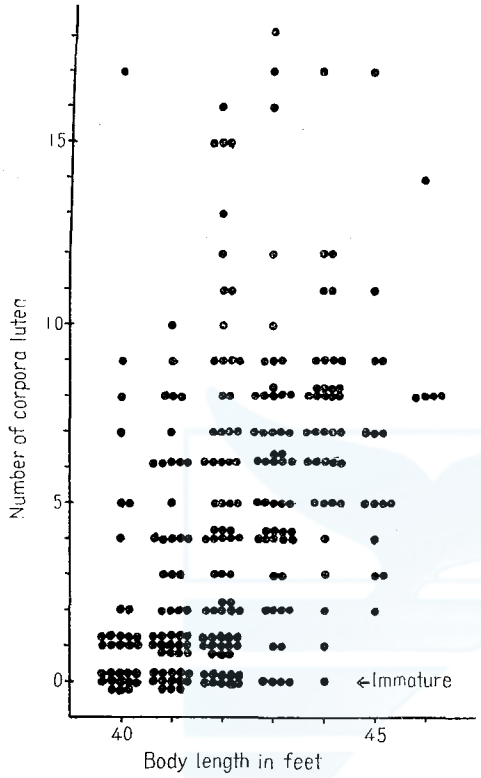

Fig. 9. Number of Corpora Lutea and Body Length

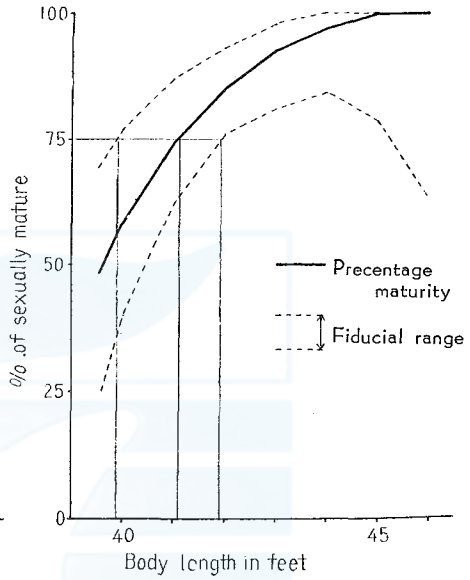

Fig. 10. Sexual Maturity of Female

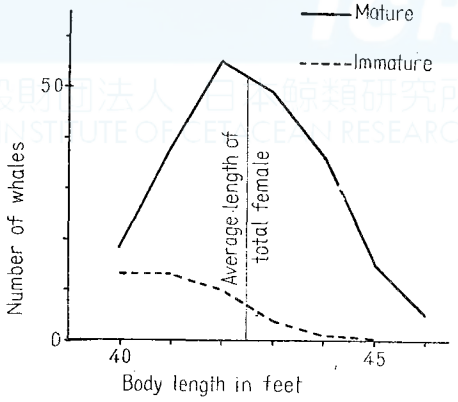

Fig. 11. Frequency Curve of Mature and Immature Female

dividuals, or the percentage maturity, is calculated for each length class of the female. The result is illustrated in Fig. 10.

By the statistical method, the length corresponding to the 75% maturity in Fig. 10 is estimated at 41.1 ft., and within the fiducial range of 39.9–41.9 ft. at the 5% level of significance. This fiducial range is wider than was estimated for the male in the preceding chapter, probably because fewer females are examined than males. (259 females are examined as against 424 males.)

Of the females taken in the 1951 and 1952 seasons, 84% were sexually mature. This percentage maturity is lower than that of the males taken in the same seasons.

Fig. 11 shows the length composition of the sexually mature and immature groups of the females taken in the 1951 and 1952 seasons. The modal and the mean length of the mature group are 42.0 and 42.5 ft., respectively.

Discussion and Conclusions

Since the appropriateness of determining the sexual maturity of the female whale on the basis of the corpora lutea evidence is almost established, it may be said that maturity or immaturity of each individual female has been determined with great certainty in this study. In estimating the length of this sex at sexual maturity, a much large sample has been used than in the preceding studies. (Omura's (1950) sample was the largest in the past, containing 93 females, while our sample consists of 259.) Nevertheless, the fiducial range of the estimate has been considerably wide. These facts seem to suggest that a still larger sample is necessary for a narrower fiducial range.

The determination of sexual maturity of the male is much more difficult than in the female. The most reliable method over derived for this determination is probably such histological one as was used in this study. If well developed spermatozoa are detected in the histological sample of a testis little problem occurs in interpreting the result. If spermatozoa are not detected in the sample piece, two interpretations are possible: (1) the testis is immature and (2) the testis is mature, and contains well developed spermatozoa in some other part of it than the sample piece. The latter possibility can not be denied entirely, although the maturity of the various parts of a testis was compared in the preliminary study and the histological sample for the present study was taken from one of those parts where maturity is attained

earliest. As a counter-measure, the juice squeezed from the testis was smeared on the slide glass and examined microscopically. But this method did not prove to be effective. Consequently, we have decided to regard a testis as immature if completely metamorphosed spermatozoa was not found in its histological sample, and to content ourselves with the fact that the percentage maturity computed according to this criterion increases sharply above certain length of the whale or weight of the testies.

Regarding the accuracy of the estimated lengths of the whale at sexual maturity, following two points should be mentioned. Firstly, these estimates are based on the whales taken by the commercial whaling operations, and these whales are not warranted to be a representative sample of that stock of the whale of which we wish to know. Secondly the length of the whale is not measured very accurately.* The accuracy of the aforementioned estimated length is limited, in either sex, by these factors, however carefully the data may be analyzed.

In this study, the weight of the pair of testes of 1.5 kg. has been used as a criterion to distinguish sexually mature and immature males. If 1.2, 1.4, 1.6, 1.8 or 2.0 kg. is used as the criterion instead of 1.5 kg. and the same process of computation is followed as in Chapter II, the length of the male at sexual maturity is estimated respectively at 40.2, 40.3, 40.5, 40.6 or 40.7 ft., or with in the fiducial range that was computed with 1.5 kg. as the criterion. This fact may be interpreted to suggest that the weight of the testes of 1.5 kg. is an appropriate criterion. In the light of the results of the present study, e.g. the result of the histological examination and the estimated length at sexual maturity, the weight of the testis of 1.0 kg. seems to large as a criterion for distinguishing mature and immature males. And it is our opinion that, while the weight of the single testis is a good index of the maturity of the testis, the weight of the both testes is superior to the former as an index of the sexual maturity of an individual, and that the double of the weight of a single testis at its maturity is to be used as the criterion for distinguishing the sexually mature and immature males.

The results obtained in this study are summarized as follows.

1. The sexual maturity of the sei whale of the so-called "southern

* This does not mean that whalers make false statements, for their convenience, of the length of the whales they have caught. The measurement of the length of the whale become "inaccurate", because it is difficult to take the measurement strictly in compliance with the definition ("on the level in a straight line"), because the whale on the dismembering deck is seldom straightened and seldom in the position that is normal when it is alive in the sea, and because the reading under 1 ft. is rounded up.

type" is studied with the material secured in the Bonin whaling ground in May and June.

2. On the basis of histological examinations, the weight of a single testis at it maturity is estimated at 0.74 kg., its fiducial range being 0.63–0.95 kg. at the 5% level of significance. A male is regarded as sexually mature, if its both testes, in combination, weigh more than 1.5 kg. (the double of 0.74 kg.) The length of the male at sexual maturity, which is defided as the length corresponding to the percentage maturity of 75%, is statistically estimated at 40 ft. and within the fiducial range of 39.8–40.9 ft. at the 5% level of significance.

3. Whether a female is sexually mature or immature is determined from the presence or absence of a corpus luteum in its ovaries. The length of the female at sexual maturity, which is defined in the same manner as that of the male, is estimated at 41 ft. and within the fiducial range of 39.5–41.9 ft. at the 5% level of significance.

4. The present regulations forbid the floating factory whaling catcher to take sei whales under 40 ft. long in the Bonin waters. This size limit is considered to be more stringent and protecting the whale stock more effectively, if not perfectly, than any other size limit now applied to various species of whales.

In conclusion, we wish to express our sincere gratitude to the crew of the Baikal Maru fleet of the Kyokuyo Whaling Co., Ltd. for supplying the material for this study, and to Messrs. S. Nishimoto and K. Ozaki, government inspectors, and Messrs. T. Kawakami and K. Fujino, biologists, for collecting the material in the field.

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