Biological observations of fin whales sampled by JARPAII in the Antarctic

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ABSTRACT
The aim for the sampling of fin whales under JARPAII is the investigation of temporal trend in some biological parameters, as well the acquirement of feeding ecology information as input parameters for the ecosystem modelling work. For the reason given in SC/F14/J1 the number of fin whales sampled in the first period was smaller than the originally planned so that the utility of these samples for the objectives mentioned above is still limited. This paper presents new biological information of 17 Antarctic fin whales sampled by JARPAII in the first period (2005/06-2010/11). The information summarized in this paper is on body proportion, reproductive status, age/length relationship, body length/body weight relationship and ecological markers (external parasites). For some parameters comparisons were made with data of the commercial whaling period in the Antarctic which stopped some 36 years ago. The main results were that body weight of whales in the JARPAII period is heavier than those previously reported for the Antarctic in the 1950's. Further, results suggested the possibility that whales are reaching sexual maturity at younger ages. These results are consistent with the increasing abundance trend observed for this species in recent decades. The biological analyses based on JARPAII were based on small sample sizes. Further biological sample and data from this species will be needed to confirm the results found in this study.

KEYWORDS: ANTARCTIC, BIOLOGICAL PARAMETERS, COMMERCIAL WHALING, FIN WHALE, SCIENTIFIC PERMITS

INTRODUCTION

The fin whale, *Balaenoptera physalus* (Linnaeus, 1758) is one of the main component of the Antarctic ecosystem, and it had been a main target species of the whaling industry during the 20th century as same as the blue whale, *Balaenoptera musculus* and the humpback whale, *Megaptera novaeangliae*. By the adoption of the New Management Procedure (NMP) all stocks of the southern fin whale were classified as protected stocks in 1976 (IWC, 1977) by the International Whaling Commission (IWC), and that ban has continued up to now.

More than 30 years have passed since the ban of whaling on this whale species and the population has been increasing at annual rates of 13-16% as estimated by the JARPA survey in Areas III East to VI West from the season 1987/1988 (Matsuoka *et al*, 2005; Matsuoka *et al*, 2006). The information on the biological parameters can improve the rational management of whale resources. The change in some biological parameters such as pregnancy rate, sexual maturity rate, and age at sexual maturity with the change of abundance of stocks has been revealed on some whale species (Gambell, 1973; Kato, 1986). However, temporal change in these biological parameters has not been studied for 36 years in the Antarctic fin whales, because the biological sampling has not been carried out due to the ban of catch of this whale species since 1977.

Based on the result of JARPA, the Government of Japan planned the JARPAII in 2005, and the fin whale was added as target species with the Antarctic minke whale, *Balaenoptera bonaerensis* and humpback whale. The objective of the sampling of fin whales aims to investigate the temporal trend in some biological parameters as one of the means to monitor the Antarctic ecosystem (Government of Japan, 2005).

In this paper we report the biological information collected from fin whales sampled by JARPAII between 2005/2006 and 2010/2011. In some cases we compare the biological information from JARPAII with that obtained by Japanese commercial whaling during late 1940s to early 1950s.

MATERIALS AND METHOD

Samples

A total of 17 fin whales were sampled between the 2005/06 and the 2010/11 seasons. Catch records and biological data of the whales sampled are shown in Table 1. The catch positions are shown in Figure 1.

Among them, the body weight of one individual (0506F001) was not measured because of some technical reasons. Another individual (0607F001) was lost before landing on the flensing deck of the research base vessel *Nisshin-maru*. For this reason measurements could not be obtained for this individual.

Biological data from JARPAII

External measurements

The external measurements in 16 whales were conducted based on protocols from earlier reports for fin whales (Mackintosh and Wheeler, 1929; Laws, 1961), and modified by the Institute of Cetacean Research. Figure 2 shows the external measurements points. Body length was defined as the body axes length from the tip of snout to notch of flukes in parallel to the plane of the deck.

Ventral grooves

The number of ventral grooves was counted following Williamson (1973).

Body weight

Body weights were measured for a total 15 whales by summing of all body parts using electronic hanging scale (maximum capacity of 30t) and marine scale (M1100, Marel, Iceland). In females, both ovaries were removed and weighted. In males, testes were removed and weighted of both sides, separately. The gonads weight was measured by using the electronic marine scale (S-182, Marel, Iceland).

Foetuses

Three individuals (0506F002, 0506F003 and 0607F003) were pregnant. Their foetuses were measured and sampled as same as other adult whales.

Marine diatom

As a quantitative measurement of attached marine diatom in the whale body, five categories were made following Omura (1950).

Parasites

Observation of internal/external parasites was carried out.

Definition of sexual maturity

The sexual maturity of the female was determined by the presence of corpus luteum or corpus albicans in either ovary. In the case where no corpus luteum or corpus albicans was observed in both ovaries, the female was categorized as sexually immature. Conversely, if either corpus luteum or corpus albicans was observed in ovaries, the female was categorized as sexually mature. The counting of the corpus luteum and corpus albicans was not carried out because the ovary samples were lost after the earthquake and tsunami on 11 March 2011. The male sexual maturity was determined by the weight of one side of testis. In the case of one side of testis is over 2.5kg, the whale was determined as sexually mature (Ohsumi, 1964).

Age determination

The age of a whale was determined by the counting of growth layers in the earplugs (Purves, 1955; Ohsumi, 1964; Lockyer, 1972; Maeda *et al*, 2013). The left and right earplugs with glove-finger were collected carefully using scalpel, and immediately fixed in 10% formalin solution until age determination. After slicing the surface of earplugs by use of whetstone along on the rim of ear plug until layers were recognized, the layer of earplug were counted using stereoscopic microscope under low magnification (3.15x-31.5x). One pair of the light and dark laminae in the core of earplug corresponds to one year, according to an evidence by Ohumi (1964) and optimized histochemical method of Maeda *et al* (2013).

Comparative analyses with commercial samples

JARPAII data were compared with some published Japanese commercial whaling data obtained during commercial whaling operations in the Antarctic in late 1940s and early 1950s. The number of samples used for the comparative analysis was summarized in Table 2. The following items were compared:

Body proportion
The mean values (±SD) of JARPAII were calculated and compared through plotting data on the normalized axis using data of Japanese commercial whaling data.

Body and organ weights
The relationship was evaluated by applying single nonlinear regression. The following formula was used (Lockyer, 1976):

$$\textit{Body weight (t)} = a\ \textit{Body length (m)}^{\,b}$$

The coefficient of *a* and *b* were estimated by the least-squares method. Further comparison between body length and body part weights were carried out using 34 commercial whaling data of Japan. These data were calculated on mean (±SD) value in each class of 1m body length.

In order to check whether there are differences in reproductive condition, we compared the relationship of gonad weight and body length using the same data from body parts weight.

Relationship between body length or age and sexual maturity
To calculate the growth of fin whale and the frequency of sexual maturity, we conducted typical univariate descriptive analysis. In order to investigate the correlation between sexual maturity and body length or age variables, we used t-tests for continuous variables (body length values or age values). The body length or age of fin whale variables significantly associated with sexual maturity (p<0.05) were entered into a logistic regression model to assess the relative contributions, although there are various estimation methods (Cooke, 1984). For body length sampled in JARPAII, there was no significant regression coefficient in logistic model (p=0.09). We estimated logistic regression model on only commercial whaling data in seasons 1949/1950s, 1950/1951s, and 1951/1952s by sex. Also about the relationship between age and sexual maturity, same method is applying and testing the logistic regression analysis using the data obtained in JARPAII and season 1956/1957 (Nishiwaki *et al*, 1958). Each formula of logistic regression model was used:

$$p = \frac{e^{\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \beta_0}}{1 + e^{\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \beta_0}}$$

p: predicted value, x: independent variable, e: base of natural logarithm, β: parameter.

RESULTS
Biological information from JARPAII
Sex ratio and body weight
Summary of the catch composition in JARPAII is shown in Table 1. Of 17 whales sampled nine were females and eight were males (male sex ratio: 0.47). Mean body weight was 46.02tons (SD: 10.47). The maximum and minimum weights for females were 65.02tons and 22.26tons, respectively. The maximum and minimum weights for males were 51.62tons and 34.20tons, respectively.

Sexual maturity
Sexual maturity rate was 50.0% (4/8) and 62.5% (5/8) for female and males, respectively. The three pregnant whales had a single foetus, and a single corpus luteum existed on one ovary. During the dissection of all female whales, no milk was found in the mammary glands. As shown in Table 1, body lengths of foetuses were 280.7cm (female), 127.5cm (male) 243.4cm (male). Body weights of foetuses were 172.0kg (female), 19.95kg (male) and 141.0kg (male). These foetuses were of normal development from gross appearance.

Ventral grooves
The mean number of ventral grooves was 67 (SD:10) in males and 69 (SD: 5) in females, respectively.

Marine diatom
In most cases diatom film was recognized on the surface of the whale body (14 of 16 whales). Adhesions of diatom films were more densely observed in males than females (categories ++ and +++ in Table 3).

Parasites
Table 4 shows the frequency of parasites observed. The most observed sessile organisms on the skin of fin whales were *Cyamus* (44.0%). 75.0% of males and 12.5% of females had *Cyamus* on the ventral grooves. Chi-

square test revealed that the percentage of attachments of *Cyamus* significantly differed by sex ($p<0.05$). Both *Pennella* and *Conchoderma* were not observed. *Coronula sp*. was observed in males and females with a same percentage.

Internal parasites were not observed in the stomachs of 16 fin whales. Unidentified parasites were observed in the Gastroepiploic.

Comparative analyses

Average body length

Mean body length in JARPAII for females was 19.05m (SD: 1.92) (maximum and minimum lengths were 21.15m and 14.79m, respectively). Mean body length in JARPAII for males was 18.96m (SD: 0.87) (maximum and minimum lengths were 20.67m and 18.61m, respectively).

Body length (m) of each fin whale sampled in JARPAII is plotted in Figure 3 with annual mean length and ±SD of fin whales captured in Antarctic pelagic whaling during the periods 1930/1931-1975/1976. It is difficult to compare the data between the commercial and JARPAII, because there was a regulation for size limit of 70 feet (21.34m) for the fin whale in pelagic commercial whaling. On the other hand, there is a technical reason not to take more than 20m in estimated body length in JARPAII. It is found from Figure 3 that there is a trend to decrease the average body length in the years of commercial whaling periods.

Body proportion

The mean value and body proportion of the external measurements of JARPAII by sex is summarised in Table 5. Figure 4 shows the comparison of the body proportions between JARPAII and the normalized axis using the data of Japanese commercial whaling (seasons from 1948/1949 to 1950/1951). As shown in this table, no difference of variation of proportion was seen between the sexes except for the reproductive aperture (e.g. measurement point 13). Figure 4 shows the relationship between the deviations of JARPAII data that covers the external portion of 15 measurement locations as items that can be compared, with corresponding to commercial whaling data. JARPAII data are smaller than Japanese commercial whaling data in many parts in both sexes. In the length in Points 7, 14, and 21 of males in JARPA, males are larger than commercial whaling data. Females are larger than males in many points. Excepting for sex difference, dorsal fin is higher, and the skull is shorter than commercial whaling data. This trend was particularly pronounced in males.

Relationship between body length and body weight

Figure 5 shows the relationship between body length and body weight for JARPAII and commercial fin whales. Calculated coefficients a and b in the formula are a=0.005394±0.005329 and b=3.068448±0.332619 in JARPAII, and a=0.044530±0.027880 and b=2.315830±0.205040 in commercial data. From the graph, predicted body weights of fin whale captured in JARPAII tend to be heavier than that of the commercial whaling for the same body length.

Figure 6 shows the relationship between body length and gonad weight. The relationship is very similar between JARPAII and commercial fin whales.

Tables 6a-b and 7a-b, and Figure 7 show the mean weights of each body part of fin whale, by body length. Figure 7 show that the parts weight increase with body length. This increase is more pronounced in the case of the JARPAII whales for blubber (Figure 7b) and meat (Figure 7c). For bones and viscera the increase pattern is similar between JARPAII and commercial whales.

Relationship between body length and sexual maturity

Figure 8 shows the relationship between body length and maturity rate of fin whales sampled by commercial whaling during the seasons 1949/1950, 1950/1951, and 1951/1952, for female and males. JARPAII samples are plotted in both immature (0 rate) and mature (1.0 rate) individuals. Immature individuals of JARPAII ranged from 14.79m to 19.35m (17.61-19.17m in males, 14.79-19.35m in females). Mature individuals ranged from 18.73m to 21.15m (18.73-20.67m in male, 19.47-21.15m in female respectively).

It is estimated that the body length at 50% sexual maturity is 18.99m (18.69m in male and 19.90m in female) in commercial whaling. Regression coefficient between sexual maturity and body length of JARPAII did not reach statistical significance, possibly due to the small sample size. From the plotting, JARPAII data were equally distributed besides the rise of predicted probability of maturity rate in commercial whaling data except for immature one (body length=14.79m).

Relationship between age and sexual maturity
Figure 9 shows the relationship between age and sexual maturity rate of fin whales sampled by JARPAII and commercial whaling during the season 1956/1957, for both sexes combined. Immature individuals of JARPAII ranged from 6 to 9 years old, and mature individuals ranged from 7 to 22 years old. It is estimated that the 50% sexual maturity age are 8.8 years old in JARPAII and 11.0 years old in commercial whaling, respectively. The minimum age of pregnant whale obtained in JARPAII was 10 years old. Age at 50% sexual maturity of JARPAII is 2.2 years younger than Japanese commercial whaling data.

DISCUSSION

This study provided new biological information of fin whales in the Antarctic after 36 years. Although the number of whales examined was small some new and interesting results such as body proportion and parasites were obtained. During the commercial whaling period only large whales were taken. During the JARPAII survey there was the opportunity of sampling small animals for the first time. In fact the smallest whale was a 14.79m whale and several biological data were obtained from this whale. The limitation of JARPAII, however, was for animals larger than 20.0m which usually were not sampled because technical difficulties.

Body length / body weight and partial weights relationships
It was found that Antarctic fin whales collected by JARPAII are heavier than those taken by commercial whaling in the 1950s. This might suggest that the feeding condition for the Antarctic fin whale has improved in recent years. It was also found that the relative weights of the blubber and the meat are heavier for fin whales sampled by JARPAII (Figure 7). The increase in body weight of fin whales, particularly in weight of meat and blubber, might indicate faster growth which was derived from better nutritional condition in recent years.

Body length and age at sexual maturity
There is the possibility that the age at sexual maturity of the fin whale has decreased in the 2000s. Decline in the age at sexual maturity in whales in response to substantial decrease in the abundance (for example due to over-exploitation) has been reported for sei and fin whales in part of the Indian Ocean and the Antarctic Ocean, and for fin whales in the northwest Pacific Ocean (Gambell, 1973; Lockyer, 1979; Ohsumi, 1986). Our study provided evidence that the age at sexual maturity of fin whales sampled by JARPAII has decreased about 2.2 years from the 1950s.

The number of pregnant whales among the fin whales sampled by JARPAII was three out of four matured whales (75.0%). This high pregnancy rate was similar to the 1970s (Gambell, 1973).

All these evidences suggest improved nutritional conditions of the fin whales in recent years. The biological studies based on JARPAII were based on small sample sizes. Further biological sample and data from this species will be needed to confirm the results found in this study.

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Table 1

Catch records and biological data of the fin whales in the JARPAII during the seasons 2005/2006-2010/2011.

Serial No.	Catch date	Catch position		Sex	Sexual maturity	Body length	Body weight	Age	Foetus sex	Foetus body	Remarks
		Latitude	Longitude			(m)	(t)	(yrs.)		length (cm)	
0506F001	3 February 2006	65°44S	71°38E	Male	Immature	19.17	No data[1]	9			
0506F002	8 February 2006	65°54S	78°06E	Female	Mature	20.05	53.48	11	Male	127.5	Pregnant
0506F003	9 February 2006	65°48S	78°07E	Female	Mature	19.47	52.05	12	Female	280.7	Pregnant
0506F004	10 February 2006	65°37S	78°13E	Male	Mature	18.73	41.87	22			
0506F005	13 February 2006	65°22S	82°00E	Male	Mature	19.14	47.28	11			
0506F006	14 February 2006	65°10S	81°59E	Female	Immature	19.15	47.04	9			
0506F007	7 March 2006	64°34S	111°51E	Female	Mature	20.22	61.52	7			
0506F008	9 March 2006	64°53S	114°06E	Female	Immature	18.22	41.06	7			
0506F009	10 March 2006	64°48S	114°14E	Male	Immature	18.3	42.27	6			
0506F010	13 March 2006	65°36S	120°30E	Female	Immature	19.35	47.24	8			
0607F001	3 January 2007	63°53S	170°44W	Female	No data	No data	No data	No data	No data	No data	Torn off[2]
0607F002	5 January 2007	62°35S	174°17W	Male	Mature	20.67	51.62	11			
0607F003	2 February 2007	68°46S	173°41W	Female	Mature	21.15	65.02	10	Male	243.4	Pregnant
0809F001	13 March 2009	65°38S	165°08E	Female	Immature	14.79	22.26	6			
0910F001	3 February 2010	66°08S	62°32E	Male	Immature	17.61	34.2	6			
1011F001	7 January 2011	63°28S	175°40W	Male	Mature	19.05	39.63	12			
1011F002	20 January 2011	66°39S	165°32E	Male	Mature	18.99	43.78	10			

[1]The body weight was not measured.

[2]Most of the body was torn off by accident during the pulling up to the flensing deck of *Nisshin-maru*.

Table 2

Comparison of data used in this study.

Analysis items	JARPAII	Commercial whaling		
	Samples	Samples	Whaling season	Source
Body proportion	16	16	1948/1949	Fujino, 1954
		6	1949/1950	Fujino, 1954
		5	1950/1951	Fujino, 1954
Body length and weight	16	16	1947/1948	Nishiwaki, 1950
		13	1948/1949	Nishiwaki, 1950
		5	1950/1951	Ohno and Fujino, 1952
Organ weight	15	16	1947/1948	Nishiwaki, 1950
		13	1948/1949	Nishiwaki, 1950
		5	1950/1951	Ohno and Fujino, 1952
Body length and gonad weight	16	16	1947/1948	Nishiwaki, 1950
		13	1948/1949	Nishiwaki, 1950
		5	1950/1951	Ohno and Fujino, 1952
Body length and maturity	16	437	1949/1950	Mizue and Murata, 1951
		2,049	1950/1951	Ohno and Fujino, 1952
		2,583	1951/1952	Kakuwa *et al*, 1953
Age and maturity	16	288	1956/1957	Nishiwaki *et al*, 1958
Body length	16	535,740	1930/1931-1975/1976	International whaling statistics

Table 3

The adhesion level of diatom films of the fin whale in the JARPAII during the seasons 2005/2006-2010/2011.

Classification[1]	Female	Male	Total
-	2	0	2
±	0	0	0
+	6	6	12
++	0	2	2
+++	0	0	0
Total	8	8	16

[1]-: not infected; ±: with thin film; +: with patched; ++: with thick film; +++: with thick film on whole body.

Table 4

Infection rate of external parasites and diatom films of the fin whales collected from JARPAII during the seasons 2005/2006-2010/2011.

Species	Male No. of whales infected/investigated (infected rate %)	Female No. of whales infected/investigated (infected rate %)	Total No. of whales infected/investigated (infected rate %)
Cyamus	6/8 (75.0)	1/8 (12.5)	7/16 (43.8)
Coronula sp	1/8 (12.5)	1/8 (12.5)	2/16 (12.5)
Conchoderma sp	0/8 (0.0)	0/8 (0.0)	0/16 (0.0)
Pennella sp	0/8 (0.0)	0/8 (0.0)	0/16 (0.0)
Diatom film	8/8 (100.0)	6/8 (75.0)	14/16 (100.0)

Table 5

The external body proportions of the fin whales in the JARPAII during the seasons 2005/2006-2010/2011.

	Males			Females		
	Samples	Mean	%BL	Samples	Mean	%BL
1. Body length (0.01m)	8	18.96	100.0	8	19.05	100.0
2. Projection of snout beyond tip of lower jaw (0.1cm)	4	9.9	0.5	6	7.2	0.4
3. Tip of snout to blow-hole (1cm)	8	344	18.2	8	353	18.5
4. Tip of snout to angle of gape (1cm)	8	365	19.2	8	371	19.5
5. Tip of snout to centre of eye (1cm)	8	372	19.6	8	382	20.1
6. Tip of snout to tip of flipper (1cm)	8	777	41.0	8	779	40.9
7. Centre of eye to centre of ear (0.1cm)	8	91.4	4.8	8	91.1	4.8
8. Notch of flukes to posterior emargination of dorsal fin (1cm)	8	429	22.6	8	435	22.8
9. Notch of flukes to root of flukes (1cm)	7	98	5.1	9	100	5.2
10. Notch of flukes to centre of anus (1cm)	8	535	28.2	8	532	27.9
11. Notch of flukes to umbilicus (1cm)	8	860	45.4	8	860	45.1
12. Notch of flukes to end of system of ventral grooves (1cm)	8	833	44.0	8	835	43.8
13. Centre of anus to centre of reproductive aperture (0.1cm)	8	131.3	6.9	8	59.0	3.1
14. Vertical height of dorsal fin (0.1cm)	8	47.9	2.5	8	45.0	2.4
15. Length of base of dorsal fin (0.1cm)	8	108.3	5.7	8	102.1	5.4
16. Axilla to tip of flipper (1cm)	8	149	7.9	8	151	7.9
17. Anterior end of lower border to tip of flipper (1cm)	8	230	12.1	8	230	12.1
18. Border length posterior end to tip of flipper (1cm)	8	237	12.5	8	236	12.4
19. Greatest width of flipper (0.1cm)	8	52.8	2.8	8	52.3	2.7
21. Skull width (0.1cm)	8	220.6	11.6	6	205.4	10.8
22. Skull length, condyle to tip of premaxilla (0.1cm)	8	464.5	24.5	8	475.6	25.0
23. Flipper length (from condyle to tip) (1cm)	8	239	12.6	5	245	12.9
25. Notch of flukes to tip of flukes (Left side) (1cm)	4	215	11.3	3	226	11.9
26. Tip of snout to centre of ear (1cm)	8	461	24.3	8	470	24.6
27. Tip of snout to centre of umbilicus (1cm)	8	1032	54.5	8	1056	55.4
28. Tip of snout to end of ventral grooves (1cm)	8	1061	56.0	8	1055	55.4
29. Tip of snout to center of reproductive aperture (1cm)	8	1227	64.7	8	1311	68.8
30. Tip of snout to anus (1cm)	8	1358	71.6	8	1370	71.9
31. Notch of flukes to reproductive aperture (1cm)	8	664	35.0	8	589	30.9
32. Tip of snout to center of reproductive aperture (1cm)	8	1460	77.0	8	1467	77.0
33. Width of flukes (1cm)	8	407	21.5	8	426	22.4
34. Chest circumference, half (1cm)	8	436	23.0	8	452	23.7
35. Abdominal circumference, half (1cm)	8	345	18.2	8	366	19.2
36. Buttock circumference, half (1cm)	8	260	13.7	8	277	14.5
37. Body height(posterior of dorsal fin) (0.1cm)	7	182.6	9.6	8	195.4	10.3
38. Body height(navel) (0.1cm)	8	246.6	13.0	8	254.8	13.4
39. Border length posterior end to tip of flipper (1cm)	8	154	8.1	8	156	8.2

Remarks. NA: not available the measurements; N: number of samples; %BL: percentage to body length; Mean: mean length.

Table 6a

Average body parts weight (kg) of the fin whales in the JARPAII during the seasons 2005/2006-2010/2011.

Class of body length (m)	Samples[1] (female / male)	Total parts weight	Blubber	Meat	Bone	Viscera and others
14.0 -	1 (1/0)	21,982.0	5,505.8	10,700.8	2,783.2	2,992.2
17.0 -	1 (0/1)	33,996.0	7,779.1	17,080.4	4,879.5	4,257.1
18.0 -	4 (1/3)	41,837.1	10,317.3	20,463.3	5,370.9	5,685.6
19.0 -	5 (3/2)	46,090.3	11,678.0	22,318.7	5,918.1	6,175.5
20.0 -	3 (2/1)	54,992.7	13,587.8	27,499.9	7,195.1	6,709.9
21.0 -	1 (1/0)	63,999.3	16,745.8	31,439.0	7,287.7	8,526.8
Total	15 (8/7)	45,517.0	11,363.5	22,344.4	5,840.7	5,968.4

[1]Total 15 out of 17 catches.

Table 6b

Percentage of body parts weight of the fin whales in the JARPAII during the seasons 2005/2006-2010/2011.

Class of body length (m)	Samples[1] (female / male)	Total parts	Blubber	Meat	Bone	Viscera and others
14.0 -	1 (1/0)	100.0	25.0	48.7	12.7	13.6
17.0 -	1 (0/1)	100.0	22.9	50.2	14.4	12.5
18.0 -	4 (1/3)	100.0	24.7	48.9	12.8	13.6
19.0 -	5 (3/2)	100.0	25.3	48.5	12.8	13.4
20.0 -	3 (2/1)	100.0	24.7	50.0	13.1	12.2
21.0 -	1 (1/0)	100.0	26.2	49.1	11.4	13.3
Total	15 (8/7)	100.0	25.0	49.1	12.8	13.1

[1]Total 15 out of 17 catches.

Table 7a

Average body parts weight (kg) of the fin whales in commercial whaling data during the seasons 1947/1948-1950/1951.

Class of body length (m)	Samples (female / male)	Total parts	Blubber	Meat	Bone	Viscera and others
17.0 -	1 (1/0)	33,817.0	6,953.0	16,875.0	4,899.0	5,123.0
18.0 -	1 (1/0)	37,367.0	8,270.0	18,391.0	5,906.0	4,800.0
19.0 -	5 (0/5)	43,712.0	10,263.8	19,473.6	7,760.2	6,214.4
20.0 -	12 (6/6)	48,652.7	11,289.8	21,971.2	8,264.3	7,127.5
21.0 -	8 (8/0)	55,629.7	12,761.0	25,914.0	8,856.8	8,098,0
22.0 -	6 (6/0)	60,966.0	15,897.7	27,398.5	10,284.7	7,385.1
23.0 -	1 (1/0)	57,487.6	13,319.0	24,093.0	9,132.0	10,943.6
Total	34 (23/11)	51,232.3	12,141.5	23,296.6	8,543.3	7,251.9

Table 7b

Percentage of body parts weight of the fin whales in commercial whaling data during the seasons 1947/1948-1950/1951.

Class of body length (m)	Samples (female / male)	Total parts weight	Blubber	Meat	Bone	Viscera and others
17.0 -	1(1/0)	100.0	20.5	49.9	14.5	15.1
18.0 -	1(1/0)	100.0	22.1	49.3	15.8	12.8
19.0 -	5(0/5)	100.0	23.5	44.5	17.8	14.2
20.0 -	12(6/6)	100.0	23.2	45.2	17.0	14.6
21.0 -	8(8/0)	100.0	22.9	46.6	15.9	14.6
22.0 -	6(6/0)	100.0	26.1	44.9	16.9	12.1
23.0 -	1(1/0)	100.0	23.2	41.9	15.9	19.0
Total	34(23/11)	100.0	23.7	45.4	16.7	14.2

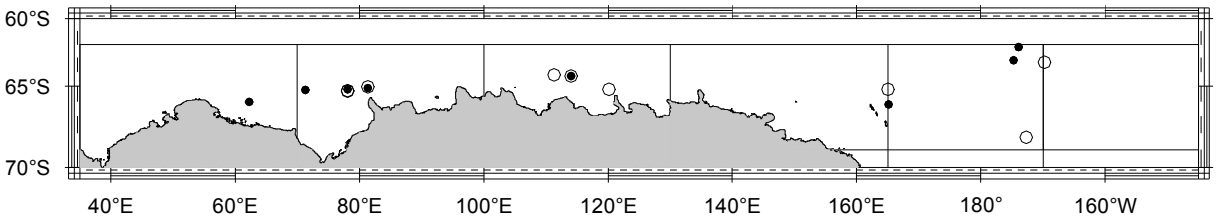

Figure 1. Catch positions of the fin whales in the JARPAII (seasons 2005/2006-2010/2011). Closed circle: female; open circle: male.

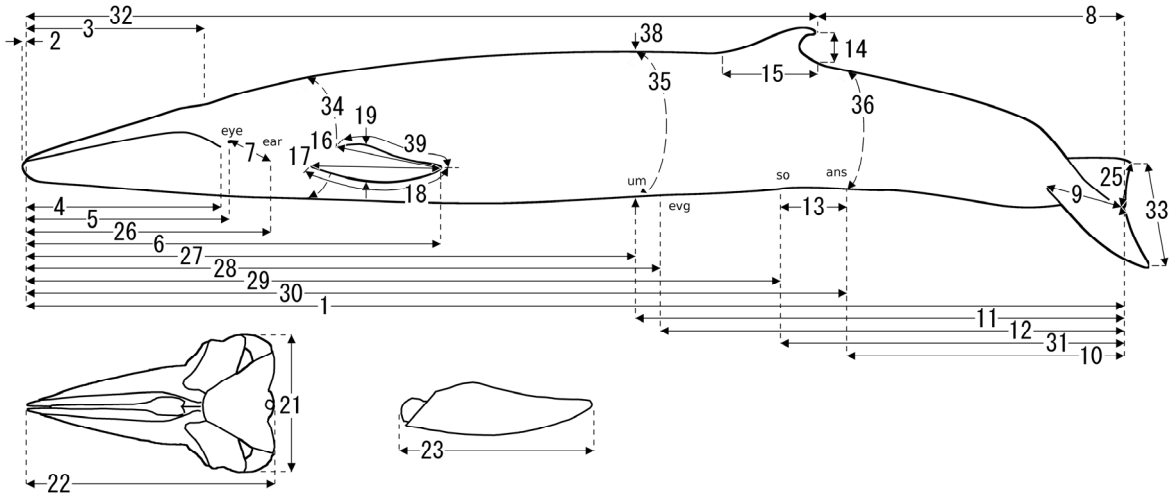

Figure 2. Measurement points of external proportions of fin whale in the JARPAII. The number corresponds to row number is below keys. 1: total length; 2: lower jaw; projection beyond tip of snout; 3: tip of snout to blowhole; 4: tip of snout to angle of gape; 5: tip of snout to centre of eye; 6: tip of snout to tip of flipper; 7: eye to ear; 8: notch of flukes to posterior emargination of dorsal fin; 9: flukes, width at insertion; 10: notch of flukes to anus; 11: notch of flukes to umbilicus; 12: notch of flukes to end of ventral grooves; 13: anus to reproductive aperture; 14: dorsal fin, vertical height; 15: dorsal fin, length of base; 16: flipper, tip to axilla; 17: flipper, tip to anterior end of lower border; 18: flipper, length along curve of lower border; 19: flipper, greatest width; 20: not available; 21: skull, greatest width; 22: skull length, condyle to tip of premaxilla; 23: flipper, tip to head of humerus; 24: not available; 25: flukes, notch to tip; 26: tip of snout to centre of ear; 27: tip of snout to centre of umbilicus; 28: tip of snout to end of ventral grooves; 29: tip of snout to center of reproductive aperture; 30: tip of snout to anus; 31: notch of flukes to center of reproductive aperture; 32: tip of snout to posterior emargination of dorsal fin; 33: width of flukes; 34: girth of chest, half; 35: girth of abdominal, half; 36: girth of buttock, half; 37: body height of posterior of dorsal fin; 38: body height of navel; 39: border length posterior end to tip of flipper.

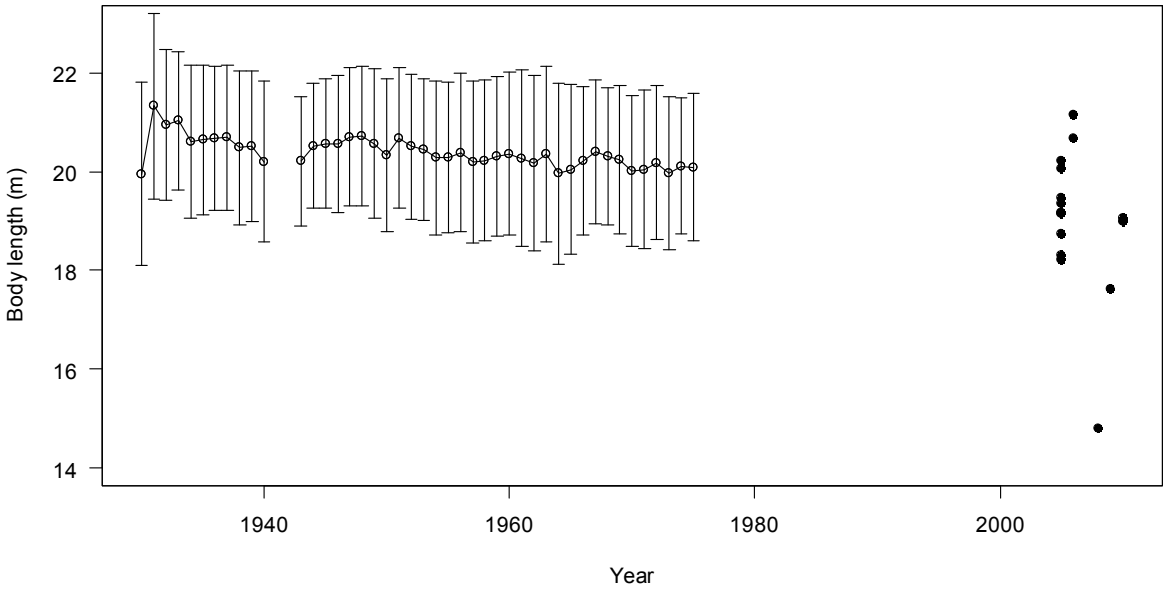

Figure 3. Yearly change in average body length of fin whale captured in Antarctic, pelagic commercial whaling (open circle: seasons 1930/1931-1975/1976) and the body lengths of fin whale sampled in JARPAII (closed circle: seasons 2005/2006-2010/2011). Vertical bars indicate plus/minus one standard error.

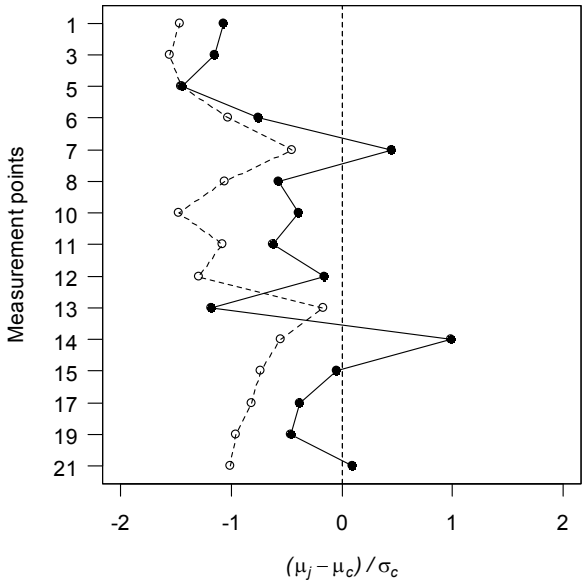

Figure 4. Body proportions of the JARPAII sample (closed circles and solid line: male; open circle and broken line: female). The data are plotted on the normalized axis using the data of Japanese commercial whaling (seasons 1948/1949-1950/1951). Measurement point key are shown in Figure 2. μ_j: mean value of JARPAII data; μ_c: mean value of the commercial whaling data; σ_c: standard deviation of the commercial whaling data.

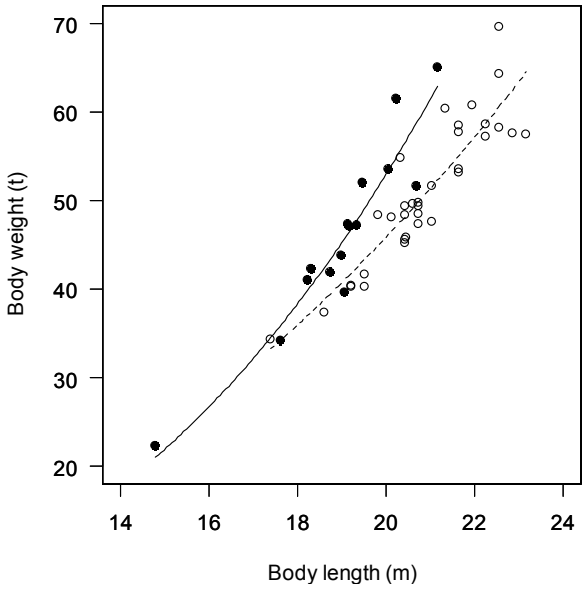

Figure 5. Relationships between fin whale body length and body weight. Closed circles and solid line: JARPAII; open circles and broken line: Japanese commercial whaling (Nishiwaki, 1950; Ohno and Fujino, 1952: seasons 1947/1948-1950/1951).

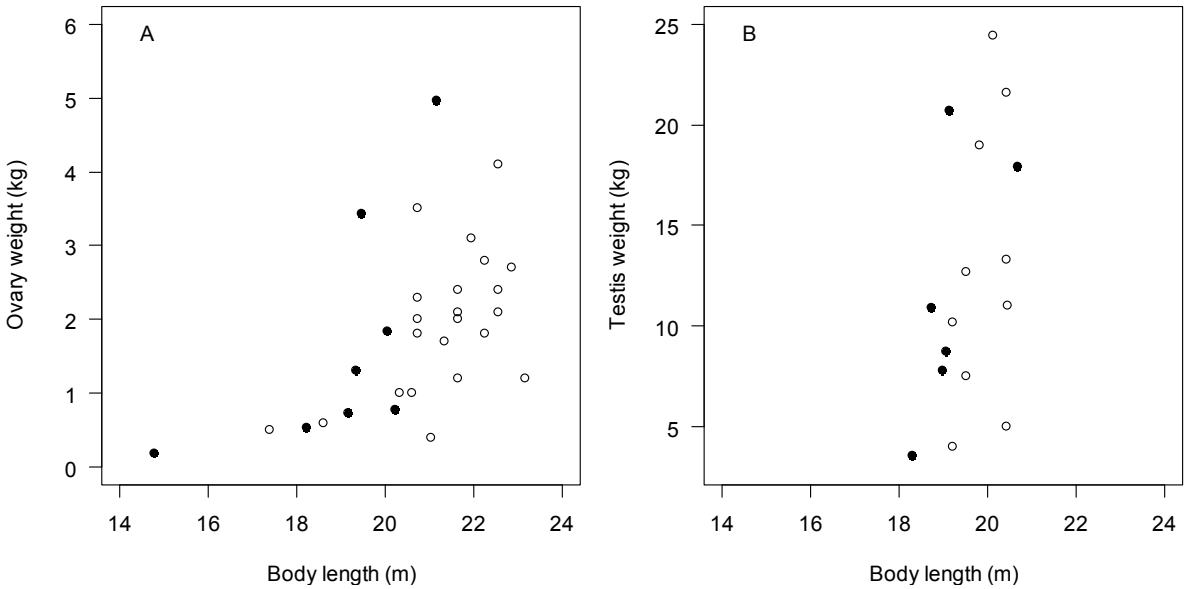

Figure 6. Relationship between body length and gonad weight. A: ovary weight; B: testes weight; closed circle: JARPAII; open circle: Japanese commercial whaling (Nishiwaki, 1950; Ohno and Fujino, 1952: seasons 1947/1948-1950/1951).

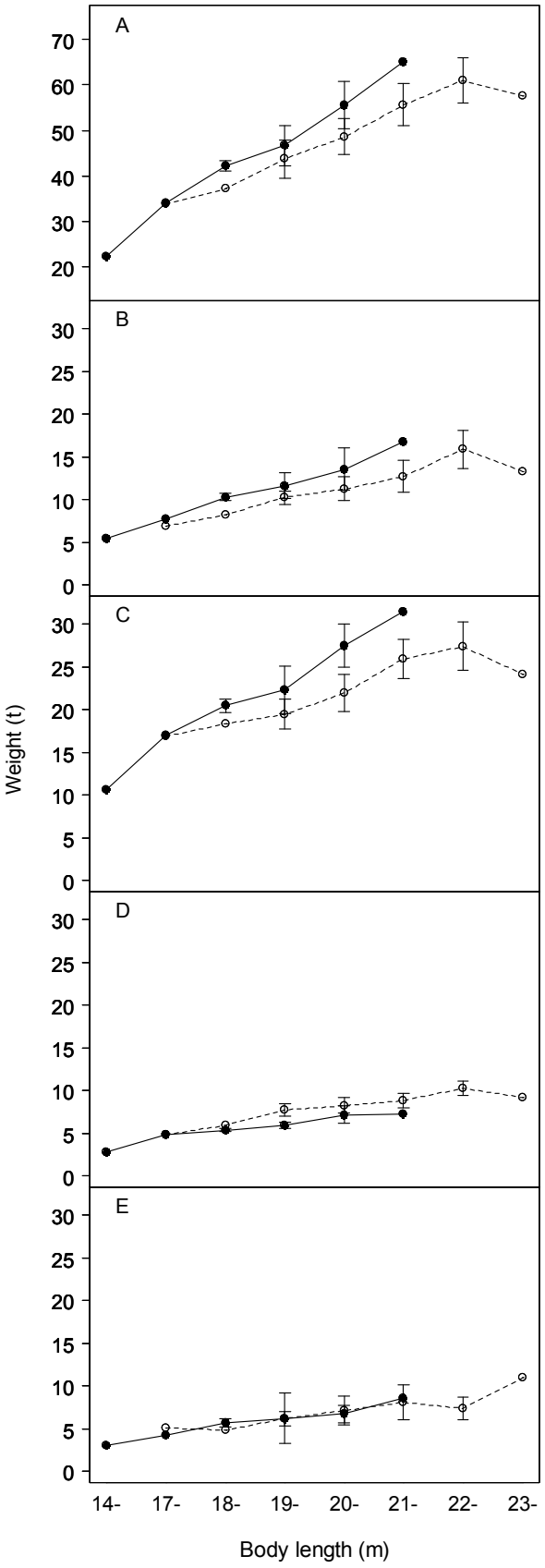

Figure 7. Comparison of body parts weight between JARPAII (closed circle and solid line) and commercial whaling (open circle and broken line: seasons 1947/1948-1950/1951). A: body weight; B: blubber; C: meat; D: bones; E: viscera and others.

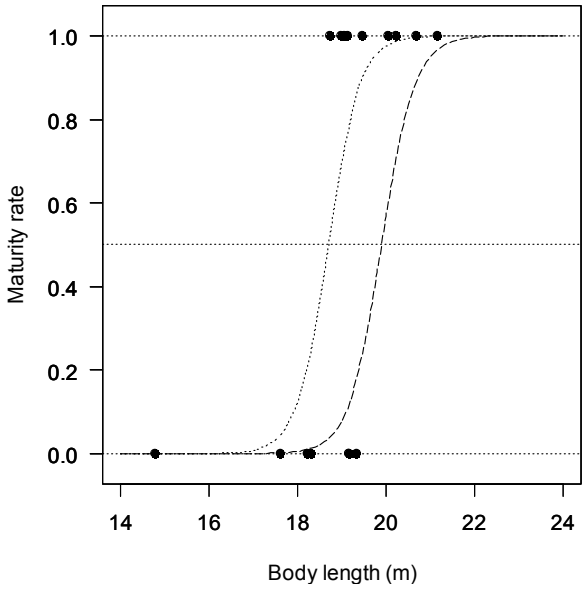

Figure 8. Relationship between body length and sexual maturity rate of the fin whales sampled by JARPAII (closed circle), and comparison of that with that commercial whaling (broken line: female; dot line: male; seasons 1949/1950-1951/1952).

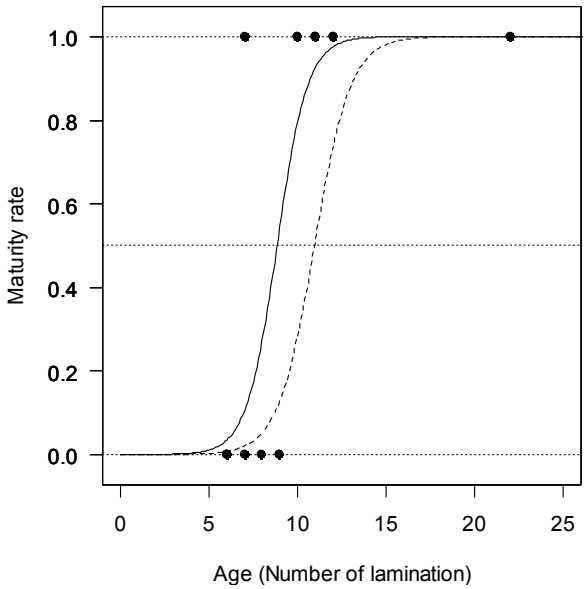

Figure 9. Relationship between age and sexual maturity rate of the fin whales sampled by JARPAII (closed circle and solid line), and comparison with that by commercial whaling (broken line: season 1956/1957).