Relationship between body size, maturity, and feeding habit of common minke whales off Sanriku in spring season, from 2003-2007 whale sampling surveys under the JARPN II coastal component off Sanriku

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ABSTRACT

Relationship between body size, maturity and feeding habit of common minke whales in coastal waters off Sanriku, northeast Japan, in spring season, was studied from animals collected during the whale sampling surveys under the JARPN II coastal component off Sanriku conducted in 2003 to 2007. From these surveys, a total of 227 common minke whales (91 males and 136 females) were collected. The ratio of sexually mature animals was calculated as 0.42 for males, 0.24 for females, and 0.31 for all the animals. Three species, krill (*Euphausia pacifica*), Japanese sand lance (*Ammodytes personatus*), and Japanese anchovy (*Engraulis japonicus*), were found in the whale stomachs, of which sand lance was the most dominant prey species, followed by anchovy. All the whales but two were sighted in waters with depth of 20-100m: no obvious difference was observed in their sighting positions between males and females, immature and mature animals, and the three prey species. Body length frequency of whales was not different among animals feeding on each of the three prey species ($P > 0.05$). Furthermore, frequency of sexual maturity stages of animals did not differ among whales feeding on each of the preys ($P > 0.05$). From these, we considered that, in coastal waters off Sanriku in spring season, both immature and mature common minke whales appear to feed on the three species evenly, which resulted in no obvious difference in feeding habits between immature and mature common minke whales.

KEYWORDS: COMMON MINKE WHALE; NORTH PACIFIC; COASTAL WATERS OFF SANRIKU, JAPAN; SCIENTIFIC PERMITS; PREY PREFERENCE; MATURITY; FEEDING HABIT

INTRODUCTION

The common minke whale, *Balaenoptela acutorostrata*, is widely distributed in the world, from offshore to coastal waters and feed on various prey species including commercially important species such as Japanese anchovy *Engraulis japonicus,* Pacific saury *Cololabis saira,* and walleye pollock *Theragra chalcogramma* (Tamura and Fujise, 2002). In coastal waters off the Sanriku (northeast part of the Pacific coast of the Japanese main island, Honshu), many common minke whales were taken, especially in spring, by the past land-based coastal whaling (Miyashita and Hatanaka, 1997). The coastal waters are also very important fishing grounds. Thus, the waters are thought to be suitable for the study area to evaluate competition between whales and coastal fisheries.

From these, the whale sampling survey in coastal waters off Sanriku was started in 2003 (Yoshida *et al*. 2004) and then conducted every year from 2005 to 2007 (Yoshida *et al*. 2006, Goto *et al*. 2007, Band *et al*. 2008), as the coastal component of the full JARPN II research plan (Government of Japan 2002, 2004). Background and details of the surveys are described in Kishiro *et al*. (2009a). The objectives of the JARPN II are: i) feeding ecology and ecosystem studies, involving prey consumption by cetaceans, prey preferences of cetaceans and ecosystem modeling, ii) monitoring environmental pollutants in cetaceans and marine ecosystem, and iii) stock structure of whales. Among them, prey preference of cetaceans is one of the important factors in considering the feeding ecology and the ecosystem modeling.

From the result of the 2007 whale sampling survey conducted in coastal waters off Kushiro, difference in feeding habit between immature and mature common minke whales was suggested (Kishiro *et al*. 2008). The difference has been also reported in other cetacean species, e.g., spotted dolphins (Bernard *et al*. 1989) and Dall's porpoises (Ohizumi *et al*. 2003). Information on the difference is very important to reveal feeding ecology and more reliable prey consumption of common minke whales. In the present study, thus, we examine relationship between body size, maturity, and feeding habit of common minke whales in coastal waters off Sanriku in spring season, from data and samples collected during the whale sampling surveys under the JARPN II coastal component off Sanriku conducted in 2003 to 2007.

MATERIAL AND METHODS

The present study was conducted from data and samples obtained from the whale sampling surveys in the 2003-2007 coastal components off Sanriku, under the JARPN II. The surveys were carried out in spring season (April and May) in coastal waters within 50 nautical miles from Ayukawa port (Fig.1). Methodology and details of the surveys are detailed in Kishiro *et al*. (2009a).

Body length measurement and determination of sexual mature stage of whales

All the animals collected were landed at the JARPN II research station established at the Ayukawa port in Sanriku, and then biological examination such as measurement of body proportion was conducted. Whale Body length was measured to the nearest 1cm on a straight and parallel to the body axis from the tip of upper jaw to the notch of fluke, by researches. In males, each side of testis was weighed after separated from the epididymis and histological samples were collected from center of the right testis. An animal with a single testis weight of 290g or more was tentatively determined as sexually mature, from the histological observation of the seminiferous tubules, spermatocyte, spermatid or spermatozoa using hematoxylin and eosin stained sections. In females, both sides of ovaries were collected and corpus luteum and albicans in ovaries were counted. An animal possessed at least one corpus luteum or albicans in ovaries was determined as sexually mature.

Prey species identification and restoring stomach contents weight

At the research land station, stomach contents were removed from whales and then weighted to the nearest 0.1 Kg by each four chamber in both cases of including and excluding liquid. When the intact or partially digested body of prey species was found, species identification was carried out from their morphological characters. When undigested fishes occurred, their standard lengths were measured to the nearest 1 mm. Then, a sub-sample (1-5Kg) of stomach contents was collected and frozen and/or fixed with 10% formalin for the laboratory work. At the laboratory, detailed species identification and restoring stomach contents weight were made by Tamura *et al*. (2009a), as follows. Prey species was identified to the lowest taxonomic level as possible using morphological characters for undigested preys or the otoliths and jaw plate for digested preys. The total wet weight of each prey species in the forestomach was estimated by multiplying average weight of fresh prey specimens, by the number of preys (including undigested full bodies, undigested skulls, and half the total number of free otoliths) in the sub-sample and multiplying ratio of the weight of sub-sample for the total weight of forestomach contents. Details of the methods are described in Tamura *et al*. (2009a). Occurrence of prey species was calculated as ratio of the number of whales counted by each of prey species found in their forestomach to total number of whales. When plural prey species were found simultaneously from a whale stomach, each of the species was counted (See, Table 3). Mean composition of restored wet weight by each of prey species was calculated as the average of ratio of restored weights by each of prey species found from respective whales.

Identification of stocks to each animal

Skin tissues of whales were collected and preserved in ethanol for the laboratory DNA analysis. In the present study, results of stock identification to each animal (J or O stocks) made by Kanda *et al*. (2009) from microsatellite analysis were used for comparison between feeding habit of J and O stock animals. Details of the genetic identification are described in Kanda *et al*. (2009).

RESULTS

Sex ratio, body length and maturity of common minke whales

During the 2003-2007 JARPN II coastal component off Sanriku, a total of 227 common minke whales were collected (Fig. 2). They consisted of 91 males and 136 females (sex ratio of males was 0.40). Statistics and frequency of body length are shown in Table 1 and Fig. 3. Average body length in each year ranged from 6.15m to 6.29m for males and 5.67m to 6.30m for females. Females with body length of 5 to 6m were most frequently recorded every year and obvious yearly change was not observed in frequency distribution of animal body length. Compositions of sex and sexual maturity stage of the whales is shown in Table 2. Sex ratio of males in each year was from 0.37 to 0.43. In the 91 males, 37 were identified as sexually mature and maturity stage could not be determined for two males. Ratios of sexually mature males in each year ranged from 0.35 to 0.46 and 0.42 for all the year. In the 136 females, 33 were classified as sexually mature, of which 31 were pregnant. Ratios of sexually mature females in each year were from 0.09 to 0.38 and 0.24 for all the year. Their sighting positions are shown in Figure 2, by sex and sexually mature stages. All the whales but two immature females were sighted at waters with depth of 20-100m. No obvious difference was observed in their sighting positions between sexes and sexually maturity stages.

Prey species found from whale stomach

In the present study, three species, krill (*Euphausia pacifica*), Japanese sand lance (*Ammodytes personatus*), and Japanese anchovy (*Engraulis japonicus*), were found from whale stomachs (Table 3). Their restored wet weights are shown in Table 4. No other prey species were detected. In the three species, sand lance was most dominant each year in the occurrence (Table 3) and in the weight except for the 2007 survey, in which the weight of anchovy was most heavy (Table 4). The second dominant species was Anchovy.

Relationship between body lengths of whales and their prey species

Relationship between whale body length and occurrence of prey species in their stomach is shown in

Figure 4. In both sexes, occurrence frequency of sand lance was highest in all the body length classes, except for a class of males with body length of 8.0 to 8.9m, in which a male took anchovies. The second frequently observed species was anchovy. Although krill was not detected in stomachs of animals with body length of 8.0 to 8.9m, this species was fed by other class females. Occurrence frequency of prey species in each body length class did not change so obviously with body length growth. Relationship of body length of whales to mean standard lengths of prey fishes obtained from their stomach is shown in Figure 5. Between them, positive relationship was not observed: larger animals did not tend to take larger preys.

Relationship between whale maturity and their prey species

Occurrence frequency of prey species by sex and sexually mature stage is shown in Table 5. The most dominant prey species was sand lance in each sex and maturity stage, followed by anchovy. Japanese anchovy and krill were also fed by both males and females and both immature and mature animals, though krill were not observed from mature male stomachs. Table 6 shows comparison of mean compositions of prey species between immature and mature whales based on restored wet weight. Result was almost same with that shown in Table 5: ratio of weights of sand lance was highest in each sex and maturity stage, followed by anchovy. Maturity ratio of whales by prey species is shown in Table 7. In males, the highest maturity ratio was observed in animals feeding on sand lance (0.45). Krill was not taken by mature animals. In females, the highest ratio was recorded in animals taking krill (0.29), followed by whales feeding on sand lance (0.27), though the ratios were almost same. The ratio calculated by pooling sexes was almost same among animals taking each of the prey species (0.20-0.34, Table 7). Difference in frequency of sexual maturity stages was tested among animals feding on each of the prey species, by the randomized chi-square test (Roff and Bentzen 1989). The significance test from the 10,000 randomizations using the Program RandChi (Okamura 2001) indicated no difference among them ($P > 0.05$). Body length frequency of whales taking each of the prey species is shown in Figure 6. Although the frequency changed by year (Fig. 6a-d), pooled data of all the years indicated similar frequency distribution between the three prey species (Fig. 6e). Furthermore, the frequency distribution of animals taking each of the prey species (Fig. 6e) was similar to it of all the animals collected during the surveys (Fig. 6f). From the the randomized chi-square test, body length frequency of whales did not differ among animals feeding on each of the prey species ($P > 0.05$).

Comparison between J and O stocks

Common minke whales distributed in coastal waters of Japan including the present study area are

thought to belong to at least two stocks: one is J stock mainly distributed in the Sea of Japan and another is O stock mainly inhabiting the western North Pacific (Hatanaka and Miyashita, 1997). Animals from each of the two stocks can be identified from genetic analysis (see, Kanda *et al*. 2009). Their analysis indicates that animals from both stocks were collected in the 2003-2007 JARPN II coastal component off Sanriku. Hence, the animals were assigned into each stock from genetic identification results made by Kanda *et al*. (2009) and comparison of feeding habit between the two stocks was carried out. All the 41 animals were assigned to the J stock and 164 were to the O stock. Table 8 shows compositions of sex and sexual maturity of whales by stock. Ratio of males was higher in J stock animals but maturity ratio in J stock animals (0.18-0.25) was lower than that of O stock (0.26-0.48). Occurrence frequency and ratio of restored weight of prey species are compared between stocks and maturity status (Table 9 and 10). Maturity ratio of whales by stock and prey species is also shown in Table 11. Between the two stocks, occurrence frequency and ratio of prey species were not obviously different: occurrence frequency and ratio of sand lance was highest in each maturity stage of both sexes and stocks (Table 9 and 10). Furthermore, maturity ratio of whales by prey species is almost same between the two stocks (Table 11). These results suggest that there was no distinct difference in feeding habit between the two stock animals, as discussed to animals off Kushiro (Kishiro *et al*. 2009b).

Geographic comparisons in the research area

Sighting positions of whales collected are shown in Figure 7, by their prey species and maturity stage. All the whales but two taking krill were sighted at waters with depth of 20-100m and no obvious difference was observed in sighting positions between the prey species:

DISCUSSION

In the present study, relationship between body size, sexual maturity, and feeding habit of common minke whales migrating into coastal waters off Sanriku in spring season was studied from animals collected during the 2003-2007 JARPN II coastal component. Three species, krill, Japanese sand lance, and Japanese anchovy, were found from whale stomachs. In these, the sand lance was most dominant prey and the second one was anchovy. Although body length frequency of whales feeding on each of the prey species changed in each year (Fig. 6a-d), probably from yearly change of prey species occurrence as shown in Murase *et al*. (2009), pooled data of all the years indicated similar frequency distribution between the three prey species (Fig. 6e). Indeed, the randomized chi-square test showed that body length frequency was not different among animals feeding on each of the three prey species ($P > 0.05$). Furthermore, frequency of sexual maturity stages did not differ among whales feeding on each

of the preys ($P > 0.05$). From these, we considered that, in coastal waters off Sanriku in spring season, common minke whales appear not to change prey species with changes in their maturity stage.

The analysis on feeding habit of common minke whales was also conducted from animals collected in coastal waters off Kushiro in autumn season (Kishiro *et al*. 2009b). In their study, five species, walleye Pollock, krill, Japanese anchovy, Pacific saury, and Japanese flying squid, were observed in the whale stomachs as major prey species. They found that smaller and immature whales tended to feed on walleye pollock and krill, while larger and mature whales tended to take Pacific saury. Flying squid was observed only in mature animal stomachs and Japanese anchovy was taken by both immature and mature whales evenly. For the species, caloric value was calculated (Tamura *et al*., 2009b): the value contained in the walleye pollock and krill was calculated as 1480 and 850Kcal/Kg, respectively, which was lower than that of the Pacific saury (3,140Kcal/Kg). From these, they though that, possibly, off Kushrio, common minke whales change their feeding habit with changes in their maturity stage: immature animals mainly take lower caloric but not so migratory species, i.e., walleye pollock and krill, while mature whales seek higher caloric but highly migratory species, Pacific saury. Since Japanese anchovy is widely distributed throughout the research area in shoals, they considered that both immature and mature whales can take it easily.

Whales migrating into coastal waters off Sanriku in spring season are thought to be on the route to the northward feeding ground after winter breeding season. Their main destination is thought to be the Okhotsk Sea (Hatanaka and Miyashita 1997). Our study indicates that, on the route, they stay in coastal waters off Sanriku and feed on krill, sand lance, and Japanese Anchovy. The main research area in the present study is located on the continental shelf off Sanriku, in which topography of sea bottom is monotonous. Most of whales were sighted at waters with depth of 20-100m (Fig. 2). Fauna of prey species for common minke whales is thought not to be so diverse there, in comparison with coastal waters off Kushiro, where the sea bottom topography is very various, whales were collected not only on the continental shelf but also at steep canyon with depth of 1000m or more, and five prey species were found from whale stomachs (Kishiro *et al*. 2009b). Indeed, in coastal waters off Sanriku, the prey species surveys concurrently conducted with the whale sampling surveys indicate that walleye pollack, common squid, and Pacific saury do not occur there in spring, but on the other hand, sand lance, Japanese anchovy, and krill are widely distributed throughout the research area in large shoals (Kawahara *et al*. 2004, Yonezaki *et al*. 2006, 2007, 2008). In the research area, probably, sand lance, Japanese anchovy, and krill are easy preys for both immature and mature common minke whales, as

discussed about Japanese anchovy off Kushiro (Kishiro *et al*. 2009b). From these, we considered that, in coastal waters off Sanriku in spring season, both immature and mature common minke whales feed on the 3 species evenly, which resulted in no obvious difference in feeding habits between immature and mature common minke whales.

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Table 1. Body length (m) of common minke whales, collected during the 2003-2007 JARPN II coastal component off Sanriku.

Year	Male					Female				
	Mean	S.D.	Min.	Max.	n	Mean	S.D.	Min.	Max.	n
2003	6.28	0.89	4.7	7.83	21	6.30	1.13	4.28	8.02	29
2005	6.29	0.82	4.49	7.41	23	6.55	1.15	4.66	8.4	37
2006	6.15	1.12	4.29	7.62	26	5.83	1.04	4.08	8.07	34
2007	6.25	1.34	4.24	8.06	21	5.67	1.17	4.05	8.8	36
Total	6.24	1.04	4.24	8.06	91	6.08	1.17	4.05	8.8	136

Table 2. Composition of sex and sexual maturity stage of common minke whales, collected during the 2003-2007 JARPN II coastal component off Sanriku.

Year	Male			Female				Total	Sex ratio*	Maturity ratio		
	Imm	M	Uk	Imm	Preg	Ovu	Rest			Male	Female	Total
2003	12	8	1	20	9	0	0	50	0.42	0.40	0.31	0.35
2005	15	8	0	23	13	0	1	60	0.38	0.35	0.38	0.37
2006	14	12	0	31	3	0	0	60	0.43	0.46	0.09	0.25
2007	11	9	1	29	6	1	0	57	0.37	0.45	0.19	0.29
Total	52	37	2	103	31	1	1	227	0.40	0.42	0.24	0.31

*: Ratio of males.

Table 3. Occurrence of prey species found in stomach of common minke whales, collected during the 2003-2007 JARPNII coastal component off Sanriku.

Year	Krill	Sand Lance	Anchovy	Unknown	Total*
2003	20 (34.5)**	37 (63.8)	1 (1.7)	0 (0.0)	58
2005	3 (4.5)	57 (86.4)	6 (9.1)	0 (0.0)	66
2006	1 (1.4)	49 (67.1)	20 (27.4)	3 (4.1)	73
2007	1 (1.2)	38 (48.1)	33 (41.8)	7 (8.9)	79
Total	25 (9.1)	181 (65.6)	60 (21.7)	10 (3.6)	276

*: Since some animals fed on two prey species simulteniously, total number was not always equal to number of animals collected.

**: In parenthesis, % occurrence.

Table 4. Restored wet weights (kg) of prey species of common minke whales, in the 2003-2007 JARPN II coastal component off Sanriku.

Year	n*	Krill	Sand Lance	Anchovy	Total
2003	38	586.7 (37.9)**	962.7 (62.1)	0.0 (0.0)	1549.4
2005	50	104.8 (5.7)	1556.2 (84.2)	186.7 (10.1)	1847.7
2006	43	0 (0.0)	925.4 (82.3)	198.5 (17.7)	1123.9
2007	39	13.0 (1.6)	386.5 (47.1)	421.8 (51.4)	821.3
Total	170	704.5(13.2)	3830.8(71.7)	807.0(15.1)	5342.3

*: Animals with stomachs broken by harpoon were excluded.

**: In parenthesis, % of total weight.

Table 5. Occurrence of prey species of common minke whales by sex and sexual maturity stage, in the 2003-2007 JARPN II coastal component off Sanriku.

Sex	Maturity stage	Krill	Sand lance	Japanese anchovy	Unknown	Total
Male	Immature	8 (11.9)*	42 (62.7)	15 (22.4)	2 (3.0)	67
	Mature	0 (0.0)	34 (79.1)	8 (18.6)	1 (2.3)	43
	Total**	8 (7.1)	77 (68.8)	24 (21.4)	3 (2.7)	112
Female	Immature	12 (9.6)	76 (60.8)	32 (25.6)	5 (4.0)	125
	Mature	5 (12.8)	28 (71.8)	4 (10.3)	2 (5.1)	39
	Total	17 (10.4)	104 (63.4)	36 (22.0)	7 (4.3)	164
Total	Immature	20 (10.4)	118 (61.5)	47 (24.5)	7 (3.6)	192
	Mature	5 (6.1)	62 (75.6)	12 (14.6)	3 (3.7)	82
	Total**	25 (9.1)	181 (65.6)	60 (21.7)	10 (3.6)	276

*: In parenthesis, % occurrence.

**: Animals with unknown maturity stage are also included.

Table 6. Mean compositions (%) of restored wet weights of prey species of common minke whales by sex and sexual maturity stage, in the 2003-2007 JARPNII coastal component off Sanriku.

Sex	Maturity stage	n*	Krill	Sand lance	Japanese anchovy
Male	Immature	36	20.8	54.9	24.3
	Mature	32	0.0	87.7	12.3
	Total*	70	9.5	72.7	17.8
Female	Immature	76	14.0	71.3	14.7
	Mature	24	19.8	70.3	9.9
	Total	100	16.0	71.0	13.1
Total	Immature	112	16.4	65.7	18.0
	Mature	56	9.1	79.7	11.2
	Total*	170	13.2	71.7	15.1

*: Animals with unknown maturity stage are also included.

Table 7. Maturity ratio of common minke whales by sex and their prey species, in the 2003-2007 JARPN II coastal component off Sanriku.

Sex	Year	Prey species	Immature	Mature	Total	Maturity
Male	Total	Krill	8	0	8	0.00
		Sand lance	42	34	76	0.45
		Japanese anchovy	15	8	23	0.35
		Total	65	42	107	0.39
Female		Krill	12	5	17	0.29
		Sand lance	76	28	104	0.27
		Japanese anchovy	32	4	36	0.11
		Total	120	37	157	0.24
Total		Krill	20	5	25	0.20
		Sand lance	118	62	180	0.34
		Japanese anchovy	47	12	59	0.20
		Total	185	79	264	0.30

Table 8. Composition of sex and sexual maturity by stocks of common minke whales, collected during the 2003-2007 JARPNII coastal component off Sanriku.

Stock	Year	Male			Female				Total	Sex ratio*	Maturity ratio		
		Imm	M	Uk	Imm	Preg	Ovu	Rest			Male	Female	Total
J stock	2003	4	0	0	1	1	0	0	6	0.67	0.00	0.50	0.17
	2005	7	3	0	3	1	0	0	14	0.71	0.30	0.25	0.29
	2006	5	3	0	4	1	0	0	13	0.62	0.38	0.20	0.31
	2007	2	0	0	6	0	0	0	8	0.25	0.00	0.00	0.00
	Total	18	6	0	14	3	0	0	41	0.59	0.25	0.18	0.22
O stock	2003	7	7	1	16	7	0	0	38	0.40	0.50	0.30	0.38
	2005	8	3	0	18	12	0	0	41	0.27	0.27	0.40	0.37
	2006	6	8	0	23	2	0	0	39	0.36	0.57	0.08	0.26
	2007	8	9	1	21	6	1	0	46	0.39	0.53	0.25	0.36
	Total	29	27	2	78	27	1	0	164	0.35	0.48	0.26	0.34

*: Ratio of males.

Table 9. Occurrence of prey species of common minke whales by stocks, sex, and sexual maturity stage, collected in the 2003-2007 JARPN II coastal component off Sanriku.

Stock	Sex	Maturity stage	Krill	Sand lance	Japanese anchovy	Unknown	Total
J stock	Male	Immature	0 (0.0)*	16 (76.2)	4 (19.0)	1 (4.8)	21
		Mature	0 (0.0)	6 (100.0)	0 (0.0)	0 (0.0)	6
		Total	0 (0.0)	22 (81.5)	4 (14.8)	1 (3.7)	27
	Female	Immature	0 (0.0)	11 (61.1)	7 (38.9)	0 (0.0)	18
		Mature	1 (25.0)	2 (50.0)	1 (25.0)	0 (0.0)	4
		Total	1 (4.5)	13 (59.1)	8 (36.4)	0 (0.0)	22
	Total	Immature	0 (0.0)	27 (69.2)	11 (28.2)	1 (2.6)	39
		Mature	1 (10.0)	8 (80.0)	1 (10.0)	0 (0.0)	10
		Total	1 (2.0)	35 (71.4)	12 (24.5)	1 (2.0)	49
O stock	Male	Immature	7 (17.9)	24 (61.5)	7 (17.9)	1 (2.6)	39
		Mature	0 (0.0)	24 (72.7)	8 (24.2)	1 (3.0)	33
		Total**	7 (9.5)	49 (66.2)	16 (21.6)	2 (2.7)	74
	Female	Immature	11 (11.6)	56 (58.9)	24 (25.3)	4 (4.2)	95
		Mature	4 (12.1)	24 (72.7)	3 (9.1)	2 (6.1)	33
		Total	15 (11.7)	80 (62.5)	27 (21.1)	6 (4.7)	128
	Total	Immature	18 (13.4)	80 (59.7)	31 (23.1)	5 (3.7)	134
		Mature	4 (6.1)	48 (72.7)	11 (16.7)	3 (4.5)	66
		Total**	22 (10.9)	129 (63.9)	43 (21.3)	8 (4.0)	202

*: In parenthesis, % occurrence.

**: Animals with unknown maturity stage are also included.

Table 10. Mean compositions (%) of restored wet weights of prey species of common minke whales by stocks, sex, and sexual maturity stage, collected in the 2003-2007 JARPN II coastal component off Sanriku.

Stock	Sex	Maturity stage	n	Krill	Sand lance	Japanese anchovy
J stock	Male	Immature	10	0.0	61.1	38.9
		Mature	5	0.0	100.0	0.0
		Total	15	0.0	74.9	25.1
	Female	Immature	9	0.0	82.3	17.7
		Mature	1	0.0	100.0	0.0
		Total	10	0.0	86.2	13.8
	Total	Immature	19	0.0	69.4	30.6
		Mature	6	0.0	100.0	0.0
		Total	25	0.0	78.9	21.1
O stock	Male	Immature	22	22.6	61.5	15.9
		Mature	24	0.0	85.9	14.1
		Total*	48	8.4	76.8	14.7
	Female	Immature	60	16.9	67.9	15.1
		Mature	21	24.9	62.6	12.5
		Total	81	19.6	66.2	14.3
	Total	Immature	82	18.5	66.1	15.3
		Mature	45	10.8	75.7	13.4
		Total*	129	15.0	70.6	14.5

*: Animals with unknown maturity stage are also included.

Table 11. Maturity ratio of common minke whales by stock, sex, and their prey species, collected in the 2003-2007 JARPN II coastal component off Sanriku.

Sex	Prey species	J stock				O stock			
		Immature	Mature	Total	Maturity	Immature	Mature	Total	Maturity
Male	Krill	0	0	0	0.00	7	0	7	0.00
	Sand lance	16	6	22	0.45	24	24	48	0.50
	Japanese anchovy	4	0	4	0.35	7	8	15	0.53
	Total	20	6	26	0.39	38	32	70	0.46
Female	Krill	0	1	1	0.29	11	4	15	0.27
	Sand lance	11	2	13	0.27	56	24	80	0.30
	Japanese anchovy	7	1	8	0.11	24	3	27	0.11
	Total	18	4	22	0.24	91	31	122	0.25
Total	Krill	0	1	1	0.20	18	4	22	0.18
	Sand lance	27	8	35	0.34	80	48	128	0.38
	Japanese anchovy	11	1	12	0.20	31	11	42	0.26
	Total	38	10	48	0.30	129	63	192	0.33

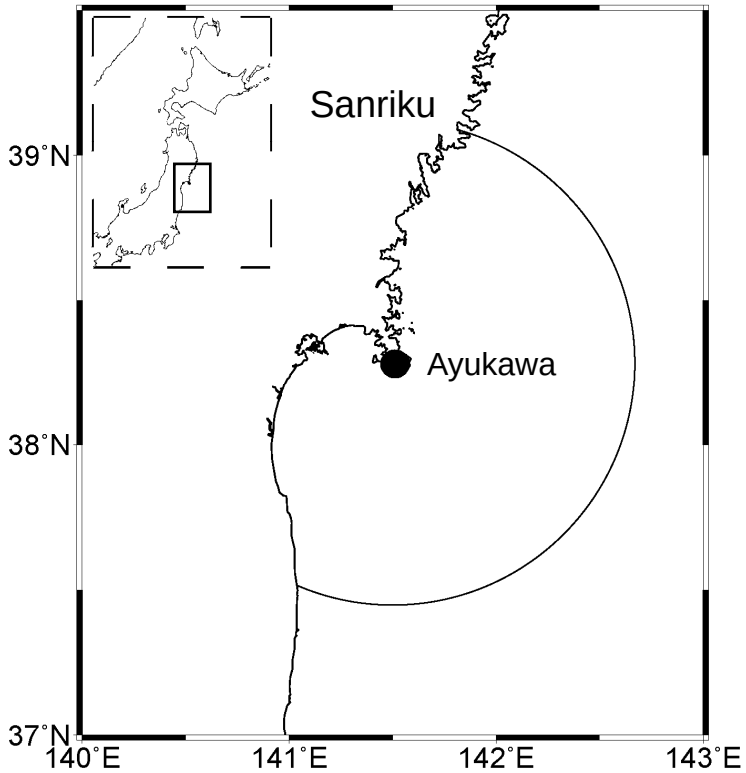

Figure 1. Research area of the whale sampling surveys in the 2003-2007 coastal components off SANRIKU, under the JARPN II.

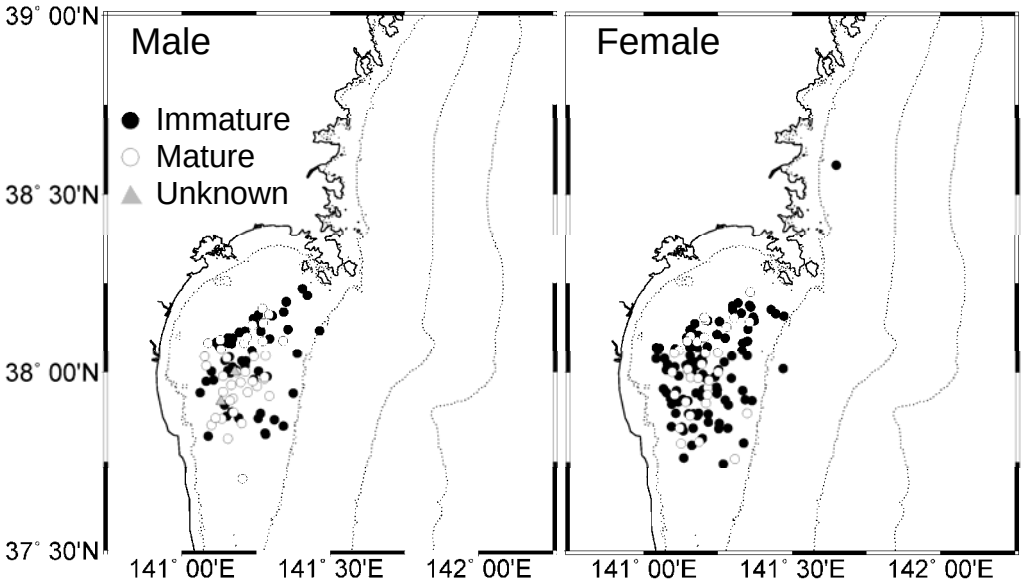

Figure 2. Sighting positions of common minke whales collected in the 2003-2007 coastal components off SANRIKU, under the JARPN II. Isobaths of 20m, 100m, 200m, and 400m are also shown.

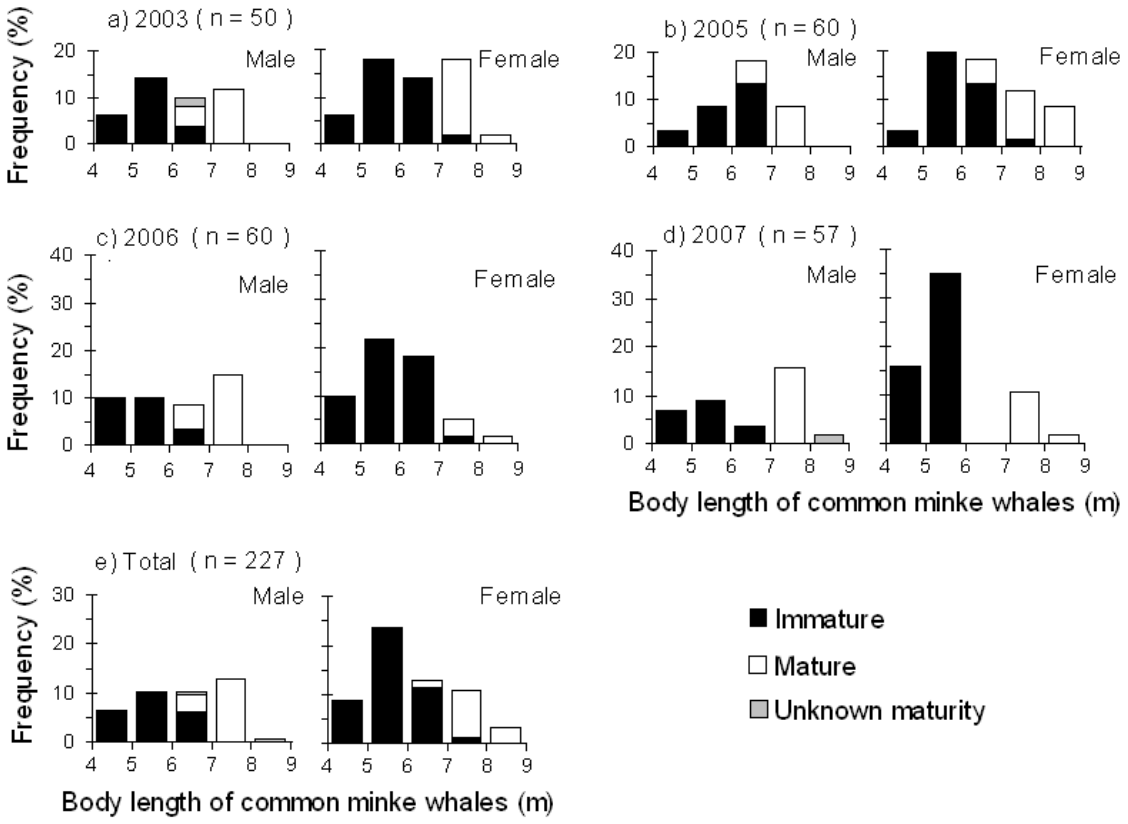

Figure 3. Body length frequency of common minke whales collected in the 2003-2007 coastal components off SANRIKU, under the JARPN II.

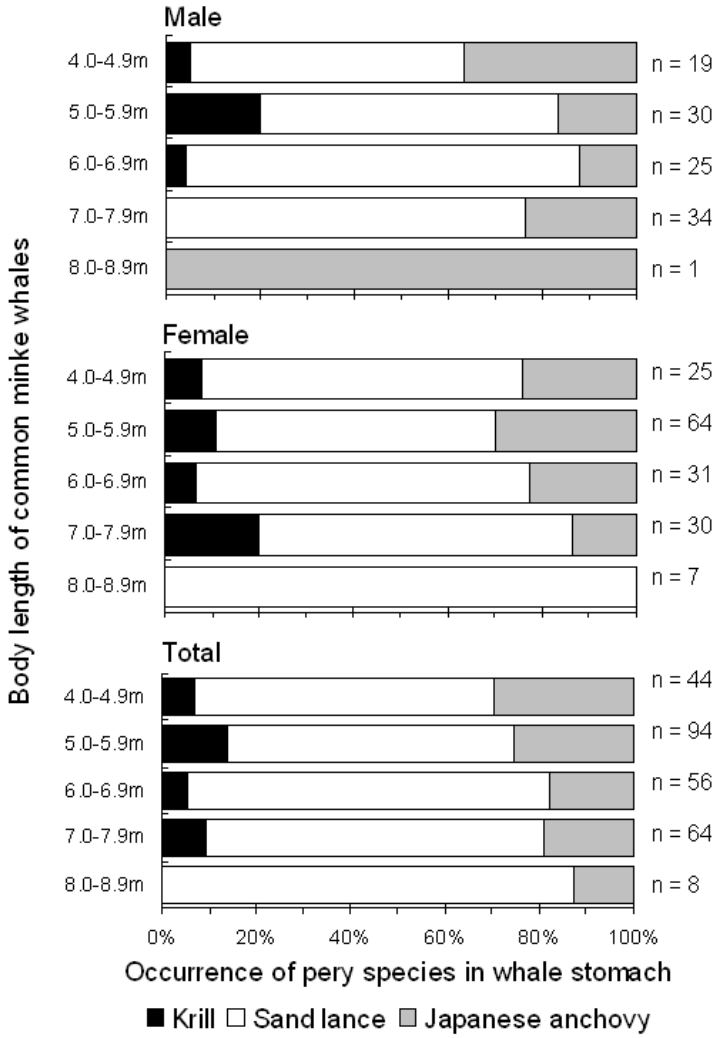

Figure 4. Relationship of body length of common minke whales to composition of their prey species occurrence in the 2003-2007 coastal components off SANRIKU, under the JARPN II.

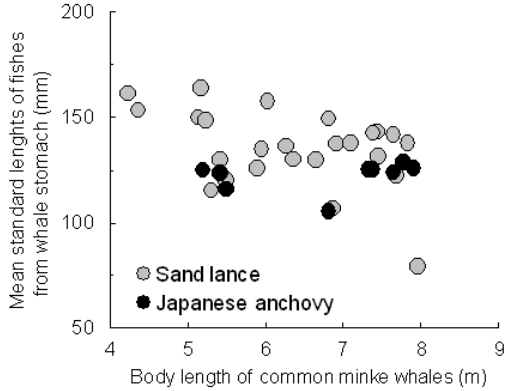

Figure 5. Relationship of body length of whales to mean standard lengths of fishes obtained from their stomach.

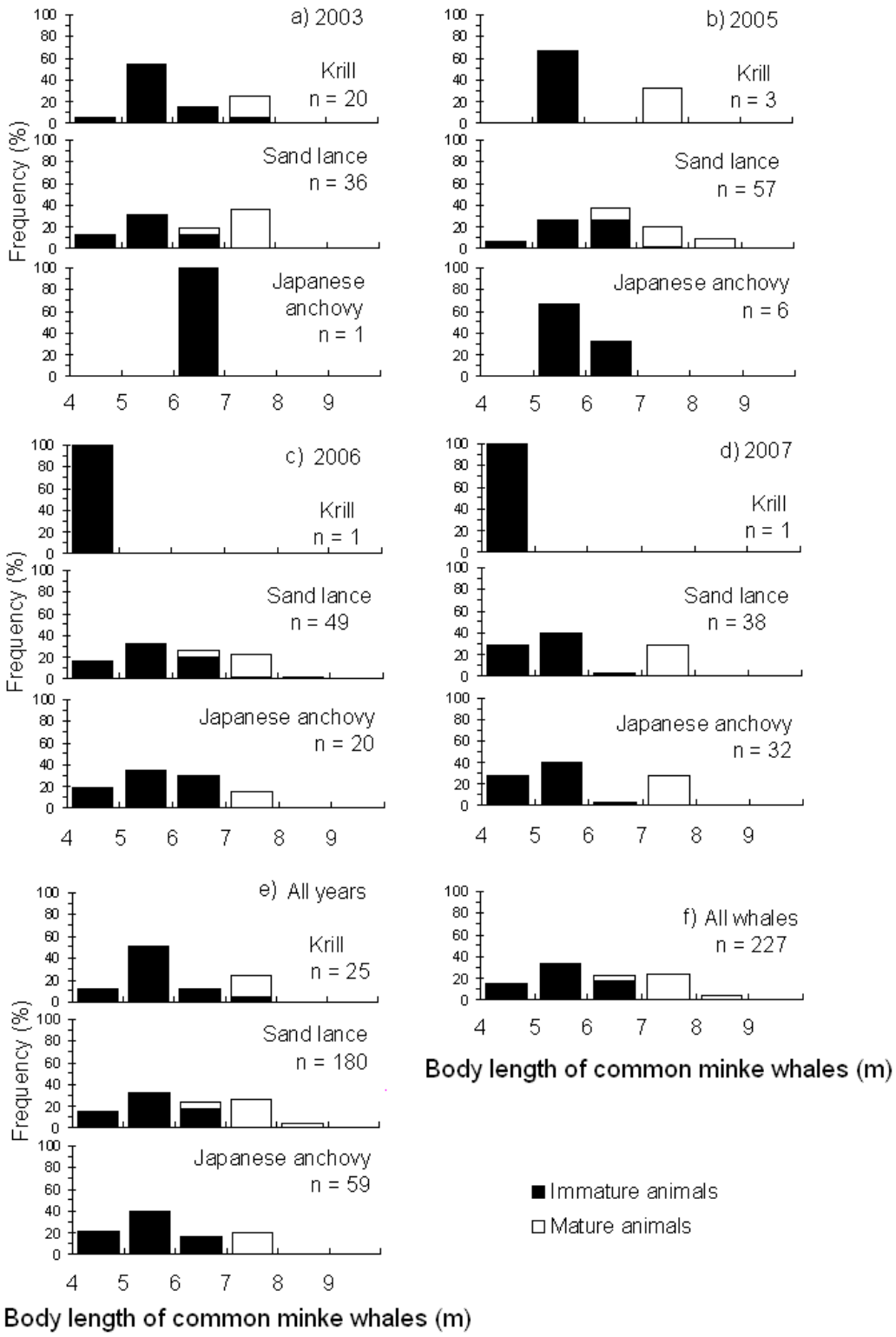

Figure 6. Sexual maturity and body length frequency of common minke whales collected in the 2003-2007 JARPN II coastal component off Sanriku, shown by prey species (a-e).

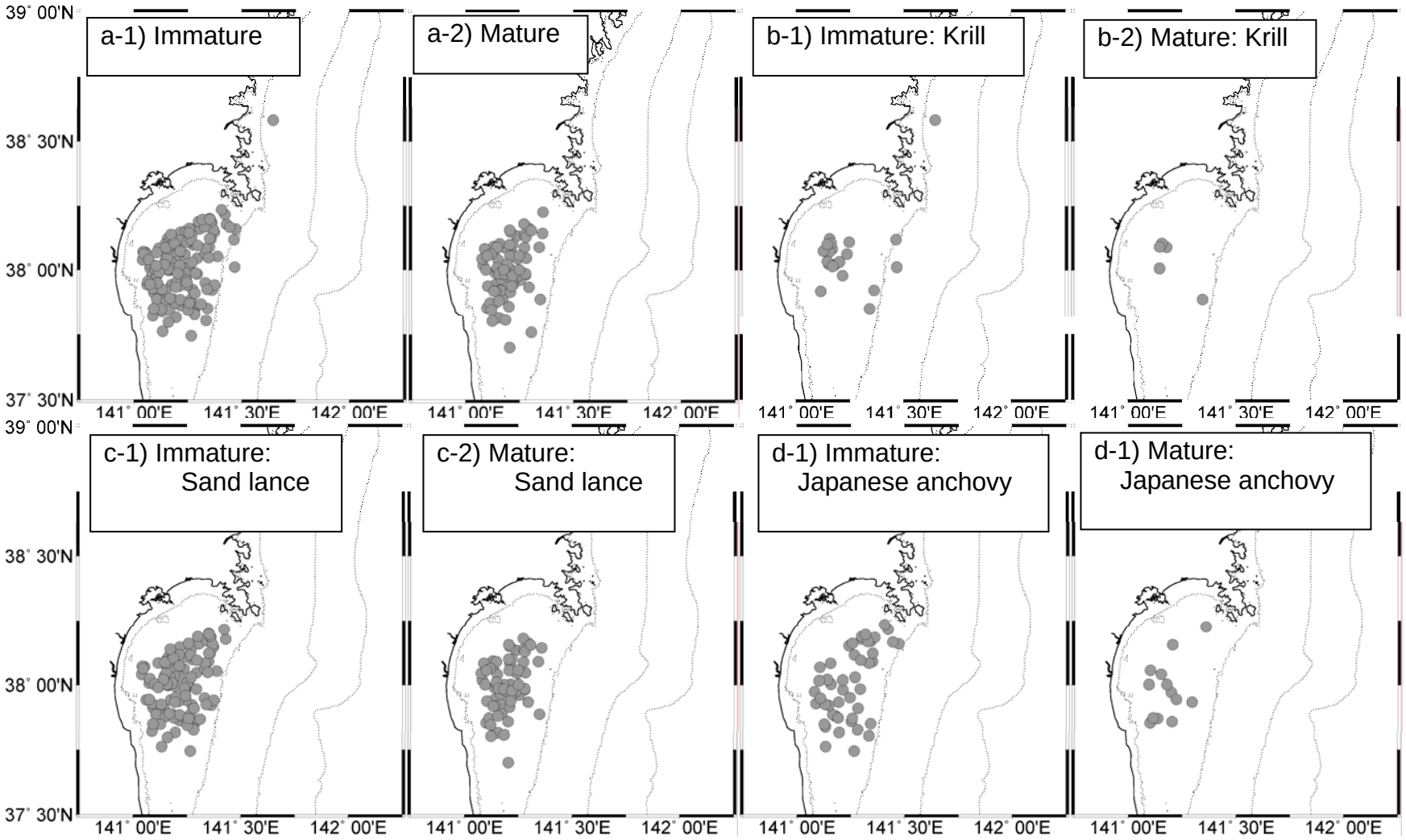

Figure 7. Sighting position of common minke whales collected in the 2003-2007 JARPN II coastal component off Sanriku, shown by their sexual maturity stage and prey species. Isobaths of 20m, 100m, 200m, and 400m are also shown.