SEXUAL SEGREGATION OF THE SPERM WHALE IN THE NORTH PACIFIC*

SEIJI OHSUMI

INTRODUCTION

The whaling for the sperm whale (*Physeter catodon*) have been operating widely in the North Pacific. Sperm whales were killed by 7 Russian and Japanese whaling fleets chiefly in the Bering Sea, coasts of the Aleutian Islands and the Gulf of Alaska in 1964. And land stations were distributed in the coasts of California, Canada, Kuril Islands and Japan in the same year. Recently number of sperm whales caught have been gradually increasing, especially in the pelagic whaling ground in the northern part of the North Pacific. And regulation of sperm whale fishing has become to be need. However, for reasonable regulation of sperm whale fishing, we must have more ecological knowledges on the whale.

As one of well-known knowledges on the ecology for the sperm whale, so called " harem " schools distribute in low and middle latitude, and it does not move to high latitude even in summer season. On the contrary, males which separate from harem school distribute in high latitude in summer season (Matthews, 1938). But, this knowledge is mearly general, and there seems to be no study which deals the sexual segregation quantitatively. In present paper, I want to discuss on this problem.

Japanese whalers have been operating to catch sperm whales in the northern part of the North Pacific by factory ship whaling, and coastal whaling continues in the adjacent waters to Japan. And we have relatively many biological materials of the whale from both waters. I will discuss the sexual segregation of the sperm whale between high and middle latitudes dealing with the materials as a model. That is to say, I used the material from the Aleutian waters as a model which represent the whales distributed in the high latitude, and the material from coast of Japan as another model of the sperm whales distributed in the middle latitude. Of course, it is a problem that there are some possibilities that they belong to different sub-population by means of blood typing investigation (Fujino, 1963). However, I used the materials only as two models in the high and middle latitude, and I consider my discussion will adapt for each sub-populations.

MATERIALS AND METHODS

Upper teeth of the sperm whale are used for the age determination of the investigated individuals. Preparation and reading of upper tooth growth layers are the same as the paper of Nishiwaki *et al.* (1958). Age determination is based on the

* Brief paper was read in the Meeting of Jap. Soc. Sci. Fisheries in Oct., 1965.

paper of Ohsumi *et al.* (1963), that is to say, one growth layer in the dentine is defined as one year.

As the materials, I used the biological data of the sperm whales which had been collected by the staffs of the Whales Research Institute in some whaling stations adjacent to Japan from 1960 to 1964 and in the Aleutian waters (Areas IV and V) in 1961 and 1962. The number of materials of which age were determined with upper teeth is as follows:

	Coast of Japan	Aleutian
Males	1,035	1,975
Females	2,237	—

For estimating the size distribution of the sperm whales which are really distributed in the Aleutian waters, I used data of the estimated body lengths which were observed by whale marking vessels in the northern part of the North Pacific. According to the data, almost of the sperm whales which distribute in the Aleutian waters are lone or small schools of few individuals, and the distribution of the females is considered to be very few. Then, I used a length-age key of the male sperm whale adjacent to Japan for exchange of the estimated size distribution by the marking vessels to estimated age distribution.

SEASONAL CHANGE OF THE SEX RATIO IN THE WHALING GROUND OF MIDDLE LATITUDE

Sex ratios of the sperm whales changes seasonally in the waters of middle latitude.

Clarke (1956) studied on the seasonal change of ratios of the male sperm whales in the catch in the Azores waters. The ratios are the highest in the winter and the lowest in August.

TABLE 1. NUMBER OF SPERM WHALES INVESTIGATED BY THE STAFFS OF WHALES RESEARCH INSTITUTE IN THE COAST OF JAPAN FROM 1960 TO 1964

Sex	Maturity	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Males	Immature	1	2	2	21	66	51	14	157
	Mature	19	47	81	297	347	160	22	973
	Unknown	7	5	14	58	57	16	3	160
	Total	27	54	97	376	470	227	39	1,290
Females	Immature	2	3	16	26	80	39	19	185
	Mature	11	51	88	372	941	578	99	2,140
	Unknown	4	25	24	127	201	116	18	515
	Total	17	79	128	525	1,222	733	136	2,840
Grand total		44	133	225	901	1,692	960	175	4,130
Sex ratio of males		61.4	40.6	43.1	41.9	27.7	23.7	22.3	31.3
% of immature	Males	5.0	4.1	2.4	6.6	15.9	24.2	40.3	16.5
	Females	15.4	5.6	15.4	6.5	7.9	6.3	16.1	8.0

In the coast of Japan, the male ratio is the highest in spring and the lowest in October in the seasons from 1946 to 1952 when the whaling operated throughout the year. According to the biological investigations by the Whales Research In-

stitute from 1960 to 1964, the male sex ratios gradually decline from May to November as shown in Fig. 1, and the tendency is almost the same as that from 1946 to 1952. The seasonal changes are seemed to be different about two months each other between Azores and Japan. This is considered to be caused by the difference of the oceanographical construction between each waters.

Such seasonal changes of the sex ratio are considered to reflect the change of migration of sperm whale herds. In the late winter and spring seasons, the male sperm whales which are mainly mature lone bulls begin to migrate from lower latitude, and they leave from the middle latitude to higher latitude, after then, breeding herds mainly consisted with mature females and baby or juvenile individuals come to middle latitude waters. Mature male groups begin to migrate from higher latitude by the end of fall. According to Slepzov (1955), the large males appear in the migration season of spring and fall in Kuril waters. Japanese coastal waters are considered to be a northward migratory course of lone or male schools in the spring time.

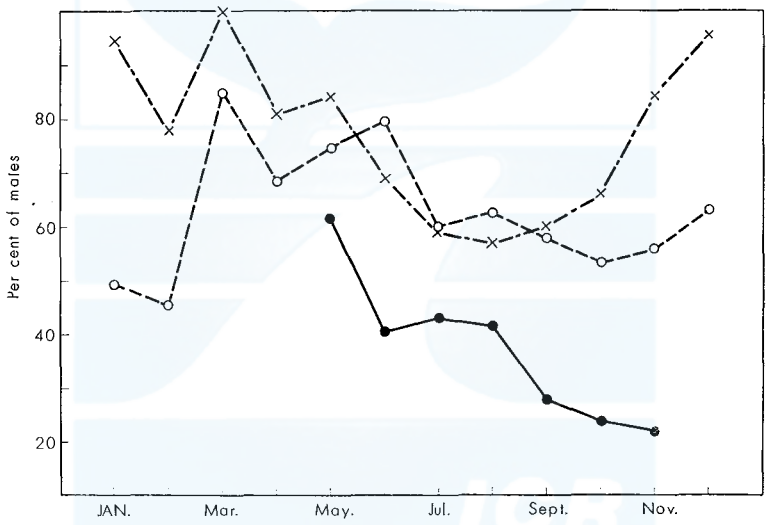

Fig. 1. Seasonal change of male sex ratios in the sperm whales in the northern hemisphere. Open circles and broken line: Coast of Japan, 1946–1952. Closed circles and solid line: Coast of Japan, 1960–1964. Closses and chain line: Azores, 1939, 1954.

Present materials were collected mainly in August, September and October for the case of coastal Japan, and in June, July and August for the case of northern Pacific respectively. Therefore, they seem to represent the optimum distributions of the sperm whale herds in each latitudal areas.

AGE DISTRIBUTION OF THE SPERM WHALES IN THE ADJACENT WATERS TO JAPAN

Table 2 and Fig. 2 show the age distributions of the male and female sperm whales caught in the waters adjacent to Japan from 1960 to 1964 in a semilogarithmic graph based on number of growth layers in the dentine of upper tooth. There is a remarkable difference between males and females. In younger age, the distribution of the males is almost the same as of the females, but from 12 years of age the total mortality coefficient in the females is lower than that in the males. Following three factors will be concerned with this phenomenon.

1. Difference of natural mortality rate between males and females.
2. Difference of fishing mortality rate between males and females.
3. Segregation of males.

Considering the age distribution of the male sperm whales in the Aleutian waters, the first factor will be abandoned, because the natural mortality rate of the males in this area is not so different from the females as shown in the next chapter.

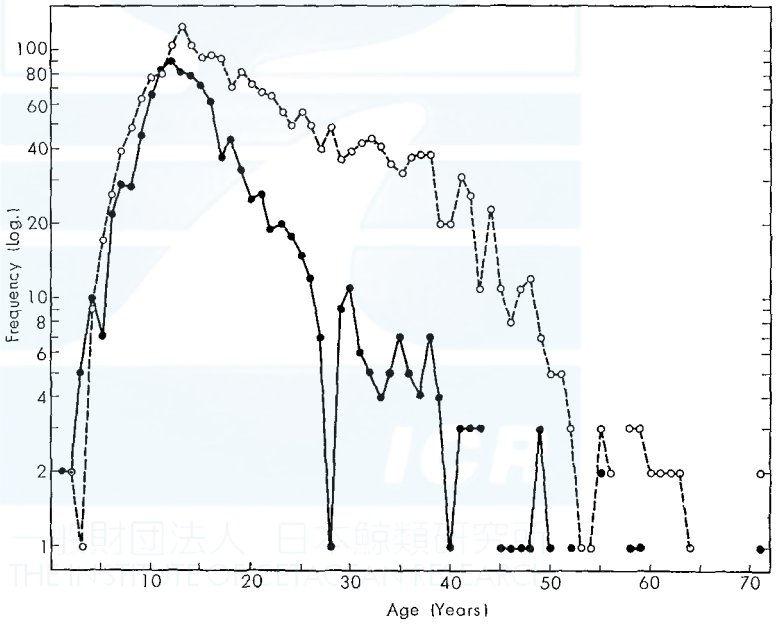

Fig. 2. Age distributions of male and female sperm whales from the waters adjacent to Japan in 1960–1964.
Open circle and broken line: Female. Closed circle and solid line: Male.

The second factor may be considerable, because adult males are larger than the females, and whaling efforts have been added more to the former than to the latter. But, I consider in the operation system for the sperm whale in the coastal waters the second factor is seemed to be not so affected on this phenomenon. The

third factor must affect mainly to the difference of present total mortality rate in the middle latitudal waters. If not, we cannot explain the distribution of adult males in high latitudal waters.

TABLE 2. AGE DISTRIBUTIONS OF THE SPERM WHALES IN THE COAST OF JAPAN (1960–64) AND ALEUTIAN ISLANDS (1961, '62).

Age	Coast of Japan		Aleutian Males	Age	Coast of Japan		Aleutian Males
	Males	Females			Males	Females	
1	2	—	—	36	5	37	57
2	2	2	—	37	4	38	29
3	5	1	—	38	7	38	45
4	10	9	—	39	4	20	51
5	7	17	—	40	1	20	43
6	22	26	—	41	3	31	54
7	29	39	—	42	3	26	41
8	28	48	—	43	3	11	39
9	45	63	—	44	—	23	32
10	67	77	—	45	1	11	25
11	84	81	1	46	1	8	22
12	90	105	—	47	1	11	32
13	82	124	3	48	1	12	31
14	79	103	7	49	3	7	21
15	72	92	19	50	1	5	17
16	62	95	21	51	—	5	22
17	37	93	43	52	1	3	25
18	44	71	42	53	—	1	19
19	33	82	60	54	—	1	18
20	25	73	63	55	2	3	11
21	26	68	62	56	—	2	13
22	19	66	78	57	—	—	13
23	20	56	61	58	1	3	14
24	18	50	76	59	1	3	7
25	15	56	75	60	—	2	7
26	12	50	75	61	—	2	7
27	7	40	82	62	—	2	7
28	1	49	60	63	—	1	1
29	9	36	66	64	—	—	9
30	11	39	65	65	—	—	8
31	6	42	71	66	—	—	3
32	5	44	56	69	1	—	—
33	4	41	55	71	—	2	—
34	5	35	51	75	1	1	—
35	7	32	63	77	—	1	—
	(cont.)			Total	1,035	2,237	1,975

In present paper, I presume that natural and fishing mortality rates are respectively almost the same for the males and females in Japanese coastal waters, and the deviation of age distribution in the females minus those in the males presents the age distribution of the males segregated to the high latitude. And this hypothesis will be examined in the following chapters.

AGE DISTRIBUTION OF THE MALES IN THE ALEUTIAN WATERS AND COMPARISON OF IT WITH THE ASSUMED AGE DISTRIBUTION

In Fig. 3, solid line shows the age distribution of the male sperm whale caught by Japanese fleets in the Aleutian waters in 1961 and 1962 in a semi-logarithmic graph. In these years Japanese whalers caught 4,349 sperm whales, and males were 4,305 (98.9%) among them. According to Ohsumi & Nasu (unpublished), in the waters around the Aleutian Islands and Bering Sea, female sperm whales distribute very few, and they relate with the distribution of warm water mass.

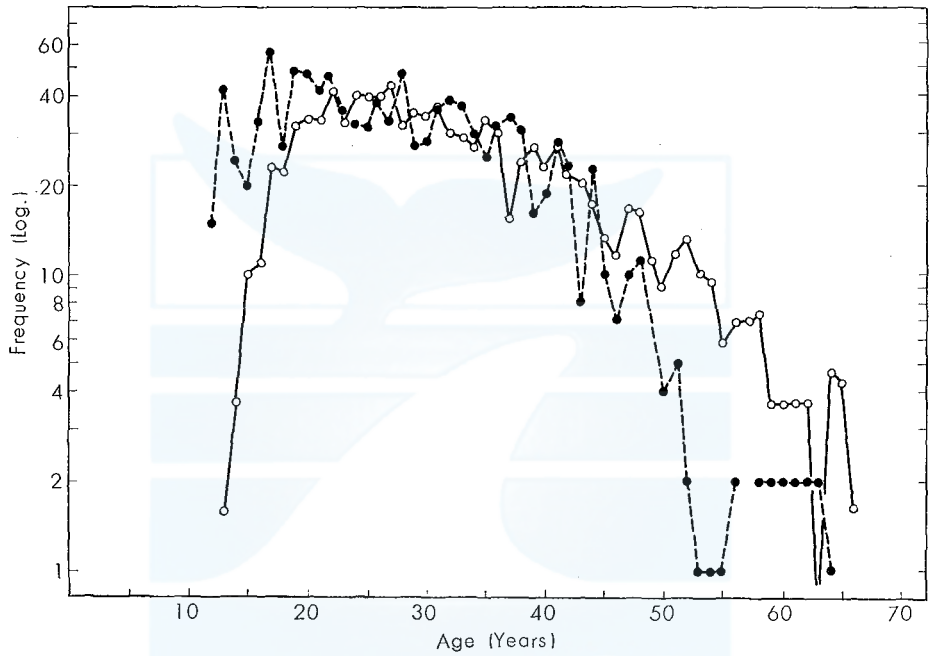

Fig. 3. Age distribution of the sperm whales in the North Pacific.
Closed circle and broken line: Females ninus males in the Japanese coastal waters.
Open circle and solid line: Males caught in the Aleutian waters (1961–1962).

Fig. 3 also shows the age distribution which was represented as the deviation of two age distributions between females and males (females minus males) in the Japanese coastal waters, assuming that the deviational part presents in the high latitude segregated from middle latitude.

Comparing above two age distributions, they are very fittable each other in the range of ages from about 25 to 45 years. But, in younger generations, the possiblly segregated males are more frequent than the males which were caught. I think this is caused by the size limitation in the catch by whalers. For the factory ship whaling, legal size is limitted as 38 feet or more. According to age-length key, the

average age of the male sperm whales which are 38 feet long is 18.6 years. Therefore, in younger generations, the age distribution of the whales caught have a danger that it does not show the real population which distributes in the waters.

TABLE 3. SIZE DISTRIBUTION OF THE SPERM WHALES OBSERVED BY INVESTIGATION VESSELS AND CAUGHT BY CATCHER BOATS IN THE ALTUTIAN WATERS

Body length (feet)	Observed		Caught (1957–59)	
	Whales	%	Whales	%
33–34	1	0.4	—	—
35–36	11	4.3	—	—
37–38	17	6.6	87	1.7
39–40	61	23.6	527	10.5
41–42	43	16.6	719	14.4
43–44	30	11.6	772	15.5
45–46	43	16.6	776	15.6
47–48	26	10.0	812	16.2
49–50	17	6.6	719	14.4
51–52	2	0.8	447	8.9
53–54	4	1.5	125	2.5
55–56	3	1.2	12	0.3
57–58	1	0.4	—	—
Total	259		4,996	

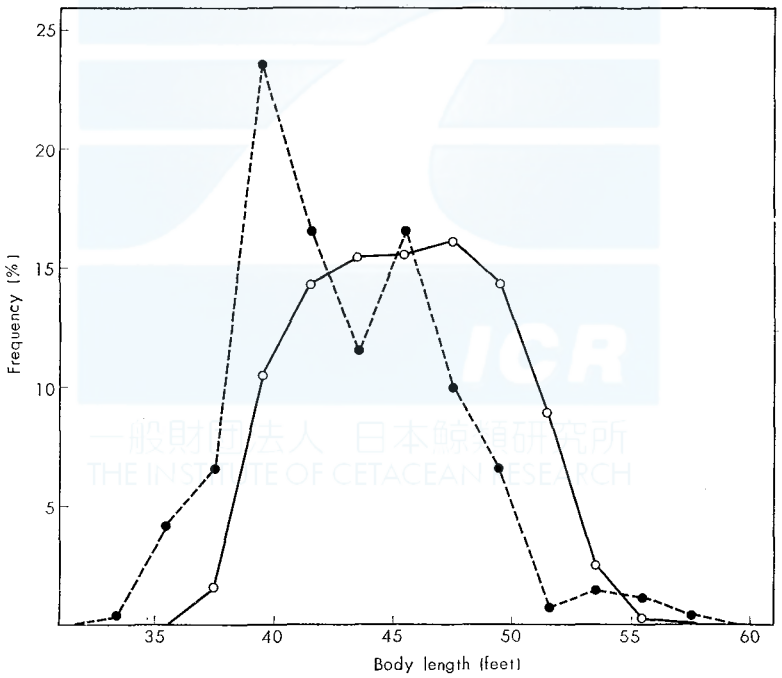

Fig. 4. Size distribution of the sperm whales observed and caught in the Aleutian waters. Open circle and solid line: estimated length by investigation vessels. Closed circle and broken line: caught whale.

For the solution of this problem, I used the records of estimated body lengths of the sperm whale which had been observed with Japanese research vessels in the course of whale marking in the northern part of the North Pacific. Research vessels recorded all whales which were found in the waters, so we may regard the records represent the whales distributed in the waters. Table 3 and Fig. 4 shows the size distributions of the whales observed and caught in Aleutian waters. The size distribution of the whales caught is like normal distribution and has a mode at about 45 feet, on the contrary, that of whales observed does not show a normal distribution, and there is a mode at about 40 feet. Fig. 4 also shows that there are many small sized sperm whales in high latitude, but they were not caught because of the size limitation. Of course, this size distribution was based on estimated body lengths, and they have some errors from true body length. According to the data of the sperm whales which were recaptured soon after marking, our estimation of body length of the swimming whales has a tendency of under-estimation from actual ones in the range of body lengths from 33 to 45 feet long. However, it will be true that

TABLE 4. AGE-BODY LENGTH KEY FOR THE MALE SPERM WHALES IN THE COASTAL WATERS OF JAPAN

Age	Body length (feet)													Total
	33–4	35–6	37–8	39–40	41–2	43–4	45–6	47–8	49–50	51–2	53–4	55–6	57–8	
6– 7	2	1												3
8– 9	13	3	1	1										18
10–11	33	29	2	2										66
12–13	38	36	16	—										90
14–15	18	42	21	5										86
16–17	10	29	24	8			1							72
18–19	11	19	8	5	5	1	—							49
20–21	8	10	11	2	2	—	1		1					35
22–23	1	6	4	4	4	1	4		—					24
24–25	1	6	6	2	3	1	2	1	1					23
26–27	3	3	2	2	—	1	3	—	—					14
28–29		1	—	1	—	1	1	—	1					
30–31		2	1	—	2	3	2	2	—					12
32–33		—	1	1	—	1	1	1	—					5
34–35		1	—	2	—	1	—	—	1		1			6
36–37		—	—	3	1	—	—	—	1		—			5
38–39		1	—		1	—	1	1	—	2	—			6
40–41			—			—		—	2	—	—			2
42–43			1			—		1		—	—			2
44–45						—		1		—	—			1
46–47						—				—	—			—
48–49						—				1	—		1	2
50–51						1				—	1			2
52–53										1	—			1
58–59										—	—	1		1
68–69										—	1			1
74–75										1				1
Total	138	189	98	38	18	11	16	7	7	5	3	1	1	532

more small sperm whales distribute in high latitude than the whales caught in the waters.

It is estimated that the observed sperm whales were almost males from the school composition of them, because they were almost lone or small numbers in a school, and it is seldom to find a large school like harem school in Aleutian waters.

TABLE 5. TOTAL MORTALITY COEFFICIENTS FOR THE SPERM WHALES BY AREAS, SEXES AND RANGES OF AGES

Area	Sex	Ages	Total mortality coefficient
Coast of Japan	Males	12–25	0.165
		26–50	0.081
	Females	12–52	0.073
Aleutian	Males	24–66	0.071

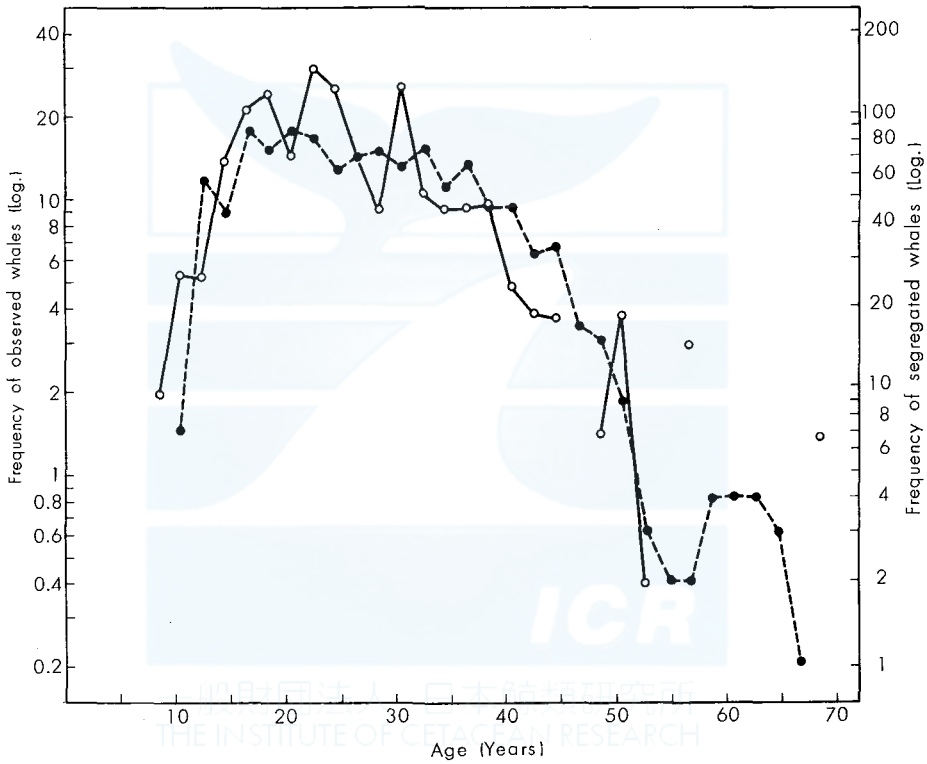

Fig. 5. Age distribution of the sperm whales.
Open circle and solid line: age distribution of the distributed sperm whale in the Aleutian waters calculated by size distribution and age-length key.
Closed circle and broken line: female ninus males in Japanese coastal waters.

To compare the age distribution of possiblly segregated males with that of observed sperm whales which were distributed in Aleutian waters, I calculated the estimated age distribution of the latter from estimated size distribution by means of age-length key of the male sperm whales from the coastal waters of Japan. I

did not use the age-length key of the male sperm whales in the Aleutian waters, because it is different from that of distributed whales by size limitation.

Fig. 5 shows the age distributions of the sperm whales segregated from middle latitude and observed in the Aleutian waters respectively. From this figure, we can find that the both fairly fit each other. Estimation that the deviation of age distributions between females and males in Japanese coastal waters means the segregation of males from middle latitude to high latitude may be comfirmed from this examination.

There is another difference in the age distributions between the whales caught and segregated in the older generation (Fig. 3). There is an uncertainty in the latter distribution because of scarsity of number of samples in older ages. But, it is also considerable that whalers select large whales for their catch as possible, and the large sized or old whales apt to be caught by whalers than the actually distributed whales.

THREE MODELS OF AGEAL SEGREGATION AND COMPARISON OF REALLY AGEAL SEGREGATION OF MALE SPERM WHALES WITH THEM

When natural mortality coefficient (M) and fishing mortality coefficient are settled in constant throughout life span for the mother population, the age distribution of it is shown in Fig. 6A, having a total moritalty coefficient (Z_1). If individuals which are over age of i disperse with a constant dispersal coefficient, the age distribution changes into Fig. 6B. Fig. 6C shows age distribution of a population in which the individuals over i years old increase in their dispersal coefficients acceleratively year by year with constant acceleration rate. Fig. 6D is a age distribution in the third population in which individuals over i ages increase their dispersal coefficient with constant accelerate coefficient until the age of j and after then they disperse with constant dispersal coefficient.

Now, comparing with above three models of ageal segregation, the age distribution of males in the coastal waters of Japan resembles with Model D (Fig. 6D). Owing to size limitation of catch, the age distribution in young generation does not represent the true age distribution, but in this stage age distributions are almost the same in males and females. This means that in young stage males distribute in the middle latitudal waters in the same way as females. Age distribution of males changes at the age of about 12 years from that of females. This phenomenon will mean that segregation of males begins from about 12 years of age, and this age will correspond with i-age in Model D. According to Nishiwaki *et al.* (1958), the age at sexual maturity of the male sperm whale is considered to be about 10 tooth laminations. Then, the segregation of males will begins after sexual maturity.

The total mortality coefficient of males in the range from 12 ages to 25 ages is relatively high value, and after 25 ages the total mortality coefficient becomes lower and shows almost the same value of females. This means that in the ageal range from 12 to 25 years males segregate from middle latitude waters with the almost constant accelerated rate age to age, and after then individuals segregate with con-

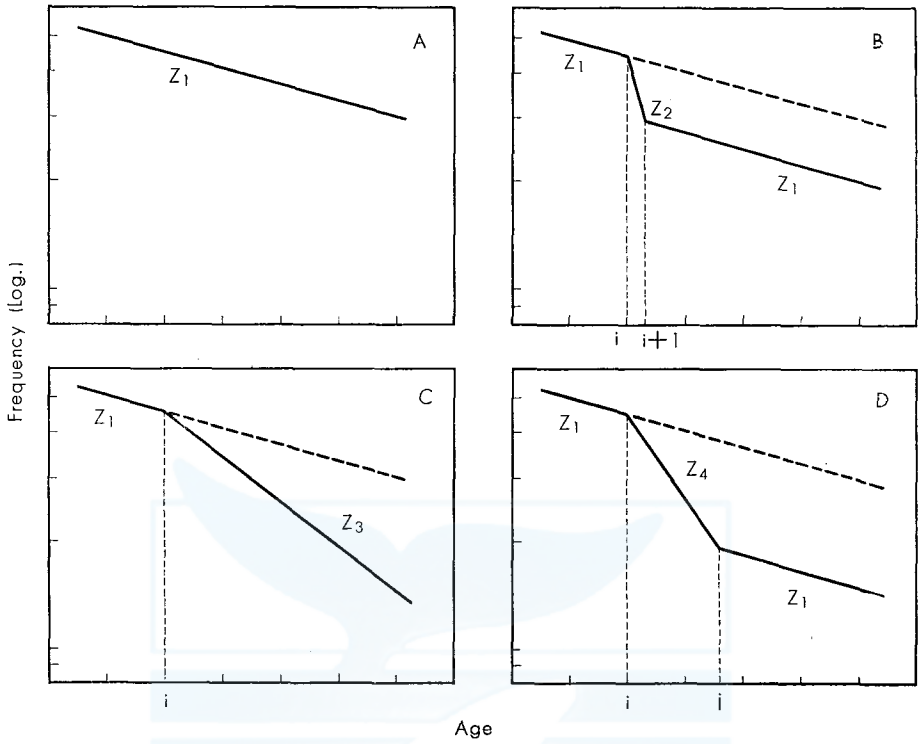

Fig. 6. Age distributions in the four cases of which various ageal segregation table plase.
A: Mother population
B: Segregated over i years old with the rate of Z_2—Z_1
C: Segregated over i years old increasing with the constant rates (Z_3—Z_1)
D: Segregated over i years increasing with constant rates (Z_4—Z_1) until j years old.

stant segregation rate.

Table 5 shows the calculated total mortality coefficients of the sperm whales in the coastal waters of Japan and in the Aleutian waters. In these values, the coefficient of males in the ageal range from 12 to 25 years (0.165) will correspond with Z_2 in Model D, and that of females (0.073) correspond with Z_2, respectively. The coefficient of Japanese water males in the ageal range after 26 years (0.081) is not so different with those of females in the Japanese coastal waters or males in the Aleutian waters. The deviation between Z_2 and Z_1 (0.092) will mean the accelerated segregation coefficient between one age and the next age until 25 ages. Age of 25 years corresponds with *j*-age in Model D. Average body length of males at 25 years is 45 feet according to the growth curve in the paper by Nishiwaki *et al.* (1958), and the weight of testis in larger side is 2.8 kg according to Nishiwaki *et al.* (1956).

In the sperm whale, although males attain at sexual maturity, it takes some years until they can join into the breeding activity. This problem is one of the important subjects in the ecology of the sperm whale, but I think that 25 years of

age or the body length of 43–45 feet will be the minimum age or body length at attainment of full maturity in the male sperm whale. If so, the segregation of males will be concluded as follows: In the sexually immature stage, males remains in " harem " school, and after attainment of sexual maturity some of males begin to segregate from the harem. The rate of segregation of the males increases age to age until they attain at full maturity. After then the segregation rate becomes constant. For the proof of this assumption, investigation of school composition of the sperm whale will be need.

THE RATIO OF SEGREGATED MALES IN HIGH LATITUDE OF MOTHER POPULATION

In Model D population, the segregation rate of population size over i age (K) is shown in following formula:

$$K = 1 - \frac{(1-e^{-M_1})\ [1-e^{-(j-i)M_4}]}{1-e^{-M_4}} - e^{-[(j-i)M_4+M_1]}$$

When $M_4=0.073$, $M_2=0.165$, $i=12$ and $j=25$ are set into this formula, the segregation rate is calculated as 0.416. This means that about 42 per cent of sexually mature males disperse to high latitude from mother male population.

From Table 2, the actual segregation rate which calculated as the rate of deviation between females and males over 12 age is also calculated as 60.8 per cent.

If the sex ratio is the same for males and females in mother population, the population size of males which segregates from mother population and distributes in high latitude is about 21 to 30 per cent of mother population size.

However, as mentioned above, in the Aleutian waters the population size as the object for whaling must be smaller than the population size of whales which distribute in the high latitude, because the legal size is 38 feet for factory ship whaling. Comparing two age distributions in Fig. 3, the available rate as the object for whaling is calculated to be 86 per cent of the real population size of males in high latitude.

CHANGE OF SEGREGATION RATE OF MALE SPERM WHALE ACCORDING TO THE AGE

The segregation rates in each age were calculated smoosing the age distributions which were shown in Fig. 2. The change of segregation rates according to the age is shown in Fig. 7. After the age at sexual maturity, the segregation rate increases remarkably accompanying with increment of age until about 25 years of age. And it becomes maximum at the age of 40 years. After then it decreases accompanying with increase of age. In the middle ages ranging from 25 to 53 years, the segregation rates are over 75 per cent, and at the maximum it attains to about 90 per cent.

However, there are some males which are fully mature but not segregated to high latitude. Most of these males are considered to be so-called harem leaders.

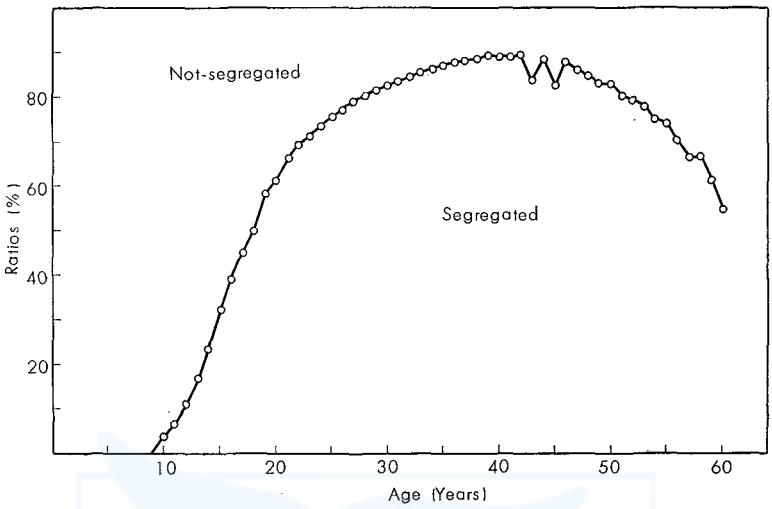

Fig. 7. Change of ratio of segregated sperm whale males according to age.

As mentioned above, after about 40 years of age segregation rates decrease accompanying with ages, although there is an uncertainty whether this result is true or not because of scarsity of number of samples in older age. If it is true, this phenomenon will mean that old bulls remain in the middle latitude as harem leaders.

DISCUSSION

One of the questions in the present paper is whether the materials from Japanese coastal waters represents the mother population from which males segregate to high latitude or not. Townsend (1935)'s laboring work on the distribution of sperm whales by means of logbook data in the American Whaling Age is considered to show seasonal change of distribution and density of the whales in the world. However, conserning with North Pacific Ocean, there is no catch records in the waters arround the Aleutian Islands Chain and Bering Sea. I think this means that American whalers chased chiefly " harem " schools and did not chased lone and large bull in the high latitude, because harem school was more easy to be caught than lone bull by them. If it is true, the distributions of the sperm whales which were shown by Townsend should represent chiefly those of harem school. Fig. 8 shows the latitudal frequency distributions of the sperm whales in the Pacific Ocean in summer and winter seasons drawn from the maps by Townsend. As mentioned by him, it is clear that there is seasonal movement in the sperm whale. In Fig. 8, A will be main distribution of sperm whales of northern hemisphere stock in summer, and it will move to A′ in winter. If so, the main stock of northern hemisphere sperm whale in the Pacific will distribute in the range from 20°N to 40°N in summer. Then my materials which were obtained from the adjacent waters to Japan will be able to represent the main population of North Pacific sperm whale.

For the solution of the sexual segregation in the sperm whale, we must investigate the composition of school in the sperm whale directly. Clarke (1956) described on the classification of sperm whale schools in Azores waters. According to his classification, there are three kinds of schools in the sperm whale. They are juvenile, bachelor and harem schools. Sex ratio, number of individuals in a school, age composition, sexual condition etc. are important subjects to study as well as the number and ratios of above three kinds of schools in the ocean.

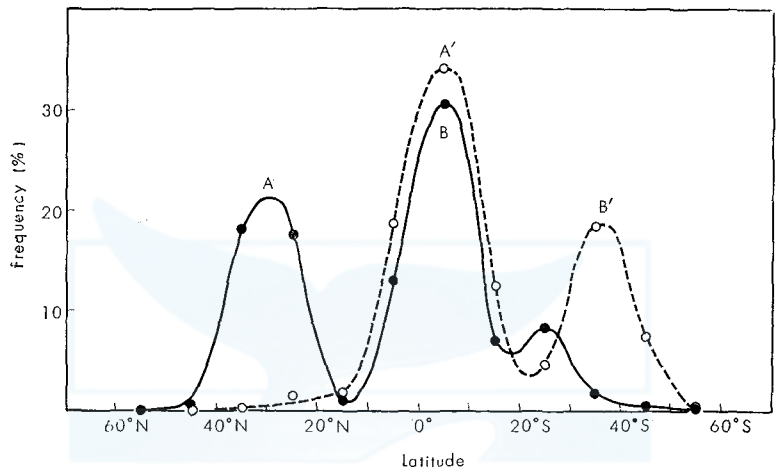

Fig. 8. Latitudal frequency distribution of the sperm whales in the Pacific in summer and winter season after the log-book records of American whaling ships. Drawn from maps by Townsend (1935).
Solid line: Summer (July to September). Broken line: Winter (January to March).

Concerning with sexual segregation of the sperm whale, it is practically need for the regulation of whaling how many adult males are need at least for the meintainance of reproduction in the sperm whale population. If 25 years is the age when join into breeding activity in the male, using the age distribution of sperm whale from the coast of Japan, the tentative ratio of needful adult males can be calculated, when we assume that harem males remain in middle latitude even in summer- autumn season.

The result is that one adult male leads about 16 mature females. However, it will not be solved, unless we have knowledges on the sexual behavior of the sperm whale.

SUMMARY

Sexual segregation of the sperm whale from middle latitude to high latitude was discussed chiefly by means of the age distributions of the sperm whale caught in coastal waters of Japan and in the Aleutian waters.

1. There is a seasonal change of sex ratio in the sperm whale caught in the coast of Japan. The sex ratio of males is the highest in the spring and the lowest in

October and November. This phenomenon is considered to be caused by change of the seasonal migration of males in this waters.

2. The age distribution of the male sperm whales is different from that of the females in the coastal waters of Japan. And this phenomenon is considered to represent the sexual segregation according to the age in the middle latitude.

3. By means of estimated body lengths of the sperm whales which were observed in Aleutian waters by marking vessels and age-length key for the male sperm whales, an age distribution was obtained. This age distribution closely fits with the deviation of age distributions between females and males in the coastal waters of Japan. This is considered to proove the assumption that the deviation of two age distributions between females and males in middle latitude segregate to high latitude waters.

4. Owing to the size limitation for sperm whale catch, the age distribution of the male whales in the Aleutian waters does not represent the real age distribution of the whales which distribute in the high latitude.

5. Segregation of male sperm whales from middle latitude begins soon after the age at sexual maturity. And until the age of 25 years, the segregation rate increases with the ages. After then, the segregation rate becomes nearly constant. The age of 25 years in suggested to be the age at full maturity when males become to have breeding activity.

6. About 40–60 per cent of mature males of mother population are suggested to segregate to the high latitude waters. Therefore, the population size of males which distribute in high latitude will be about 20–30 per cent of mature sperm whales in mother population.

7. Rates of segregated males in each generation increase rapidly from 12 to 25 years, and it attains to about 90 per cent in maximum at the age of 40 years. After then, the segregation rates decrease gradually with the age.

ACKNOWLEDGEMENTS

The materials used in the present paper were collected by the efforts of biologists and inspectors who had investigated the whales in the whaling grounds. My sincere thanks are due to them. I am much indebted to many members of the Japanese Whaling Companies for the help in investigation and collection of the materials.

Dr. M. Nishiwaki and Mr. T. Kasuya kindly read the number of growth layers in the dentine of many maxillary teeth with me for the age determination of the materials. I should like to thank them.

REFERENCES

CLARKE, R. (1956). Sperm whales of the Azores. *Discovery Repts.*, 28: 237–98.

FUJINO, K. (1963). Identification of breeding subpopulations of the sperm whales in the waters adjacent to Japan and around Aleutian Islands by means of blood typing investigations. *Bull. Jap. Soc. Sci. Fisheries,*

29 (12): 1057–63 (In Japanese).
MATSUURA, Y. & MAEDA, K. (1942). Biological observations on whales caught in the northern Pacific. *Data of Whaling*, 9(1): 1–59 (In Japanese).
MATTHEWS, L. H. (1938). The sperm whale, *Physeter catodon*. *Discovery Repts.*, 17: 93–168.
NISHIWAKI, M., HIBIYA, T. & KIMURA (OHSUMI), S. (1956). On the maturity of the sperm whale (*Physeter catodon*) found in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 11: 39–46.
NISHIWAKI, M., HIBIYA, T. & OHSUMI, S. (1958). Age study of sperm whale based on reading of tooth laminations. *Ibid.*, 13: 135–53.
OMURA, H. (1950). Whales in the adjacent waters of Japan. *Ibid.*, 4: 27–113.
OHSUMI, S. (1965). Reproduction of the sperm whale in the northwest Pacific. *Ibid.*, 19: 1–35.
OHSUMI, S., KASUYA, T. & NISHIWAKI, M. (1963). Accumulation rate of dentinal growth layers in the maxilary tooth of the sperm whale. *Ibid.*, 17: 15–35.
SLEPTSOV, M. M. (1955). Biologia i promisel Kitov dalnevostozuih morei (Translated into Japanese).
TOWNSEND, C. H. (1935). The distribution of certain whales as shown by log book records of American whale ships. *Zoologica*, 19(1): 1–50.