Trend of blubber thickness in common minke, sei and Bryde's whales in the western North Pacific during JARPN and JARPN II periods

KENJI KONISHI[1)], TSUTOMU TAMURA[1)], MUTSUO GOTO[1)], TAKEHARU BANDO[1)], TOSHIYA KISHIRO[2)], HIDEYOSHI YOSHIDA[2)], AND HIDEHIRO KATO[3)]

1) The Institute of Cetacean Research, 4-5, Toyomi-cho, Chuo-ku, Tokyo, 104-0055, Japan.
2) National Research Institute of Far Seas Fisheries, 5-7-1, Shizuoka, 424-8633, Japan.
3) Tokyo University of Marine Science and Technology, Faculty of Marine Science, 4-5-7, Konan, Minato-ku, Tokyo, 108-8477, Japan

Contact e-mail: konishi@cetacean.jp

ABSTRACT

The trend of blubber thickness in common minke whale *Balaenoptera acutorostrata*, sei whale *B. borealis* and Bryde's whale *B. edeni* sampled in the western North Pacific from May to September in 2000-2007 JARPN II were analyzed. The purposes of this study were to examine the time trends of blubber thickness in common minke, sei and Bryde's, and the factors that influence the energy storage of these whales. Minimum AIC model based on the results of stepwise multiple regressions analysis of the minke whale data from 1994 to 2007 was; Blubber thickness = -27.48+0.10Year+0.01Date+0.06Latutude-0.01Longitude+1.07 (Sex: male=1, female=2). Minimum AIC model in the same regression analysis for sei whale was; Blubber thickness = -452.17+0.23Year+0.02Date +0.16Body length (m)+1.72(Sex: male=1, female=2). Minimum AIC model in the same regression analysis for Bryde's whale was; Blubber thickness = 135.85-0.07Year+0.01Date -0.10Latitude+0.02Longitude+0.24Body length (m)+1.21(Sex: male=1, female=2). Our study showed that the blubber thickness of minke whale has increased throughout the JARPN and JARPN II period. The results of the statistical analyses showed that blubber thickness in sei whales has increased during the 5-years of the JARPN II research period, while that in Bryde's whales have decreased during 7 years. Other explanatory variables, such as "date", "body length" and "sex" shows similar results to previous study of the Antarctic minke whale. The feeding areas of Bryde's and sei whales show very little overlap, and their distribution is separated by sea surface temperature (SST). The interpretation of the above results need further study to clarify the role and prey consumption by the baleen whales in the western North Pacific ecosystem.

INTRODUCTION

Baleen whale stocks energy by food intake into its blubber as lipid, and the blubber thicker increase through the feeding season (Lockyer 1987; Víkingsson 1995; Næss *et al*. 1998, Konishi 2006, Konishi *et al*. 2008). Long time trend of energy storage sometimes gives very useful information. A recent study demonstrated that indicators of energy storage, such as the blubber thickness and blubber weight, have deceased in Antarctic minke whale for nearly two decades (Konishi *et al*. 2008). Since environmental and biological factors influence the food availability of animals which is reflected in energy storage, this study could contribute to ecosystem study and also to management of whales. The purpose of this study is to examine the time trends of blubber thickness in common minke, sei and Bryde's, and what the factors influence the energy storage of these whales.

MATERIALS AND METHODS

Sampling and measurements

Blubber thickness used in the present study were measured in common minke, sei and Bryde's whales taken by the Japanese Whaling Research Program under Special Permit in the western North Pacific (JARPN) (1994-1999 for mike whale) and JARPN II (2000-2007 for the minke, sei and Bryde's whale). To cover the research of

minke whale in early and late period and coastal area, the JARPN II coastal component of two regions (Sanriku and Kushiro) has conducted since 2002. For the analyses in the mike whale, we used only O-stock mink whale from offshore and coastal components in JARPN II to this analyses, according to the mtDNA definition (Kanda *et al.*, 2009). To avoid any bias resulting from growth or lactation, we used only mature males and pregnant females, but not lactating females or immature animals, for the present analyses. Males of minke, Bryde's and sei whales were defined as sexually mature by testis weight (larger side) of more than 290g, 560g and 1,090g, respectively (Bando *et al*., unpublished data). Female were defined as sexually mature by the occurrence of at least one corpus luteum or albicans in their ovaries. Data used in this study was listed in Table 1.

Blubber thickness was measured to the nearest mm, by dissecting perpendicularly from skin to muscle without including connective tissue and black surface skin. The measurement position of blubber thickness was lateral side at the section of dorsal fin where most commonly measured site from commercial whaling period. Sex and maturity were recorded for each whale on the basis of routine observations of reproductive organs during dissection and tissue observations in the laboratory.

Statistical analysis

Almost baleen whales accumulate fat during the summer feeding period and migrate to low latitude areas for reproduction. The time spent in the feeding area and geographical and biological variables which could be related to blubber thickness should be considered in body condition analysis. To take these factors into account and possibly exclude some of them, we conducted stepwise multiple linear regression analyses using Akaike's information criterion (AIC) for model selection. In these analyses, first step included all explanatory variables, and stepwise procedure continued when a model without an explanatory variable had smaller AIC. Blubber thickness (in cm) was the dependent variable. We allowed the following independent variables: "year", "date" (May 1st. = day 1), catching position (Latitude and longitude), sex (male=1, female=2), "body length" (in m).

RESULTS

Common minke whale

Blubber thickness ranged from 1.5 to 6.6 cm in mature males, and from 2.2 to 7.7 cm in pregnant females over the whole research period. First, we conducted stepwise multiple regressions analysis in the minke whale from 1994 to 2007. Minimum AIC model was;

Blubber thickness = -27.48+0.10Year+0.01Date +0.06Latutude-0.01Longitude +1.07 (Sex: male=1, female=2)

Minimum AIC model did not included Body length. The results indicated that blubber thickness increased with year, time spent feeding and from south to North.

As second run in the minke whale, we also conducted the same analysis with the dataset from 2000 to 2007 to test if the yearly trend of blubber thickness was constant.

Minimum AIC model in the regression analysis in the minke whale was;

Blubber thickness = -206.46+0.10Year+0.01Date +0.11Latitude-0.02Longitude +1.39 (Sex: male=1, female=2)

Minimum AIC model did not included Body length. The results also indicated that blubber thickness increased with year, time spent feeding and from south to North.

Sei whale

Blubber thickness ranged from 2.7 to 7.8 cm in mature males, and from 3.7 to 9.3 cm in pregnant females over the whole research period. Minimum AIC model in the regression analysis in sei whale was;

Blubber thickness = -452.17+0.23Year+0.02Date +0.16Body length (m) +1.72(Sex: male=1, female=2)

Minimum AIC model did not included Latitude and Longitude. The results indicated that blubber thickness increased with year, and time spent feeding and body length.

Bryde's whale

Blubber thickness ranged from 2.6 to 6.9 cm in mature males, and from 3.6 to 9.3 cm in pregnant females over the whole research period. Minimum AIC model in the regression analysis in Bryde's whale was;

Blubber thickness = 135.85-0.07Year+0.01Date -0.10Latitude+0.02Longitude+0.24Body length (m) +1.21(Sex: male=1, female=2)

Minimum AIC model included all independent variables. The results indicated that blubber thickness decreased with year and from North to South and body length.

DISCUSSION

Annual trend in body condition

Our study showed the blubber thickness of minke whale has increased throughout JARPN and JARPN II period. The results of the statistical analyses showed that blubber thickness in sei whales have increased during the 5-years in JARPN II research period, while that in Bryde's whales have decreased during 7 years. The common minke whales and sei whales almost distributed in the same area, however Bryde's whale distributed in the warm area (Konishi *et al.* 2009). These results seem to reflect their prey availability in the feeding grounds.

Elucidation of the role of cetaceans in the western North Pacific ecosystem

Other explanatory variables, such as "date", "body length" and "sex" shows similar results to previous study in the Antarctic minke whale (Konishi *et al.* 2008). Sei whales and Bryde's whales almost do not overlap their feeding area, and their distribution is separated by Sea surface temperature (SST) (Konishi *et al.* 2009). The interpretation of above results need further study to clarify the role and consumption of the baleen whales in the western North Pacific ecosystem.

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Table 1 Data used in this study

		Variables	Mean	SD	min	max
Minke whale	Mature Male	Date (May 1st=1)	75.99	41.78	-15	181
	N=842	Latitude (deg)	42.18	2.44	37.13	48.90
		Longitude (deg)	152.05	8.17	141.10	169.76
		Body length (m)	7.46	0.30	6.58	8.62
		Blubber thickness (cm)	3.14	0.81	1.5	6.6
	Pregnant female	Date May 1st=1	53.35	48.71	-20	159
	N=86	Latitude (deg)	41.41	3.14	36.95	47.23
		Longitude (deg)	149.01	9.44	141.10	168.88
		Body length (m)	7.89	0.43	6.85	8.8
		Blubber thickness (cm)	4.04	1.00	2.2	7.7
Bryde's whale	Mature Male	Date (May 1st=1)	80.79	28.58	38	135
	N=85	Latitude (deg)	37.40	1.46	35.02	40.27
		Longitude (deg)	152.93	6.03	144.85	167.67
		Body length (m)	12.46	0.47	11.27	13.3
		Blubber thickness (cm)	4.55	0.87	2.6	6.9
	Pregnant female	Date (May 1st=1)	76.08	28.66	29	135
	N=93	Latitude (deg)	37.29	1.48	35.00	40.23
		Longitude (deg)	154.70	6.40	141.87	168.75
		Body length (m)	12.94	0.61	11.16	14.14
		Blubber thickness (cm)	5.87	1.26	3.6	9.3
Sei whale	Mature Male	Date (May 1st=1)	68.61	29.09	21	131
	N=157	Latitude (deg)	40.83	2.54	35.30	47.08
		Longitude (deg)	160.20	5.56	144.65	169.67
		Body length (m)	13.77	0.51	12.28	15
		Blubber thickness (cm)	4.83	0.89	2.7	7.8
	Pregnant female	Date (May 1st=1)	63.53	28.97	19	129
	N=142	Latitude (deg)	40.47	2.51	35.08	45.87
		Longitude (deg)	159.98	5.36	149.67	169.83
		Body length (m)	14.58	0.63	13.01	16.32
		Blubber thickness (cm)	6.55	1.18	3.7	9.3