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Estimation of some biological parameters of western North Pacific Bryde's whales by age distributions

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ABSTRACT

This paper estimates several kinds of biological parameters of the western North Pacific Bryde's whale by use of biological data especially age distributions obtained by Japanese pelagic whaling in 1971-79 and JARPN II in 2000-03 to confirm the most reliable biological parameters which will be used for the IST of the whale stock. The values of biological parameters obtained by the present study are as follows: Total mortality rate is 0.091 (Z=0.095), natural mortality rate is 0.076 (M=0.078), fishing mortality rate is 0.015 (F=0.017), age at sexual maturity of males and females is 8 and 6 years old, respectively, full recruitment age in males and females is 11 and 8 years old, respectively, and average recruitment age in males and females is 9 and 6 years old, respectively.

KEYWORDS: AGE DISTRIBUTION, AGE AT RECRUITMENT, AGE AT SEXUAL MATURITY, BRYDE'S WHALE, FISHING MORTALITYRATE, NATURAL MORTALITY RATE, WESTERN NORTH PACIFIC

INTRODUCTION

The biological parameters are needed for the studies of population dynamics of biological resources. Among them some parameters such as natural mortality rate, fishing mortality rate, age at recruitment, and age at sexual maturity can be estimated by use of age distribution. These biological parameters for the western North Pacific Bryde's whale were examined at the work on the comprehensive assessment of this whale stock in 1995 and 1996 (IWC, 1997). However, the age distribution seems to have not yet been examined fully in recent years.

The First Intercessional Workshop for the IST for this whale stock will examine on the conditioning of biological parameters, and it will be needed to re-examine these biological parameters at this chance.

This paper will re-estimate some biological parameters by use of age and other biological data which were collected by Japanese pelagic whaling and JARPN II.

MATERIALS AND METHODS

Materials

The numbers of age data which were collected by Japanese pelagic whaling (it will be called by 'whaling' later parts) during 1971-1979 and by JARPN II during 2000-03 are shown in Table 1. The pelagic whaling was not conducted in sub-area 1 west (SA 1W), and the data from sub-area 2 (SA 2) were only collected by the whaling, and they are smaller in number compared with those in sub-area 1 east (SA 1E). Although the materials were collected from both SA 1W and SA 1E by JARPN II, the number of age materials which were collected by JARPN II (total) has been still smaller than those by whaling (total), and they are used only for estimation of age at sexual maturity.

The method of catch of whales is different between the whaling and JARPN II. In the case of the whaling there were many operation restrictions based on the Schedule of the ICRW and Japanese domestic law such as catch quota, whaling ground, whaling season, size limit, prohibition of catch of cow and calf, etc. Related to the biological parameters, the size limits for the coastal and pelagic whaling of the Bryde's whale are set to be 10.7 and 12.2 m, respectively, by the ICRW, and the western limit of Japanese pelagic whaling ground was set at 158 degree East to protect coastal whaling by Japanese Government (Ohsumi, 1995). The restriction measures by the ICRW are not applied for the JARPN II, and whales were become a target of sampling in the waters west of 170 degree East. However, since 2002, the sampling of cow and calf has not been carried out.

The biological data which will be used in this paper are date and position of whales caught, sex, age, weight of testes, number of corpora lutea and albicantia in ovaries, for each whale.

Method

The materials are divided by position caught into the sub-area 1 west (west of 155 degree East, SA 1W), sub-area 1 east (between 155 degree East and 180 degree Longitude, SA 1E) and sub-area 2 (between 180 degree Longitude and 160 degree West, SA2) following the IWC/SC.

The age was determined by earplug annual layers. The sexual maturity of the male is identified by larger testis weight of 0.8 kg and over in the commercial whaling, and combined testes weight of 1.5 kg and over in JARPN II. The sexual maturity of the female is determined by the existence of corpus luteum or corpus albicans in ovaries.

RESULTS

Age distribution

Table 1 shows number of whales in each age class by sub-area and by sex in whaling, and in JARPN II number of whales in SA1W and SA1E combined by each age class, by sex and by sexual maturity.

Sexual difference of total mortality rate

Fig. 1 shows the age distribution of males and females, respectively, in all sub-areas combined by use of data obtained by pelagic whaling. The patterns of the age distribution are almost the same between sexes with a peak is at about 10 years old, although the maximum age is 68 years old in females, and that is 53 years old in males. The total mortality coefficient of males is 0.080, and that of females is 0.084, when age data are used in the range between 10 and 40 years old. This means that the values of mortality coefficient are almost the same in both sexes. Then, age data of both sexes combined are used for later analyses.

Total mortality rate

Fig. 2 shows the comparison of age distributions of both sexes combined in SA1E and SA 2 which were obtained by the whaling. Although it is difficult to compare the age distributions in pelagic whaling between SA 1E and SA 2, because sample numbers in SA 2 (210) are smaller than those in SA 1E (436), some difference may be estimated between them. The relatively sharp peak age in SA 1E is at 10 years old. On the other hand, gentle peaks are at 15 years old in SA 2. Although further examination will be needed to confirm, this phenomenon may indicate the difference of distribution pattern of Bryde's whales between SA 1E and SA 2, caused by the difference of operational strategy for both sub-areas. There are seasonal difference of catch in both sub-areas, and catch in SA 1E was mainly in early season from May to July, whereas it was mainly in later season from June to August in SA 2.

However, the total mortality coefficient which was calculated by use of age range of 10-40 years old in SA 1E is 0.095, and those calculated by use of age range of 15-40 years old in SA 2 is 0.096. Then, both figures are almost the same. This means that there is a possibility of the same stock in SA1E and SA2.

Fig. 2 shows also age distributions of Bryde's whales of both sexes in SA1W by JARPN II. Although sample size in SA 1W (110) are still too small to compare the age distributions in other sub-areas, the peak of age distribution in SA 1W is at about 6 years old which is about 4 years younger than that of

whaling. This phenomenon indicates the difference of collection methods, and there is a size limit of catch in the case of whaling, whereas this management measure is not applied for JARPN II.

Estimation of natural mortality rate and fishing mortality rate
From above examination, the total mortality coefficient (*M*) of the western North Pacific Bryde's whale is estimated to be 0.095 as the average of those in SA 1E and SA 2. Then, total mortality rate (D) is calculated to be 0.091.

An ideal age distribution of whales caught is shown in Fig. 3. Total mortality coefficient (*Z*) includes *M* and fishing mortality coefficient (*F*) in years between age at full recruitment (*tr*) and the year when the exploitation started. This age shows a transition point (*tc*) in the age distribution. And, the value of *Z* is the same as *M* in older than the age (*tc*).

However, it is difficult to estimate the transition point of the age distribution in this paper. This means the sample size is too small to find the point, or the fishing mortality coefficient is too small to have the point.

Ohsumi (1995) describes the catch history of the western North Pacific Bryde's whale. The average number of whales caught annually during years 1945-1970 is 179.2 whales, although yearly fluctuation occurs during the years. The annual catch increased rapidly from 1971 when USSR and Japanese pelagic whaling started. The annual catch was 940.2 whales including coastal whaling during years 1971-79. Then, the average annual catch during 1945-1979 is 380.6 whales. As the population size of this stock is estimated to be 26,000 (Kitakado et al., this meeting) and if the figure is used as the base of population size, the fishing mortality rate was about 0.007 in 1945-70, and 0.015 during 34 years of 1945-79. If 0.015 is considered to be the average fishing mortality rate (fishing mortality coefficient: 0.017) during 1945-1979, the natural mortality coefficient is calculated to be 0.095-0.017=0.078. Then, natural mortality rate (D) is calculated to be 0.076.

Age at sexual maturity:
The data of whaling are not used for this purpose, because the size limit (12.2 m) which was set for the pelagic whaling by the IWC, and it is near the body length at sexual maturity (around 12 m), so that bias may occur in the sexual maturity ratios in the age near the sexual maturity.

Although the sample size of JARPN II is still small, the age at sexual maturity is estimated by use of data of JARPN II in which samples are collected without size limit.

Fig. 4 shows relation between age and sexually mature ratios of males and females, respectively. From this figure, the age at sexual maturity is estimated by the 50 % mature age. They are 8 and 6 years old in males and females, respectively.

Age at recruitment:
From Fig. 2, the age of full recruitment is determined as the peak of the age distribution, and it is estimated to be 11 years old in males and 8 years old in females. The average of both sexes is 10 years old.

The average age at recruitment is calculated to be the average age of the age before the age at full recruitment, and it is estimated to be 9 and 6 years old in males and females, respectively.

DISCUSSION

The biggest problem in use of data of the commercial whaling is the catch restrictions by the regulation of whaling (Ohsumi, 1995). These regulation measures are possible to give some bias on the data. This paper used the data of the pelagic whaling, and the size limit in the pelagic whaling (12.2 m) is different with that of coastal whaling (10.7 m). Then, the age at recruitment must be different each other, but this biological parameter for the coastal whaling was not used in this paper. When we assess the population of coastal and pelagic whaling combined, this matter must be discussed and confirmed.

In this study, the maximum age was 53 in males and 68 years old in females. Ohsumi (1963) estimated the longest life span of the North Pacific Bryde's whale to be 63 years old from the interspecies relationship. Present study supports the result. The average ages which were calculated from the age distribution are 18.7 years old in males and 16.4 years old in females. Considering the scarcity of juveniles in catch, the average life span of this stock should be younger than these figures.

In the past several papers tried to estimate mortality rates of the North Pacific Bryde's whale. Doi, Nemoto and Ohsumi (1967) estimated total mortality coefficient (*Z*) by use of growth curve and size distribution of whales caught to be 0.059-0.085. Ohsumi (1977a) estimated *Z* was 0.091 from age distribution and it was 0.080 from ovulation distribution and annual ovulation rate. Ohsumi (1977b) estimated *M* to be 0.085 from age distribution, and Ohsumi (1979) estimated *M* to be 0.074 from interspecies relationships. IWC/SC agreed that *M* is 0.07 at the comprehensive assessment workshop in 1996.

We estimated in this paper from age distribution that *Z* is 0.095, natural mortality coefficient *M* is 0.078, and fishing mortality coefficient *F* is 0.017. These figures are close to the past figures, Then, we propose to use 0.08 for the value of *M* instead of 0.07.

The value of the natural mortality coefficient in 0 years old was not estimated from the age distribution in this paper. We expect that this biological parameter will be estimated in accordance of development of JARPN II.

It was difficult to estimate age at sexual maturity (*tm*) from age and maturity data of the commercial whaling, because of the bias from size limit of catch. However, it could be estimated by use of JARPN II data, although sample size is still small. This paper estimates the age at sexual maturity is 8 years old for males and 6 years old for the females. Ohsumi (1977a) estimated this parameter by means of three methods, and he indicates that it is 8-10 years old in males and 7-8 years old in females. IWC agreed the parturition age (*tm*+1) of females is 9 years old. However, this figure will be better to change to 7 years from the present result.

Two sets of the age at recruitment were estimated in this paper. Both the full and average recruitment ages are older than the age at sexual maturity, and the average recruitment age. In the case of making a population dynamics model, this phenomenon should be considered.

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Table 1. Age and sexual maturity status of Bryde's whales collected during 1971-1979 commercial whaling and 2000-2003 JARPN II surveys.

	Male						Female					
	Whaling			JARPN II			Whaling			JARPN II		
Age	Sub-area 1E	Sub-area 2	Total	Imm	Mat	Maturity rate(%)	Sub-area 1E	Sub-area 2	Total	Imm	Mat	Maturity rate(%)
0				1		0.0				1		0.0
1				1		0.0				1		0.0
2				1		0.0				1		0.0
3	1	2	3	6		0.0	2		2	2		0.0
4	3	3	6	5		0.0	5		5	4		0.0
5	4	3	7	5		0.0	11	2	13		1	100.0
6	8	4	12	3	3	50.0	5	1	6	2	2	50.0
7	10	2	12	2		0.0	9	1	10	2	2	50.0
8	11	2	13	1	1	50.0	11	8	19	1	4	80.0
9	15	3	18		2	100.0	11	3	14		4	100.0
10	16	4	20		4	100.0	12	5	17		6	100.0
11	20	5	25		1	100.0	6	3	9		6	100.0
12	10	3	13		2	100.0	9	7	16		3	100.0
13	13	4	17	1		0.0	5	5	10		4	100.0
14	9	1	10		4	100.0	5	5	10		3	100.0
15	14	5	19	1	4	80.0	7	7	14		1	100.0
16	16	3	19		1	100.0	9	5	14		6	100.0
17	7	4	11		2	100.0	8	2	10		2	100.0
18	11	5	16				10	8	18		3	100.0
19	15	9	24		1	100.0	2	1	3			
20	5	3	8		1	100.0	7	6	13		3	100.0
21	4	3	7				2	3	5	1	1	50.0
22	9	6	15		1	100.0	5	4	9		2	100.0
23	8	3	11				7	5	12			
24	4	1	5				5		5			
25	4	3	7				6	2	8			
26	4	3	7					2	2		1	100.0
27	3	2	5				3	3	6			
28	9	1	10		1	100.0	1		1			
29	2	9	11				1	3	4		3	100.0
30	1	1	2									
31	2	1	3		1	100.0	1	2	3			
32	3	2	5		1	100.0	1	2	3		1	100.0
33	2		2				3		3			
34	1	1	2									
35	2	2	4				1		1			
36	1	1	2				2		2			
37	2	1	3									
38	2	3	5									
39	3	1	4		1	100.0						
40	1		1				2		2			
41	2		2									
42	1		1									
45		1	1									
46	2		2									
47	1		1									
49	1		1									
52		1	1									
53		2	2									
58		1	1									
68		1	1									
Total	262	115	377	27	31	53.4	174	95	269	15	58	79.5

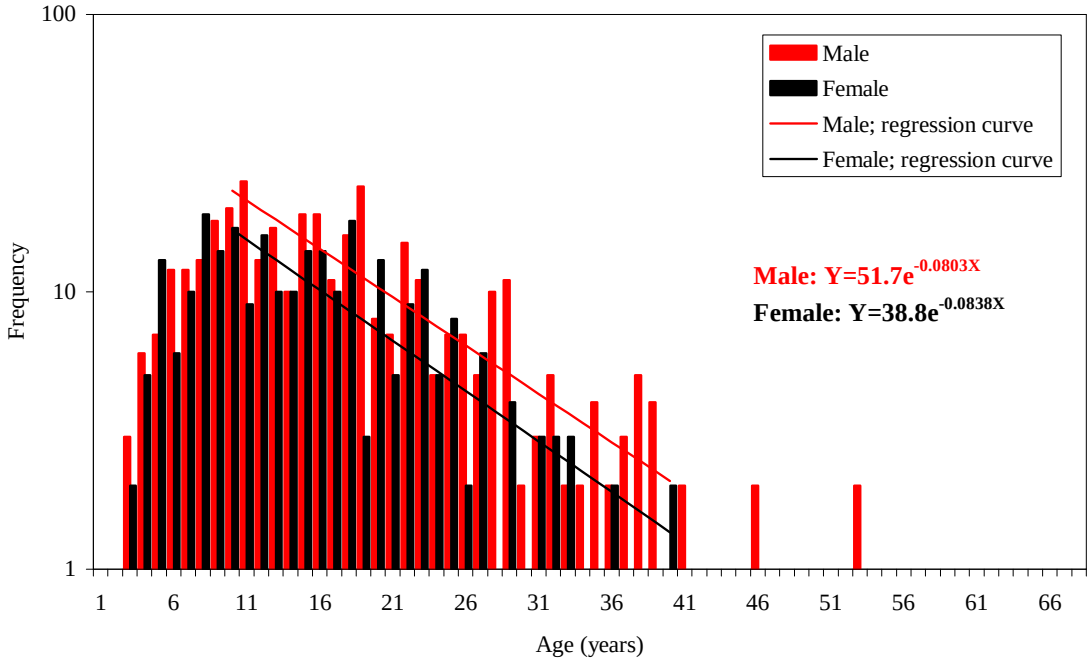

Fig. 1. Age distribution and mortality rate of male and female Bryde's whales collected during 1971-1979 commercial whaling.

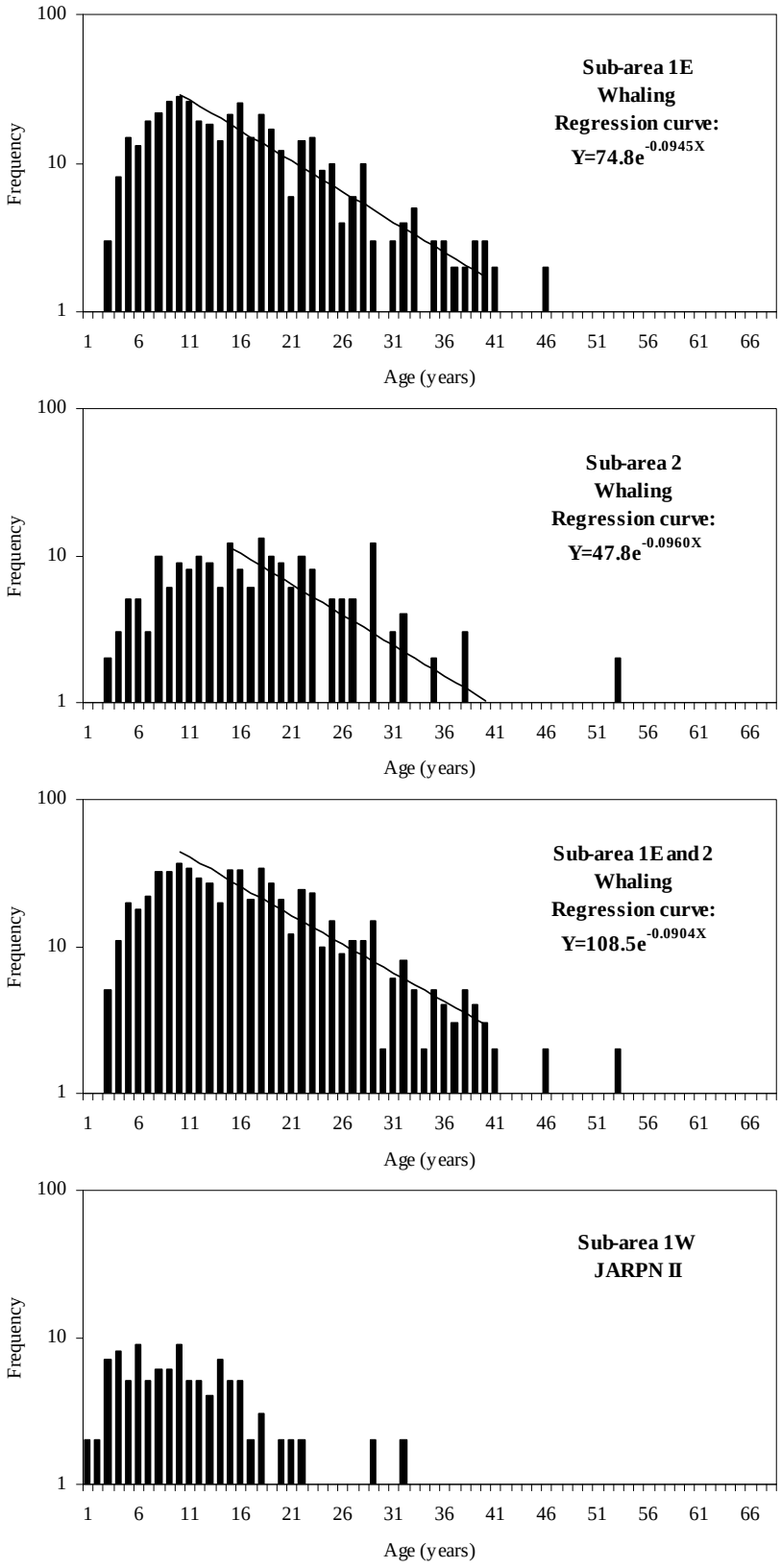

Fig. 2. Age distribution and mortality rate of Bryde's whales in each sub-area.

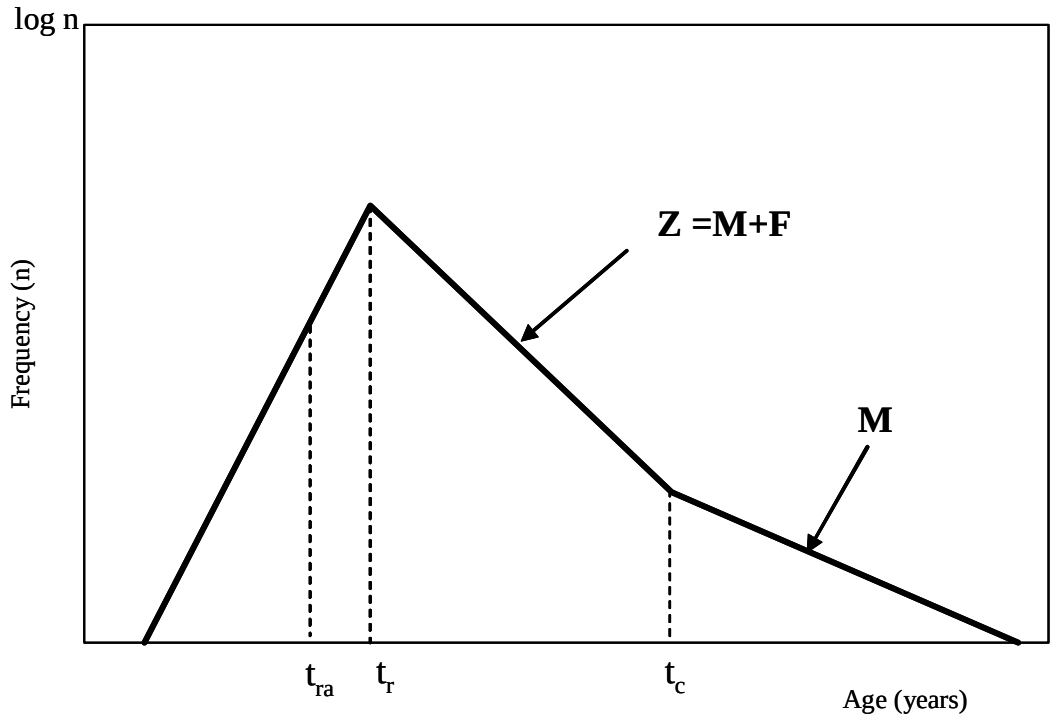

Fig. 3. Schematic diagram of age distribution and mortality rate.

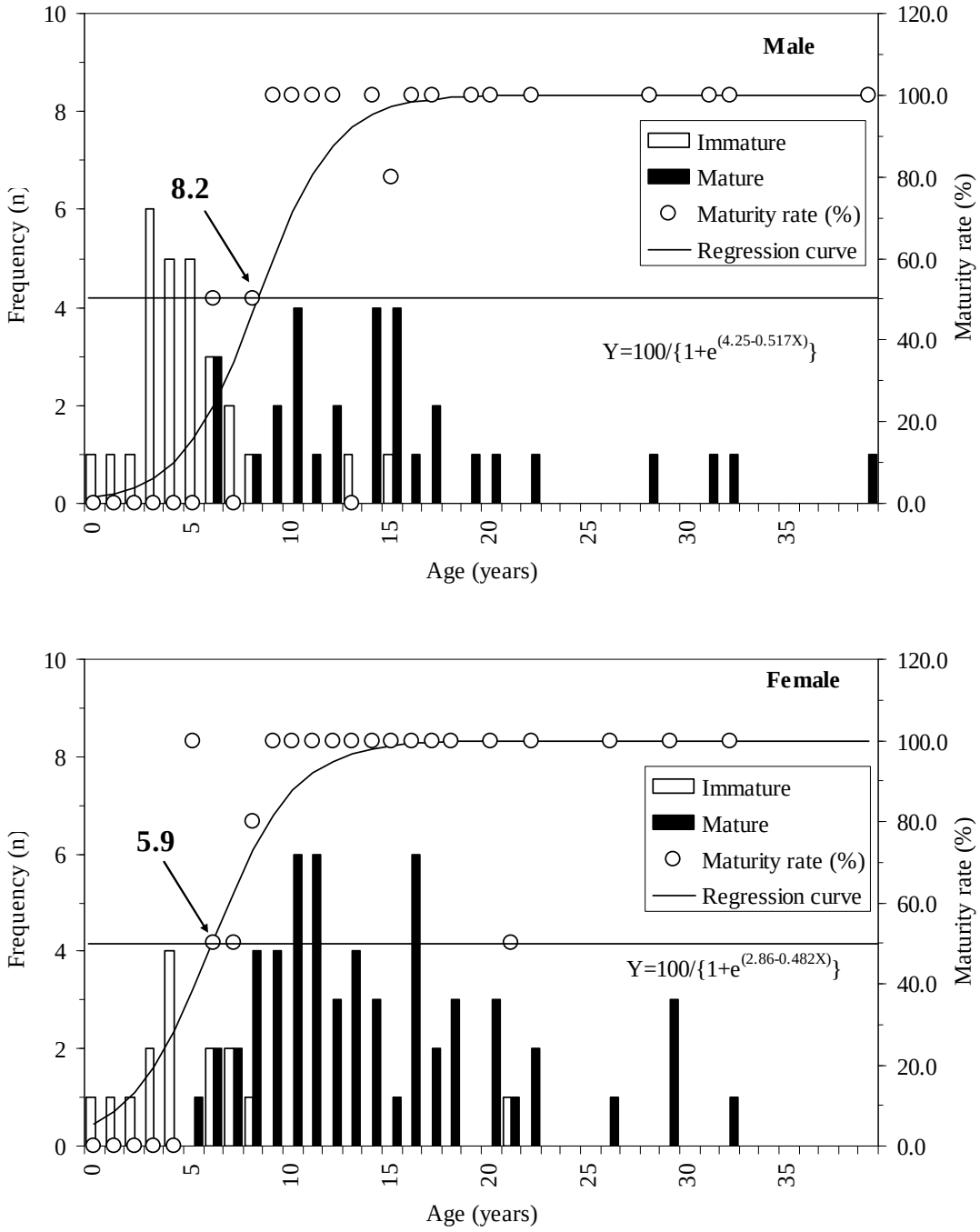

Fig. 4. Age at sexual maturity of Bryde's whales collected during 2000-2003 JARPN II surveys.