

# YEARLY CHANGE IN AGE AND BODY LENGTH AT SEXUAL MATURITY OF A FIN WHALE STOCK IN THE EASTERN NORTH PACIFIC\*

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## ABSTRACT

The age and body length at sexual maturity were studied on the eastern stock (east of 180° Longitude) of the fin whale (*Balaenoptera physalus*) in the North Pacific by means of two independent examinations of a) proportions of sexual maturity in each age and body length classes and b) age and body length distributions of females with one corpus luteum or corpus albicans in ovaries. Thus, yearly change in these two kinds of biological parameters was analysed by use of data collected from fin whales caught during 22 years from the start to the end of fundamental exploitation of this stock.

Statistically significant yearly change was observed in the ages at sexual maturity which were obtained from both the 50 % maturity and average age of females with one ovarian corpus. The age at sexual maturity was estimated to have changed from 12 to 6 years in females and from 11 to 4 years in males, respectively, from the beginning to the end of the periods of exploitation. The average age of females with one ovarian corpus was 0.5–1 year older than the average age at sexual maturity of females which was estimated from 50 % maturity.

However, no statistically significant trend was observed in the yearly change in the average body length at sexual maturity, and this parameter kept 57.2 and 60.6 feet (17.4 and 18.3 m) for males and females, respectively, during these 22 years. The average body length of females with one ovarian corpus was 0.9 feet (0.3 m) larger than the average body length of females of 50 % maturity.

These phenomena represent that the growth pattern of this whale stock changed from the start of fundamental exploitation. The change in the feeding environments along with the decline of total biomass of baleen whale populations may have affected the growth and maturity of younger animals more strongly than the older.

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## INTRODUCTION

The age at sexual maturity is recognized as an important biological parameter for the population assessment of whale stocks, and many papers have been reported on this matter, especially since the discovery of teeth (Nishiwaki and Yagi, 1953) and earplugs (Purves, 1955) as age characters for the cetacea in 1950s.

There are several methods to estimate the age at sexual maturity of whales such as: 1) proportion of sexual maturity at different ages, 2) relation between age and corpora numbers in both ovaries, 3) growth curve and body length at sexual maturity, 4) age distribution of females with one ovarian corpus and 5) age at transition phase in earplug. Among them the study of transition phase by Lockyer (1972) provided a new field of studies on the age at sexual maturity.

Possibility of the decline in age at sexual maturity of whale stocks was first suggested by Laws (1962) without direct evidence on the Southern Hemisphere fin whale, and Utrecht-Cook (1966) indicated this kind of phenomenon on the same fin whale stock by use of baleen plates which are recognized not to be so good age character. Lockyer (1972) proved this phenomenon directly on fin whales from the Southern Hemisphere based on the age at transition phase in earplugs. Her paper stimulated whale biologists strongly, and this method has become main tool to study the yearly change in the age at sexual maturity of whale stocks since then. Lockyer (1974) reported the lowered age at sexual maturity in more recent year classes on the Southern Hemisphere sei whale by use of transition phase in earplugs. Masaki (1979), Best (1982) and Kato (1983) all reported the same phenomenon by use of the transition phase of earplugs of the Southern Hemisphere minke whale. However, Cooke and de la Mare (1983) criticized these reports, and they claimed the apparent decline in the age at sexual maturity might be an artifact of the data. They also threw a question on the use of transition phase for studies of the age at sexual maturity of whales.

On the other side, trials to apply other methods than transition phase as indicators of sexual maturity have been continuing (Kato, 1983, Masaki, 1976; 1979, Lockyer, 1983) on the Southern Hemisphere minke, sei and fin whales. This paper aims to find an evidence of yearly change in the age at sexual maturity in the whale without use of the transition phase which has been in large discussion. As such a whale stock, a fin whale stock in the North Pacific was picked up to solve the question.

Fin whales which are distributed in the eastern North Pacific (waters east of 180° Longitude) have been recognized by the International Whaling Commission (IWC) as a stock based on the papers such as Fujino (1960) and Omura and Ohsumi (1964) by means of some methods including blood typing and whale marking. This whale stock began to be exploited along the coasts of California, British Columbia and Alaska from the beginning of this century,

but the fundamental exploitation started by pelagic whaling in the waters of the Bering Sea and around Aleutian Is. in 1954 (Japan Whaling Association, 1955). Since then, this fin whale stock continued to be exploited by Canada, Japan, USA and USSR whalers till 1975 when the IWC decided to stop the exploitation. According to Chapman (1976), this stock decreased to 38% of the initial population level by that year. Therefore, this whale stock will be useful for examination of change in population parameters accompanying with the change in population level, because the population level of this stock was estimated to change gradually and largely during relatively long time. In addition to this feature, detailed biological data were collected on each whale caught by Japanese pelagic whaling from the beginning to the end of the fundamental exploitation by the cooperation of many Japanese whale biologists, national inspectors and whaling workers. These data enable us to examine the yearly change in the biological parameters thoroughly.

I would like to express my sincere thanks to these people including technicians who prepared biological materials for this study. I am also indebted to Mr Hidehiro Kato of the Whales Research Institute for his kind review of my manuscript.

#### MATERIALS

All the materials used for this work were biological data on the fin whales caught in the waters east of 180° Longitude from 1954 to 1975. The following kinds of biological data were used in this study:

Position caught, 1954–1975

Whale species, 1954–1975

Sex, 1954–1975

Body length, 1954–1975 (excluding 1961)

Ovarian corpora numbers: 1954–1975

Weight of testis of each side, 1954–1975

Total age, 1957–1975 (lack of data in 1965)

The position of catch was recorded for each whale in degree and minute. The body length was measured from the tip of snout to the notch of flukes in unit of foot till 1959 and 0.1 m from 1960. Then, foot unit was used in this work converting 0.1 meter unit into foot unit. The females from which both ovaries were collected were used to identify an individual which had one corpus luteum or corpus albicans in total. The sexual maturity of a female was determined as an individual which had at least one corpus luteum or corpus albicans in the ovaries. The sexually immature female was determined as an individual which had neither corpus albicans nor corpus luteum in both ovaries. Other animals were excluded for determination of sexual maturity of females. The male sexual maturity was determined by means of weight of testis, and an individual which had a testis of 2.5 kg and over in any side of testis was regarded as sexually mature based on Ohsumi (1964). If testis of one side was

TABLE 1. NUMBER OF MATERIALS WHICH WERE USED FOR EXAMINATION OF AVERAGE AGE AT SEXUAL MATURITY OF THE FIN WHALE IN THE EASTERN NORTH PACIFIC

Year	Males			Females		
	Immature	Mature	Total	Immature	Mature	Total
1957-58	93	139	232	35	71	106
1959-60	219	257	476	298	271	569
1961-62	183	357	540	255	333	588
1963-64	109	236	345	130	227	357
1966-67	128	110	238	150	93	243
1968-70	46	128	174	74	94	168
1971-73	18	81	99	33	60	93
1974-75	10	69	79	20	42	62
Total	806	1,377	2,183	995	1,191	2,186

TABLE 2. NUMBER OF MATERIALS WHICH WERE USED FOR EXAMINATION OF AVERAGE BODY LENGTH AT SEXUAL MATURITY OF THE FIN WHALE IN THE EASTERN NORTH PACIFIC

Year	Males			Females		
	Immature	Mature	Total	Immature	Mature	Total
1954	71	289	360	103	288	391
1955	122	506	628	168	407	575
1956	65	363	428	105	286	391
1957	83	511	594	130	385	515
1958	156	385	541	170	298	468
1959	114	254	368	157	229	386
1960	169	378	547	230	369	599
1962	110	501	611	114	401	515
1963	104	437	541	126	332	458
1964	92	417	509	120	315	435
1965	141	367	508	156	293	449
1966-67	215	354	569	289	329	618
1968-69	43	225	268	81	143	224
1970-71	69	254	323	101	180	281
1972-73	18	81	99	28	57	85
1974-75	21	93	114	34	65	99
Total	1,593	5,415	7,008	2,112	4,377	6,489

not collected and obtained was less than 2.5 kg in weight, such an individual was excluded from the data for determination of sexual maturity of males. The total age was represented as the total numbers of growth layers in earplug which was read by naked eyes or binocular dissecting microscope after the preparation of the material. The individual of which neonatal line or germinal layer was lost from an earplug was not used in this study. The growth layers in earplug of the fin whale are clearest and easiest to read among all baleen whales.

Tables 1 and 2 show the number of materials used in this study by sex, by maturity and by year.

## RESULTS

### *Proportion of sexually mature whales at each age*

Age distribution of sexually immature and mature whales were tabulated on each sex and in each year, and proportions of sexually mature whales at different ages were calculated and plotted in Figs 1 and 2. A curve of change in the proportion was drawn by eye on each graph. Then, the average age at sexual maturity was determined as the age at which 50 % of individuals were sexually mature.

In the early period of exploitation till 1958, sexual maturity started from about 7 years of age and finished by about 16 years of age in the case of males, although the feature in the earliest period was unknown because of no collection of earplugs till 1956. Accompanying with the development of exploitation of this whale stock, the starting age decreased gradually, and it became to be about 2–3 years in the latest period of 1974–75. However, the finishing age of sexual maturity remained almost the same till the middle period of exploitation of 1968–70, and then it became suddenly younger to about 9 years of age in the latest period of 1974–75. The average age at sexual maturity represented as the age of 50 % of sexual maturity gradually decreased from 12.4 to 4.3 years during the periods.

Similar patterns were observed for females. The sexual maturity started from about 9 years of age and finished by about 15 years of age in the early period of exploitation of 1957–58. The starting age of sexual maturity gradually decreased since then, and it became to be about 3 years of age in the latest period of 1974–75. On the other hand, the finishing age remained at almost the same age till the middle period of exploitation of 1968–70, and then it decreased rapidly. It became to be about 12 years of age at the latest period of 1971–75. The average age of females at sexual maturity decreased gradually from 11.2 years in 1957–58 to 5.8 years in 1974–75.

Fig. 3A illustrates yearly change in the average age at sexual maturity in both sexes. The trend in decrease of the age at sexual maturity is clear in both sexes, and there is a trend that they have changed parallelly in each other sex with the difference of about 1.5 years of age. Thus, the figure of males in 1957–58 should be larger than the actual figure. In the case of females the

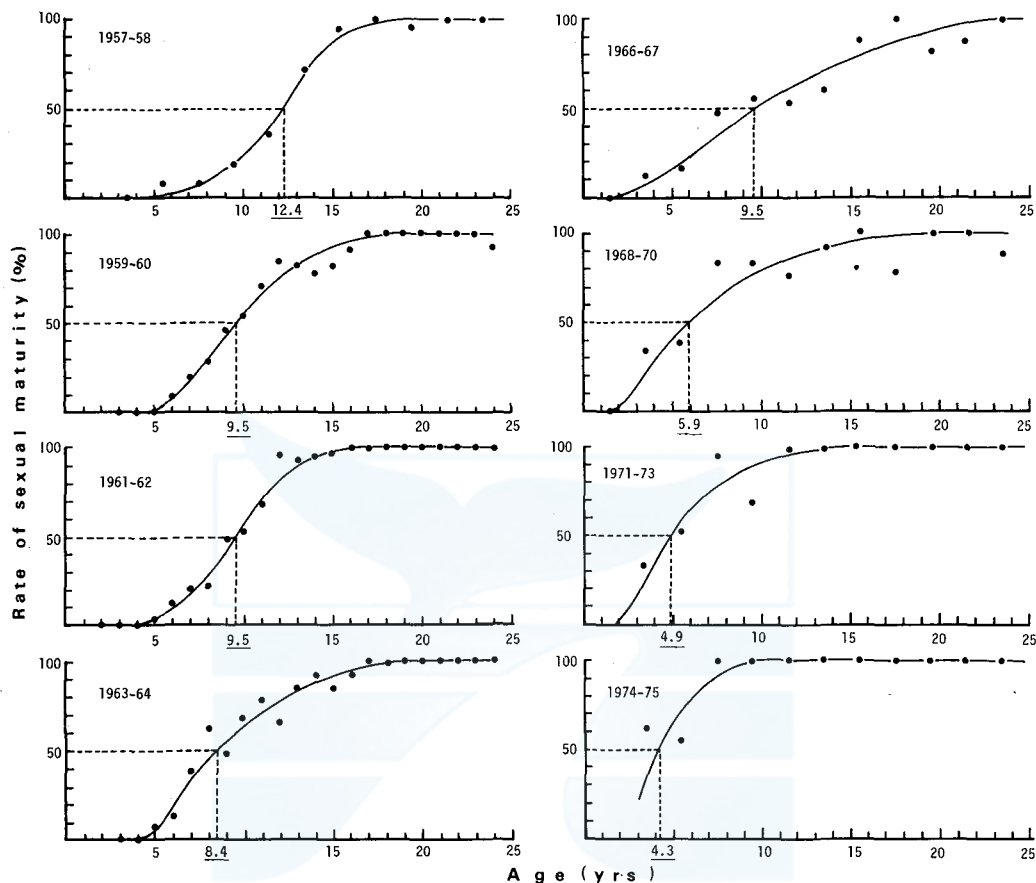


Fig. 1. Average age at sexual maturity of the male fin whale in the eastern North Pacific in each year.

age was about 11 years in 1957-58, and it became to be about 6 years in the period of 1974-75. In males it was about 10 years in 1957-58, and it became to be 4 years in 1974-75. The trend in decline of the average age at sexual maturity was detected statistically with 1 % of risk of error for both sexes. Although there are no data at the start of fundamental exploitation in 1954, the average age at sexual maturity in the period can be estimated to be about 11 and 12 years for males and females, respectively, from a backward extrapolation of the line of trend in Fig. 3A.

#### *Age distributions of females with one ovarian corpus*

As the sexual maturity of the female is determined as the onset of ovulation, a cetacean female which has one corpus luteum or corpus albicans in ovaries can be regarded as a pubertal or just matured individual. Thus, age distribution

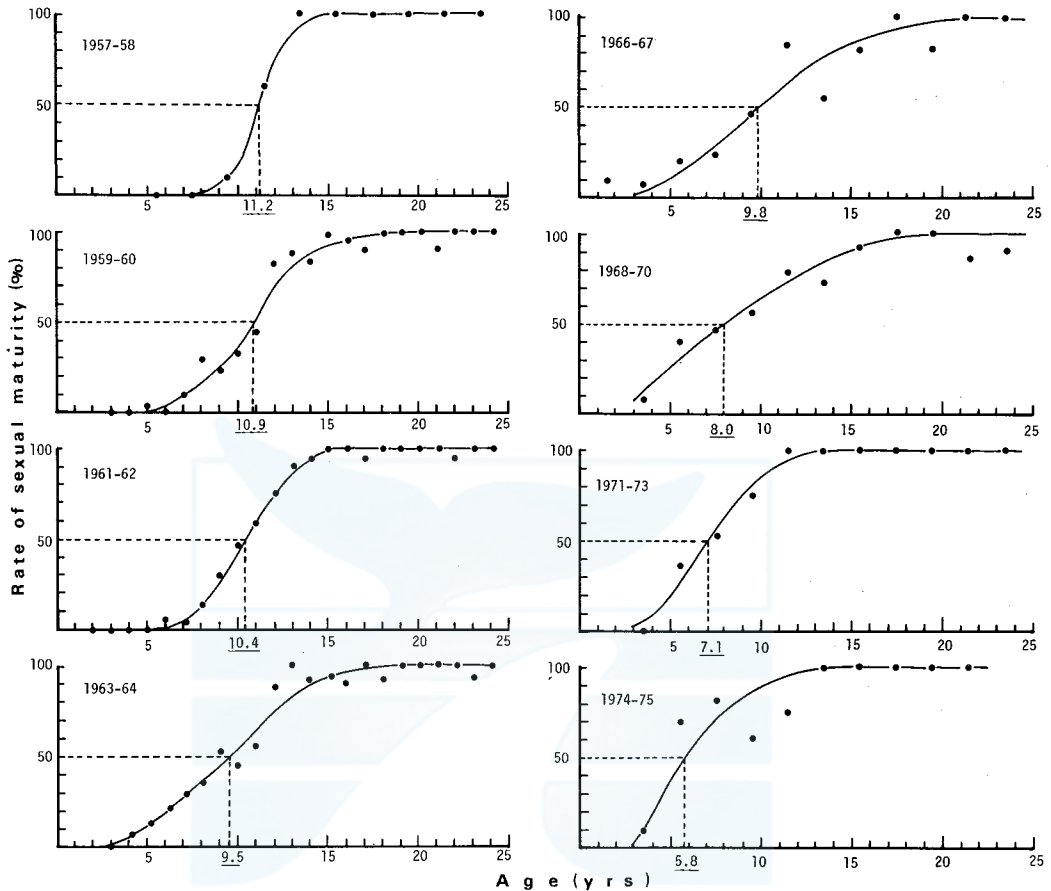


Fig. 2. Average age at sexual maturity of the female fin whale in the eastern North Pacific in each year.

of these animals will indicate the age at sexual maturity independently from the proportions of sexually mature individuals, although the former method will give higher figure, because it includes all females between the first and the second ovulation. On the other hand, it is difficult in the case of males to identify the similar stage to one ovarian corpus like females by means of testis weight, because there is large individual variation in the weight of testis at sexual maturity, so that it is impossible to apply this kind of method for males.

Fig. 4 shows age distributions of females with one ovarian corpus in each period of exploitation. The age showed a normal distribution in the earlier period of exploitation. The attainment of this stage started from 8-9 years of age, and finished by about 20 years of age in the same period. Then, the starting age gradually moved to younger ages, and it became to be about 4 years in the latest period of exploitation. However, the finishing age of this stage

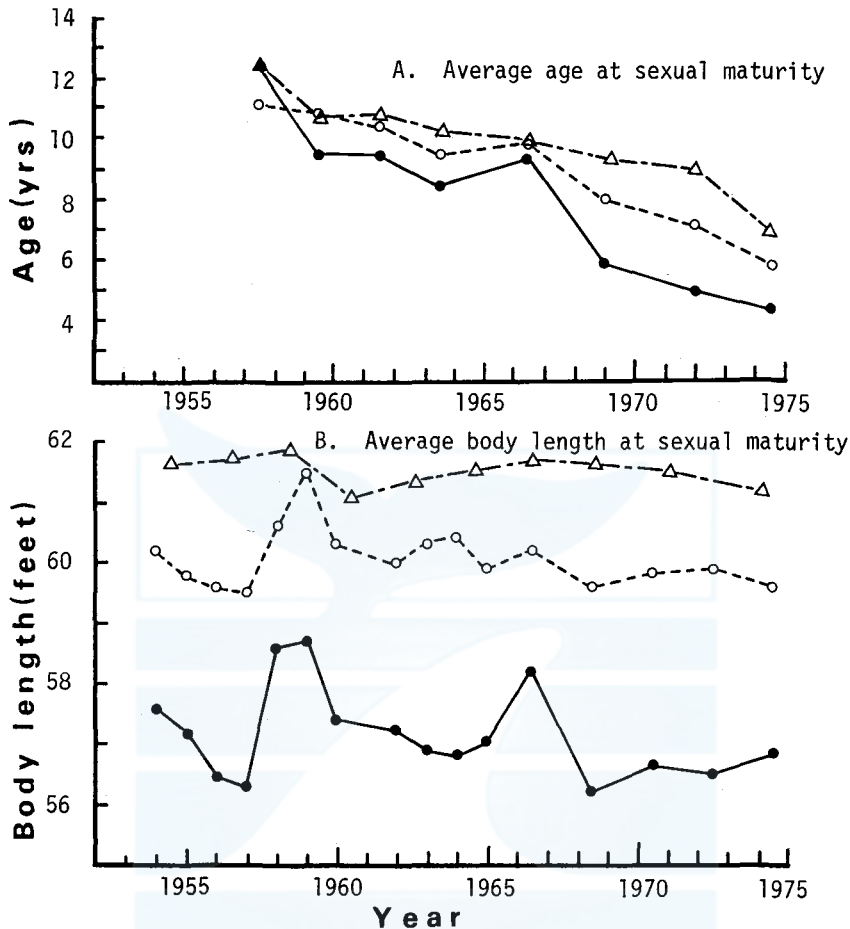


Fig. 3. Yearly change in average age and body length at sexual maturity of the fin whale in the eastern North Pacific. Open circle and broken line: Females, Closed circle and solid line: Males, Cross and chain line: Females which have one corpus luteum or corpus albicans in the ovaries.

remained at almost the same age till the middle period of exploitation, and then it rapidly moved to younger ages in the late stage of exploitation. The range of distribution was relatively narrow in the early period of exploitation, and it became gradually wider to the end of middle period of exploitation. Finally it became again narrow in the latest period. The distribution pattern became gradually skewed to younger side, and the average age of the distributions moved gradually to younger ages accompanying with the exploitation. These phenomena are almost the same as those of the proportion of sexual mature whales as examined in the previous section.

The average age at sexual maturity in each period of exploitation thus obtained in Fig. 4 was plotted on Fig. 3A as same as those in the previous section.



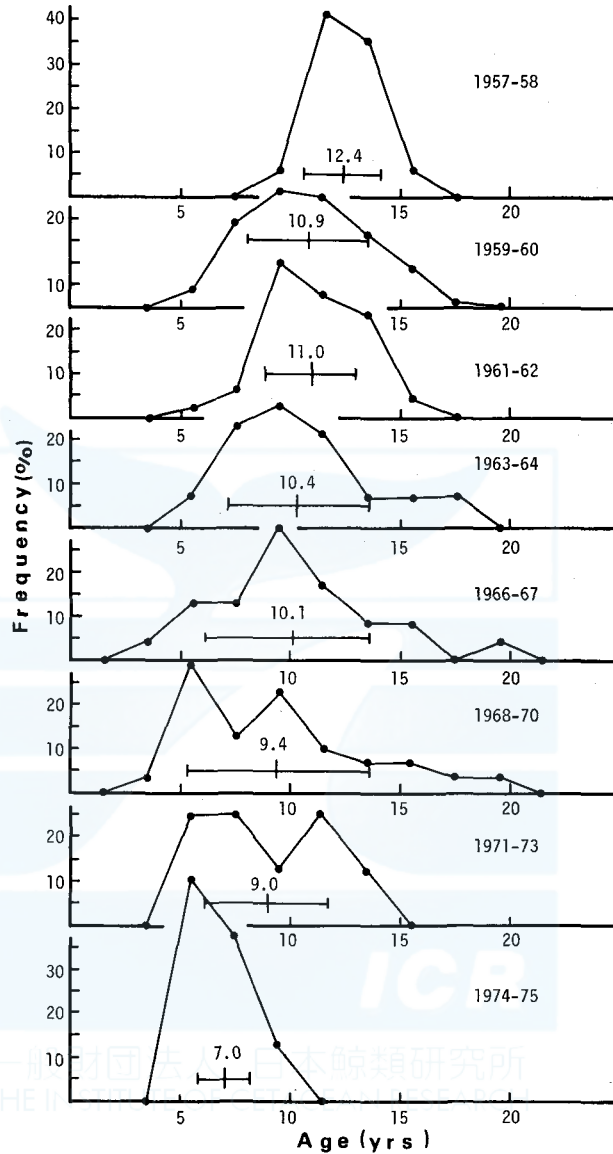


Fig. 4. Age distribution of female fin whales which had one corpus luteum or albicans in the ovaries.

Clear trend in decline in the average ages of females with one ovarian corpus was observed, and it was statistically significant within 1 % of risk of error. The line of average ages runs parallel with that of average ages of females of 50 % sexual maturity, and the former is about 0.5–1 year older than the latter. This means that the average age of females with one ovarian corpus is about 0.5–1 year older than the age at sexual maturity.

From these two independent examinations it can be concluded that the trend in decline of age at sexual maturity was proved for the fin whale stock in the eastern North Pacific.

*Proportion of sexually mature individuals in each body length*

Size distributions of sexually immature and mature whales were tabulated by sex and by year, and proportions of mature whales in each body length classes were calculated and plotted in Figs 5 and 6 for males and females, respectively. Then, a curve of change in the proportion was drawn by eye on each figure, and the body length at 50 % level of sexual maturity was determined as the average body length at sexual maturity.

Patterns of the curves are almost sigmoidal and similar each other throughout the whole periods of exploitation in both males and females. Males began to be mature from 55–56 feet, and finished maturation by 60–62 feet in body length. As the legal size limit of the North Pacific fin whale maintained at 55 feet for the pelagic whaling throughout the whale periods, this factor will not affect this analysis. The average body lengths of males during the whole periods ranged between 56.2 to 58.2 feet with the average of 57.2 feet (17.4 m). Females began to be mature from 56–57 feet in body length, and most females attained sexual maturity by 63–64 feet. The average body lengths ranged from 59.5 to 61.5 feet throughout the periods of exploitation with the average of 60.1 feet (18.3 m).

Fig. 3B shows yearly change in the average body length at sexual maturity of both sexes. Although some declining trends seem to be seen for both sexes, the trends were not detected statistically within 5 % of risk of error. Therefore, it can be estimated that the body length at sexual maturity was constant throughout the whole periods of exploitation, in spite of the existence of a feature that the age at sexual maturity moved to younger age during the periods.

*Size distributions of females with one ovarian corpus*

Fig. 7 shows size distributions of females with one ovarian corpus during periods from 1954 to 1975. The smallest body length of these females was 55 feet, and the largest was 69 feet. The distribution patterns of the frequency were almost normal through the all periods, and modes ranged between 60 and 62 feet. All the average body lengths were in a range between 61.1 and 61.9 feet with the average of 61.5 feet (18.6 m). This average figure was 0.9 feet (0.3 m) larger than the average of the average body lengths of females at 50 % maturity as examined in the previous section. This feature coincides with the fact that the mean age of females with one ovarian corpus was higher than that of 50 % maturity. Furthermore, the values of standard deviation were almost the same (1.8–2.7 feet) during all periods.

The average body length in each period was plotted in Fig. 3B to examine the trend in the average body length of females with one ovarian corpus. It was found that there was no trend in change in these values within 1 % of risk

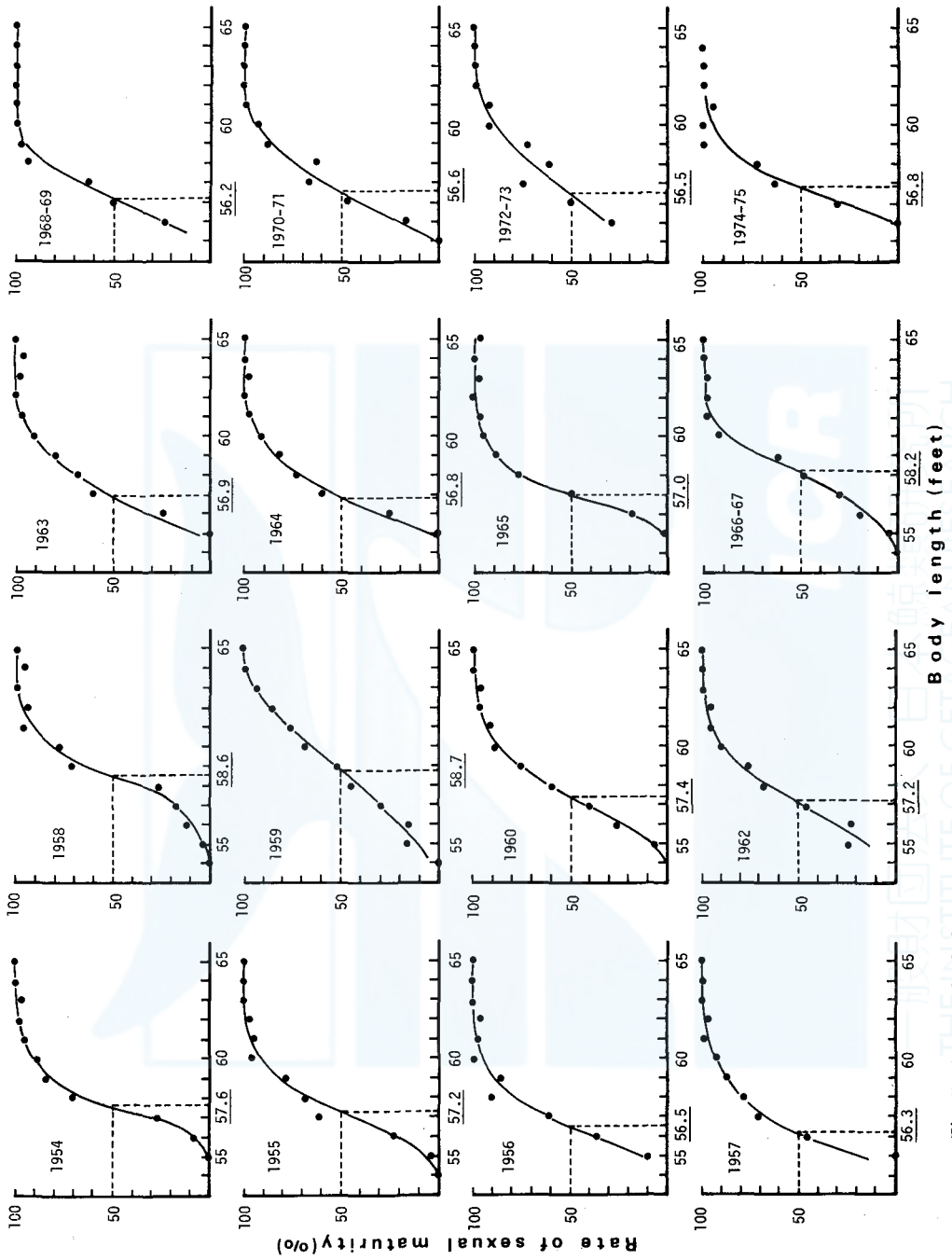


Fig. 5. Average body length at sexual maturity of the male fin whale in the eastern North Pacific in each year.

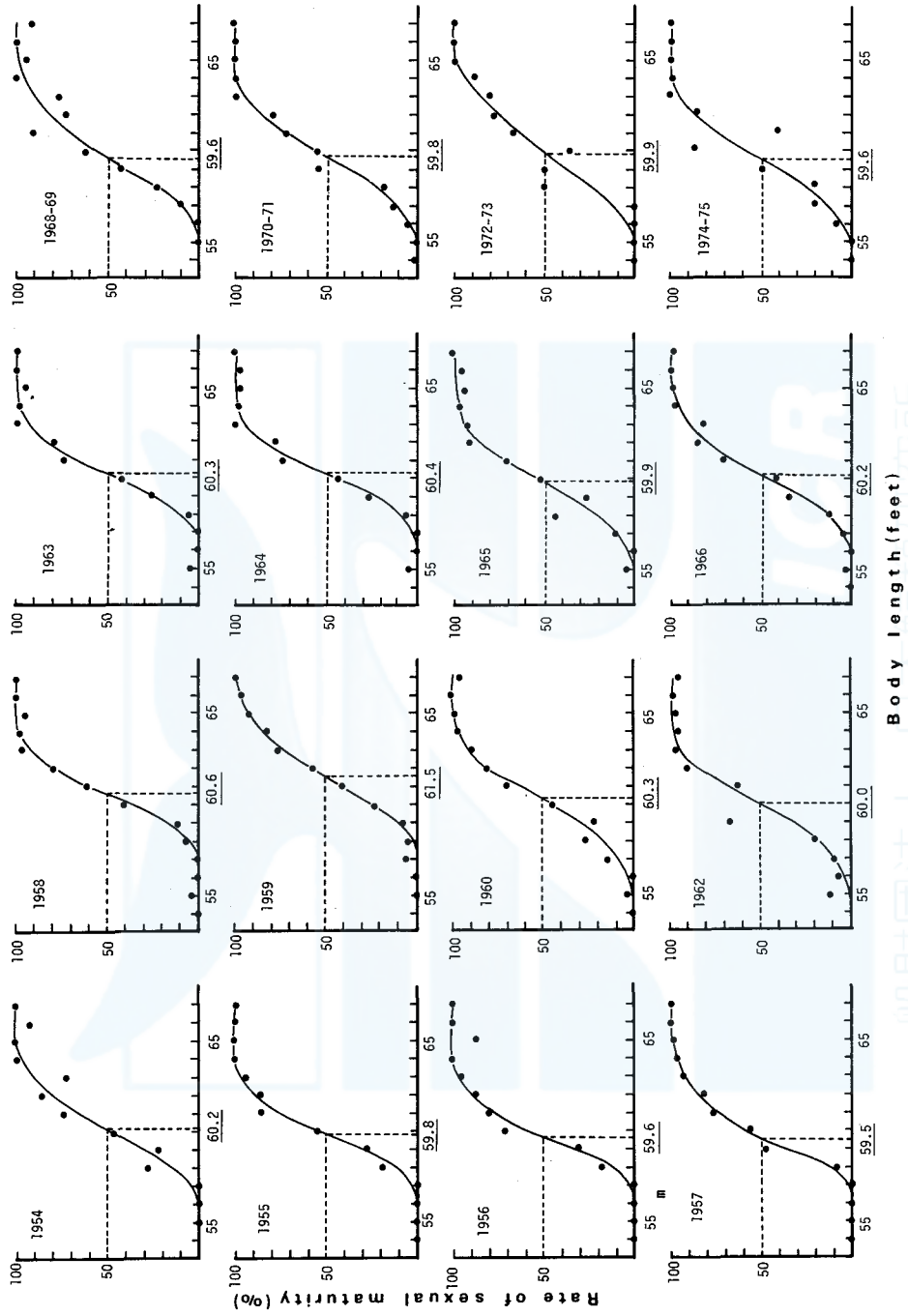


Fig. 6. Average body length at sexual maturity of the female fin whale in the eastern North Pacific in each year.

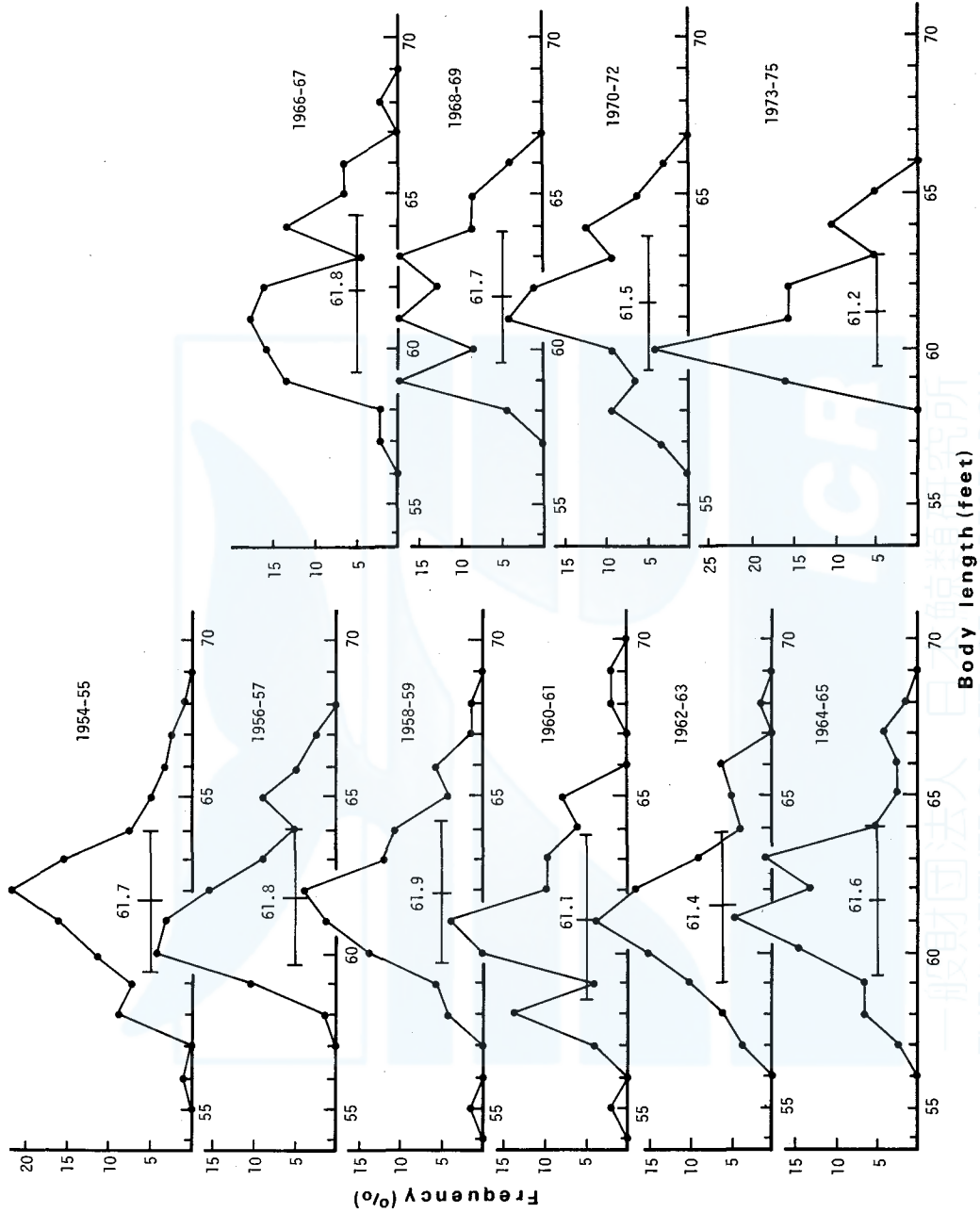


Fig. 7. Size distribution of female fin whales which had one corpus luteum or albicans in the ovaries.

of error, and the line was almost parallel to those of body length of females of 50 % maturity. Thus, this is the evidence that the body length at sexual maturity was constant even in the condition showing the age at sexual maturity declined.

## DISCUSSION

This study provided an evidence of yearly change in the age at sexual maturity in a baleen whale stock independently from the use of transition phase in ear plugs. In other word, this supports the reality of similar phenomenon on the age at sexual maturity as examined by means of transition phase, and proves the reasonability of the transition phase as a mark of the sexual maturity as proposed by Lockyer (1972).

It was found from Figs 1 and 2 that the youngest limit of age of mature whales changed rapidly to younger ages from early period of exploitation, but the oldest limit of age at sexual maturity remained unchanged for relatively long periods of exploitation. The similar phenomenon was also observed in the age distribution of females with one ovarian corpus. Fig. 8 shows a schema to illustrate the changing pattern of proportions of sexually mature individuals at different ages during the periods of exploitation as observed in this examination. A similar pattern of age at sexual maturity was observed between African elephants populations in different environment (Laws, Parker and Johnstone, 1975). These phenomena indicate that the change in the habitat of an animal stock affects on the growth and maturity of younger animals more strongly than the older animals. Thus, younger animals attain sexual maturity rapidly, when their habitat has become better than the past. On the other hand, the older animals which had spent their young stage in the past inferior environment remained in the immature stage even in the improved habitat changed.

The analyses of age at sexual maturity were made in this paper based on years when animals were caught. If the same analyses are carried out based on year classes as examined by Kato (1983) for the Antarctic minke whales, clearer result than this paper will be obtained, considering the above possibility. Further studies will be needed on this matter.

An evidence was provided in this study that the average body lengths at sexual maturity kept almost the same size during whole periods of exploitation, in spite of the condition that the average age at sexual maturity decreased significantly in the periods. Lockyer (1972) reported the same phenomenon on the Southern Hemisphere fin whale, but she reached to this result by review of several papers which described on the body lengths at sexual maturity from various regions. The present paper examined this matter by use of the same series of data collected from the same stock. In this sense, this paper will provide the first evidence on this feature in the cetaceans.

Although the average age and body length of females with one ovarian

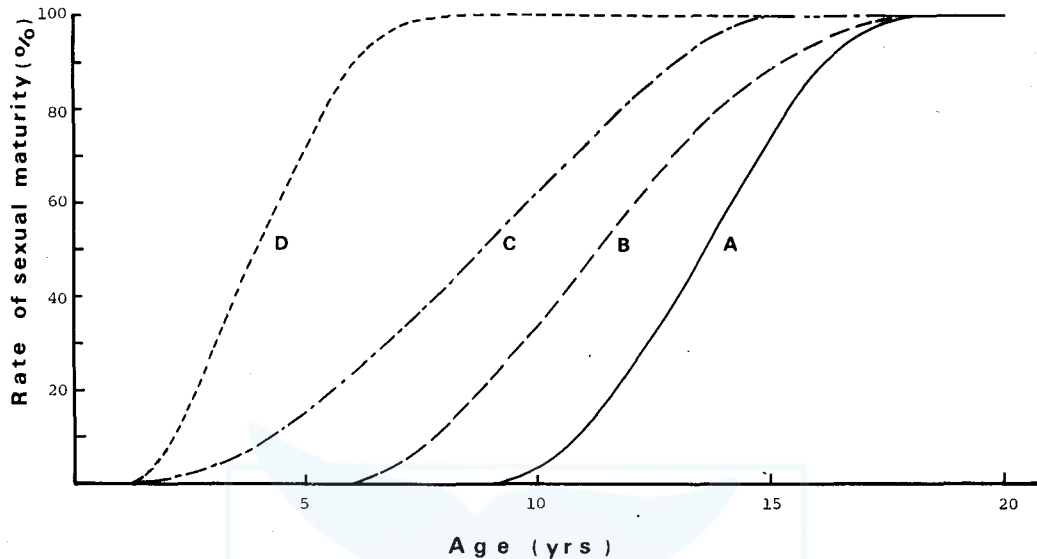


Fig. 8. Schematic figure to represent the change in pattern of proportions of sexually mature whales in each age accompanied with the change in environment of a whale stock. The approximate correspondence to actual seasons is, A: 1957-58, B: 1959-60, C: 1966-70, D: 1971-73

corpus were regarded as one of the indicators of those at sexual maturity, it was found in this paper that they were larger than those of 50 % sexual maturity. The differences were 0.5-1 year and 0.9 feet for age and body length, respectively. The age and body length of 50 % maturity is regarded as the mean value at the instance of sexual maturity, whereas females with one ovarian corpus have been already matured before their catch, so that it will be natural to reach the above result. Anyway, we must recognize that the results of both approaches are somewhat different, but the application of both of these independent methods will be useful to confirm the results of analyses.

The change in age at sexual maturity and no change in body length at the same developmental stage mean that the growth pattern of this whale stock changed during the periods of exploitation, and the whales of this stock grew faster accompanying with the decrease of population level. Furthermore, a whale stock has its fixed body length at sexual maturity, and when an individual which grows fast attains the fixed size of body, it becomes sexually mature, even if it is still young. Contrary to it, an old individual does not attain sexual maturity, unless it grows to the fixed body length.

The fin whale stock dealt in this study decreased its population level rapidly during 22 years from 26 to 10 thousands (Chapman, 1976). Blue, humpback and sei whale stocks which have similar feeding behavior to the fin

whale decreased also in the same waters during the periods (Chapman, 1976). The clear decline in the age at sexual maturity and change in growth pattern of the eastern North Pacific fin whale stock reflect change in total biomass of baleen whale populations similar to the Southern Hemisphere fin whales (Gambell, 1975). The decline of total biomass of baleen whale populations provided gradually better habitat and larger amount of intake of food per head of the fin whales, and better nutrition and less stress improved the growth and maturity.

The catch history and change in population level and its habitat are different from stock to stock even in the same whale species. The comparison of the change in biological parameters including the age at sexual maturity will be interesting to be studied in future in conjunction with the difference of biomass and their habitats.

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