Yearly trend in the proportion of pregnant animals among mature female Antarctic minke whales in the JARPA and JARPAII period

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ABSTRACT
The proportion of pregnant animals among mature females (PPF) in Antarctic minke whales was examined from samples collected during 1987/88-2004/05 JARPA and 2005/06-2010/11 JARPAII surveys. Analysis was conducted for two biological stocks which were separated at 165ºE. The PPF of both stocks appeared stable at around 0.9 and when data from all years were combined, the PPF was 0.932 for I-stock and 0.904 for P-stock. Linear regression analysis showed no significant yearly trend in either stock during the JARPAII period. From logistic regression analysis, no significant trend was detected during the JARPAII period but a significant increasing trend was detected for P-stock during the JARPA and all period. This latter result was influenced by just two lower PPF values in the 1990/91 and 1994/95 seasons. Although a high PPF was observed throughout the survey period, monitoring of PPF is important to detect possible change in nutritional condition and reproduction which affect sustainable management of these whale stocks.

KEYWORDS: ANTARCTIC MINKE WHALE, PREGNANCY RATE, TRENDS

INTRODUCTION

Pregnancy rate is necessary to estimate composition of young whales which recruit into the stock, which is an important parameter to evaluate reproductive condition of stock. Pregnancy rates of large baleen whales were known to change in response to changes in abundance, food availability or competition with other species (Gambell, 1973; Kato, 1986a; 1986b; Masaki, 1979; Lockyer, 1984). Therefore, monitoring of pregnancy rate is important for sustainable management of baleen whale stocks.

Pregnancy rate in the Antarctic minke whale had been studied mainly from commercial whaling data by several authors (Best, 1982; Kato, 1982; Masaki, 1979; Ohsumi *et al*., 1970; Ohsumi and Masaki, 1975). Ohsumi *et al*. (1970) reported the proportion of pregnant animals among mature females (PPF) from 1967/68 commercial whaling data as 0.789 (n=114), and this value becomes 0.895 if individuals that had corpus luteum but no fetus were considered as pregnant. Kato (1986a) examined apparent pregnancy rate from 1971/72 to 1982/83 commercial whaling data and reported no significant yearly trend during this period and a mean value of 0.895. The first phase of JARPA was conducted from 1987/88 to 2004/05 and data on pregnancy status were continuously collected during the survey period. Results were reported to the JARPA review meeting held at Tokyo in 2006, which showed no yearly trend for two newly identified stocks. The PPF was estimated as 0.929 and 0.854 for I-stock and P-stock, respectively (Bando *et al*., 2006).

JARPA II started in 2005/06 and new data from six years surveys were accumulated. In this study, yearly trend of PPF in Antarctic minke whale was examined for the hypothesized two stocks (I-stock and P-stock) for JARPA period, JARPA II period and both periods combined.

MATERIALS AND METHODS

Biological samples and data used

All of the mature female Antarctic minke whale samples collected during JARPA (1987/88 to 2004/05,

n=2,045) and JARPAII (2005/06 to 2010/11, n=1,198) surveys were used for the analysis (Table 1).

Proportion of pregnant animals among the mature females (PPF)
The proportion of pregnant animals among the mature females is defined as the proportion of pregnant females within the sample of sexually mature females. Sexual maturity for females was determined by the presence of corpora luteum or albicans in both ovaries.

Stock identification
Whales collected in Areas IIIE, IV and VW were treated as the 'Eastern Indian Ocean Stock' (I-stock) and those collected in Areas VE and VIW were treated as the 'Western South Pacific Stock' (P-stock), following Pastene (2006). It should be noted here that the stock structure hypothesis has been refined recently (e.g. Kitakado *et al.*, 2014) and that new grouping for estimating PPF would be necessary in future.

Statistical method
Two statistical methods were applied to examine yearly trend of PPF. Firstly, linear regression analysis was applied to catch year of JARPAII (2005/06 to 2010/11) and PPF following Government of Japan (2005). The null hypothesis was set that the slope = 0 (H_0) to examine whether the null hypothesis can be rejected at 5% level. Secondly, logistic regression analysis was conducted to examine yearly trend of PPF during JARPA, JARPAII and during all period, respectively.

RESULTS
The PPF of I-stock whales was stable at around 0.9 throughout survey period and no significant yearly trend was detected during JARPAII by linear regression analysis (Figure 1, Tables 1, 2). No significant yearly trend was detected by logistic regression analysis during JARPA, JARPAII and all period (Table 3). When data from all years was combined, the PPF was calculated as 0.932.

For P-stock whales, the PPF was stable at around 0.9 but a slightly lower value was observed in 1990/91 (PPF=0.770) and 1994/95 (PPF=0.740) (Figure 1, Table 1). No significant yearly trend was detected during JARPAII by either linear or logistic regression analysis but a significant increasing trend was detected during the JARPA and all period by logistic regression analysis (Table 2, 3). When data from all years was combined, the PPF was calculated as 0.904.

DISCUSSION
Full scale exploitation of Antarctic minke whale started at 1971/72 and the reported apparent pregnancy rate was stable at a high value throughout the commercial whaling period (Kato, 1982; 1986a; Masaki, 1979; Ohsumi *et al*., 1970; Ohsumi and Masaki, 1975; Zenitani, *et al*., 2001). A high PPF was also observed during the JARPA and JARPAII periods in this study. A significant increasing trend was detected in P-stock but this is attributed to lower PPF observed in just two year in the early period of JARPA (1990/91 and 1994/95). Therefore this 'significant' increasing trend result should be seen with caution.

The observed high PPF during the commercial whaling period and the JARPA and JARPAII periods means that Antarctic minke whale stocks have maintained a good reproductive condition from the 1970s. Age at sexual maturity of minke whale was reported to have decreased from 10-12 in the 1940s cohorts to 7-8 in the 1970s cohorts and stabilized until the 1990s cohorts (Kato, 1983; Zenitani and Kato, 2006; Bando *et al*., 2014). The decreasing trend from the 1940's seems to be associated with improved nutritional conditions from the mid of the past century.

On the other hand, the increasing trend of abundance in large baleen whale species such as blue, humpback and fin whales have been reported in recent years (Branch, 2011; Hakamada and Matsuoka,, 2014; Matsuoka *et al*., 2011; Matsuoka and Hakamada, 2014). Antarctic minke whales utilize krill as their food species and are thought to compete with other baleen whales. Therefore, an increase in the abundance of other whale species might have an adverse effect on the nutritional condition of Antarctic minke whales. Blubber thickness and stomach content weight of Antarctic minke whales have been

reported to be decreasing during the JARPA/JARPAII period (Konishi *et al*., 2008; Konishi and Walløe, 2014a; 2014b), which might indicate possible changes in the feeding environment of minke whales.

It is known that the PPF of Antarctic minke whale might be biased by segregation or date of sampling (Kato, 1986b; Ohsumi and Masaki, 1975). Whales that conceive earlier in the breeding season tend to migrate to Antarctic feeding areas earlier (Kato and Miyashita, 1991; Kato, 1995). Therefore, the observed PPF in this study might be biased upward from the true pregnancy rate, which was estimated as 0.78 from the commercial whaling data in the breeding area (Best, 1982). However, the PPF would reflect migration strategy, distribution pattern and feeding environment of Antarctic minke whales and could be an important parameter for monitoring of this stock.

Although continuation of the high PPF was observed during the JARPA II period, monitoring of the PPF is important to detect possible change in nutritional condition and reproduction which affect sustainable management of these whale stocks.

ACKNOWLEDGEMENTS

Our sincere thanks are due to all researchers and crews who participated in the JARPA and JARPA II surveys. We thank Hiroshi Hatanaka and Luis A. Pastene, of the Institute of Cetacean Research, for useful comment on this manuscript.

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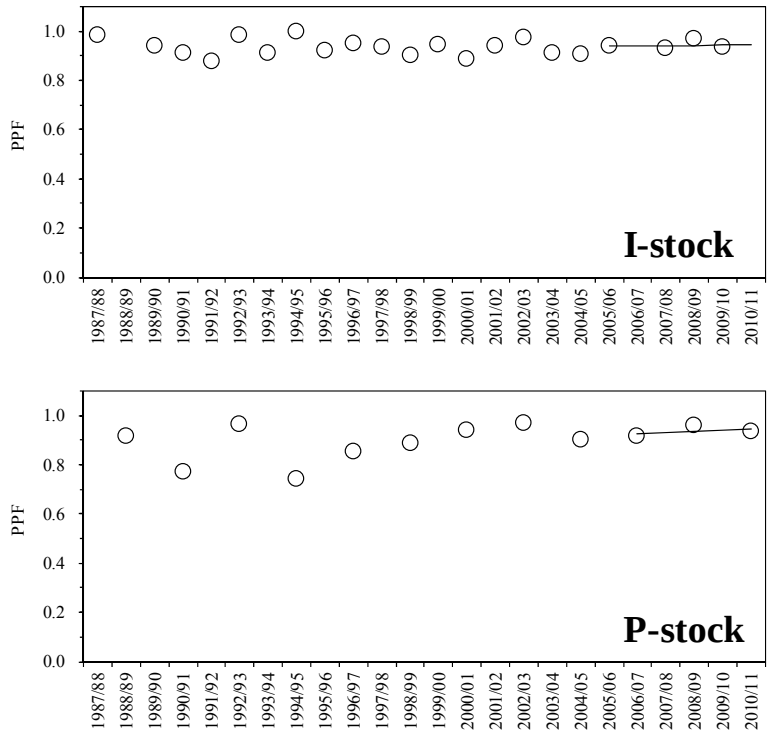

Figure 1. Yearly trend of PPF in I-stock and P-stock Antarctic minke whales collected during JARPA and JARPA II surveys. Linear regression line was applied for both stocks during JARPAII (2005/06 to 2010/11) periods.

Table 1. Number of pregnant, not pregnant matured females and PPF in I-stock and P-stock Antarctic minke whales.

Period	Season	I-stock				P-stock			
		Pregnant	Not pregnant	Number of matured female	PPF	Pregnant	Not pregnant	Number of matured female	PPF
JARPA	1987/88	57	1	58	0.983				
	1988/89					96	9	105	0.914
	1989/90	80	5	85	0.941				
	1990/91	51	5	56	0.911	57	17	74	0.770
	1991/92	72	10	82	0.878				
	1992/93	64	1	65	0.985	54	2	56	0.964
	1993/94	62	6	68	0.912				
	1994/95	14	0	14	1.000	54	19	73	0.740
	1995/96	96	8	104	0.923				
	1996/97	54	3	57	0.947	112	19	131	0.855
	1997/98	43	3	46	0.935				
	1998/99	56	6	62	0.903	16	2	18	0.889
	1999/00	106	6	112	0.946				
	2000/01	23	3	26	0.885	94	6	100	0.940
	2001/02	141	9	150	0.940				
	2002/03	35	1	36	0.972	92	3	95	0.968
	2003/04	154	15	169	0.911				
	2004/05	39	4	43	0.907	144	16	160	0.900
JARPA II	2005/06	226	15	241	0.938				
	2006/07					262	24	286	0.916
	2007/08	168	13	181	0.928				
	2008/09	30	1	31	0.968	162	7	169	0.959
	2009/10	184	13	197	0.934				
	2010/11					87	6	93	0.935
	Total	1755	128	1883	0.932	1230	130	1360	0.904

Table 2. Result of linear regression analysis for both stocks of Antarctic minke whales during JARPA II period.

I-stock

	value	SE	t	p-value
Intercept	0.916	0.162	5.647	0.030
Coefficient	0.00115	0.008	0.151	0.894

P-stock

	value	SE	t	p-value
Intercept	0.830	0.209	3.974	0.157
Coefficient	0.00485	0.009	0.512	0.699

Table 3. Result of logistic regression analysis for both stocks of Antarctic minke whales during JARPA, JARPA II and all period.

I-stock: JARPA

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	35.486	44.153	0.804	0.422
Year	-0.016	0.022	-0.745	0.456

P-stock: JARPA

	Estimate	Std. Error	z value	Pr(>|z|)	
Intercept	-89.238	39.380	-2.266	0.023	*
Year	0.046	0.020	2.317	0.021	*

I-stock: JARPA II

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	15.427	193.561	0.080	0.936
Year	-0.006	0.096	-0.066	0.947

P-stock: JARPA II

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-264.655	243.264	-1.088	0.277
Year	0.133	0.121	1.099	0.272

I-stock: JARPA+JARPA II

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	7.396	28.183	0.262	0.793
Year	-0.002	0.014	-0.170	0.865

P-stock: JARPA+JARPA II

	Estimate	Std. Error	z value	Pr(>|z|)	
Intercept	-98.810	25.960	-3.806	0.000	*
Year	0.051	0.013	3.891	0.000	*