Preliminary analyses of interaction between common minke whales and sand lance fisheries off Sanriku region

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ABSTRACT

The stomach contents of fifty common minke whales *Balaenoptera acutorostrata* sampled off Sanriku region from April to May as part of the 2003 JARPN II were analyzed. The prey species consisted of one krill (*Euphausia pacifica*) and two fish (Japanese sand lance *Ammodytes personatus* and Japanese anchovy *Engraulis japonicus*). All these prey species are target by local fisheries. Japanese sand lance and krill were dominant prey species, and their compositions in wet weight were 70.7 % and 29.3 %, respectively. The total prey consumption of Japanese sand lance and krill by common minke whales in one year was estimated as 3,900 tons and 1,600 tons, respectively. The sizes of Japanese sand lances fed by common minke whales were ranged from 120 to 130 mm, which composed to adult individuals. Distribution of common minke whale in Sendai Bay overlapped Japanese sand lance fisheries ground. Japanese sand lance is one of the important coastal fishery species, and their population has kept low level since late 1980's. There is a possibility that direct competition between common minke whale and Japanese sand lance fisheries in this region. To evaluate this competition more precisely, more information of accurate abundance and resident period of common minke whales around the Sendai Bay are needed.

KEYWORDS: COMMON MINKE WHALE; NORTH PACIFIC; FISHERIES INTERACTION, SCIENTIFIC PERMIT

INTRODUCTION

The common minke whale *Balaenoptera acutorostrata* is widely distributed in the world. In the western North Pacific, two stocks have been recognized: one in the Sea of Japan - Yellow Sea - East China Sea (J stock) and the another in the Sea of Okhotsk – West Pacific (O stock) (IWC, 1983). The abundance of common minke whales was estimated to be 19,209 animals with 95 % confidence interval (10,069 – 36,645) in the Sea of Okhotsk and 5,841 animals with 95 % confidence interval (2,835 – 12,032) in the Northwest Pacific during August and September in 1989 and 1990 (IWC, 1992). In the western North Pacific, common minke whales are opportunistic feeders consuming a broad of prey with flexible feeding habits. According to previous reports, they consume several prey species such as pelagic schooling fish and zooplankton (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992; Tamura *et al.*, 1998).

The results of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) and JARPN II feasibility study showed that common minke whales fed on various prey species such as Japanese anchovy *Engraulis japonicus*, Pacific saury *Cololabis saira*, walleye pollock *Theragra chalcogramma* and Japanese common squid *Todarodes pacificus*, and the main prey species changed seasonally and geographically. For example, they feed on Japanese anchovy in May/June and Pacific saury in July/August (Tamura and Fujise, 2000a, 2002a). The estimated prey consumption by common minke whales was comparable to that of the commercial fisheries (Tamura and Fujise, 2000b, 2002b), indicating the competition between common minke whales and fisheries may occur in the coastal area.

However, our interests of coastal matter, the *Nisshin-Maru* and large sighting/sampling vessels can not be operated in the near shore area because of various restrictions and obstacles. Furthermore, these vessels can not join survey from late autumn to early spring for operational reason.

In order to cover the geographical and seasonal gaps of JARPN and JARPN II feasibility study, sampling of common minke whales in the coastal area using small type whaling catcher boats was planed in 2002 (Government of Japan, 2002. These coastal surveys were conducted off Kushiro in 2002 and off Sanriku in 2003. The details of these surveys were reported in Kishiro *et al.* (2003) and Yoshida *et al.* (2004).

Off Sanriku region, the coastal component of JARPN II was conducted in April and May in 2003. The research area covers within the 30 n.miles (maximum 50 n.miles) from the Ayukawa port (fig.1). In previous report, common minke whales fed mainly on krill and Japanese sand lance *Ammodytes personatus* during spring off Sanriku region (Kasamatsu and Tanaka, 1992). Yoshida *et al* (2004) reported that the dominant prey species of common minke whales sampled off Sanriku region were Japanese sand lance and krill *Euphausia pacifica*.

In this document, the abundance of common minke whales and the consumption of targeted fisheries species consumed by common minke whales were calculated using some assumption off Sanriku region. Then, the prey consumption by common minke whales and fisheries catches were compared. In Japanese sand lance fisheries, small larvae and adults were exploited separately, since common minke whales feed mainly on large (>10cm) fish. So, only adult Japanese sand lance is covered in this document.

MATERIALS AND METHODS

The abundance of common minke whales off Sanriku region

The area was 17,403.9 nml^2, and the density of minke whales was assumed 0.033ind. / km^2 (data form *Syunyo Maru* sighting cruise in 1991 and 1992). The abundance of common minke whales within 50 n.miles from the Ayukawa port estimated 574 individuals (95% confidence interval was from 191 to 1,653ind.).

Sighting and sampling of common minke whales

Sighting and sampling methods of common minke whales were described by Yoshida *et al* (2003). Four small-type whaling catcher boat, *Taisho Maru* No. 28, *Sumitomo Maru* No. 31, *Katsu Maru* No.7 and *Koei Maru* No.75 were used. All common minke whales sighted excluding the cow-calf pair were targeted for sampling. When a school size was more than one animal, sampling target was selected randomly from the school. After the target was sampled by harpoon, she moved to the Ayukawa port as soon as possible, to land research station.

Sampling of the stomach contents

Biological research such as measurement of body proportion was conducted for all common minke whales sampled. After the stomach contents were removed, the contents from each stomach were weighed to the nearest 0.1 kg, and sub-sample were removed from all individuals and frozen for later examination. The contents were first classified to major prey groups, such as euphausiids, copepods, fish and others. The freshness of stomach contents was categorized into four classes (1 = fresh, 2 = lightly digested, 3 = moderately digested, 4 = heavily digested).

The sub-samples were identified to the lowest taxonomic level as much as possible. When undigested fishes were found, standard lengths and weight were measured to the nearest 1 mm and 1 g, respectively. When fishes occurred in the sub-samples, the total number of each prey species was estimated by adding the number of undigested specimens and the number of intact skulls. The total weight of each prey species was estimated by using the average weight of fresh specimens. The total number and weight of each prey species were estimated by using the results from the sub-samples. Then, the relative prey importance by weight of each prey species (*RW*) was calculated as follows:

$RW = (W_i / W_{all}) * 100$

W_i = the weight of contents containing prey group *i*

W_{all} = the total weight of contents analyzed.

The consumption by common minke whales

The sample size of common minke whales, which were used for stomach contents analyses, was listed in Table 1. The diet composition (*RW*) of common minke whales was shown in Table 2. The maturity composition of common minke whales was listed in Table 3.

The daily prey consumptions by both immature and mature common minke whales were calculated with the assumptions below.

a. Mean body weight (Tamura and Fujise, 2002b) :

Immature male:	2,500 kg
Immature female:	2,600 kg
Mature male:	4,800 kg
Mature female:	5,900 kg

These weights were obtained from JARPN and JARPNII survey data.

b. The residence time of the common minke whale off Sanriku region: 60 days (April and May)

Off Sanriku region, common minke whales mainly distribute from April and May (Hatanaka and Miyashita, 1997). And past commercial whaling season off Sanriku region was from April and May. Therefore, residence time of the common minke whale off Sanriku region was assumed to be 60 days.

c. Field metabolism Immature male or female: 1.58*80*body weight (kg) KJ / day (Markussen *et al*., 1992)

Mature male or female: 1.25*80*body weight (kg) KJ / day (Nordoy *et al*, 1995)

The average field metabolism used in these calculations was obtained from Blix and Folkow (1995). The value of 80 kJ/kg per day is based on indirect determination of oxygen consumption from studies of the respiratory rates.

d. Average caloric value of prey species: 6,000 KJ / kg

Stomach content analyses show much variation in the diet of common minke whales in the western North Pacific (Kasamatsu and Tanaka, 1992; Tamura *et al.*, 1998, Tamura and Fujise, 2000a, 2002a). In the North Atlantic, the energy contents of the prey species varies from 3,720 kJ/kg when feeding on *Parathemisto* spp. to as high as 12,500 kJ / kg when feeding on herring (Markussen *et al.*, 1992). In this study, the mean caloric value of krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese common squid *Todarodes pacificus* were calculated using bomb caloric meter. The mean caloric value of krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese common squid were calculated to be 3,600 kJ/kg, 6,400 kJ/kg, 13,000 kJ/kg, 6,200 kJ/kg and 6,600 kJ/kg, respectively (Tamura and Fujise, 2002b). Total prey species were assumed to be 6,000 kJ/kg by average of above values.

e. Assimilation efficiency: 80%

The assimilation efficiency of the common minke whales is assumed to be 80 %. (Markussen *et al*., 1992).

f. Reproduction cost: 20kg / day

The total reproductive cost for the female common minke whale was re-calculated to be $1.9*10^7$ kJ (Lockyer, 1981), assuming a length at birth fetus of 280 kg (Christensen, 1981). The pregnancy rate is 95 % for mature. All energy related to reproduction costs as obtained during the residence (feeding) time in the western North Pacific (180 days) were assumed.

The each calculated prey consumption by common minke whales from April to May is shown in Table 5.

The fisheries catches of Japanese sand lance (>10cm) and *Euphausia pacifica* around the Sendai Bay from February to May

Catch data ware provided from the Miyagi Prefecture Fisheries Research and the Development Centre and Fukushima Prefecture Fisheries Research Centre. The fisheries catch of sand lance (>10cm) and *E. pacifica* were listed in Table 6. The catches of Japanese sand lance and *E. pacifica* around the Sendai Bay from February to May were 6,000 tons and 30,000 tons, respectively.

Interaction index between common minke whales and fisheries catch

The interaction was evaluated by means of comparison between the prey consumption by common minke whales and fisheries catches as follows:

I index = $C_{all} / F * 100$

I index = Interaction index between common minke whales and fisheries

C_{all} = Consumption by common minke whales (tons)

F = Fisheries catch (tons)

RESULTS

Three prey species consisting of 1 krill and 2 fish (Japanese sand lance and Japanese anchovy) were identified in stomachs of common minke whales caught off Sanriku region as part of 2003 JARPNII. Japanese sand lance and krill were dominant prey species and composed 70.7 % and 29.3 % in wet weight (%), respectively (Table 2).

The estimated daily prey consumption weights during feeding period off Sanriku region were 120 kg and 125 kg for immature male and female, and 183 kg and 244 kg for mature male and female, respectively.

The prey consumption by common minke whales off Sanriku region from April to May was estimated to be approximately 5,500 tons. The total prey consumption of Japanese sand lance and *E. pacifica* by common minke whales were estimated as 3,900 tons and 1,600 tons, respectively.

The body length of Japanese sand lance ingested ranged from 120 to 130 mm (Fig. 2). These sizes were equivalent to adult size of Japanese sand lance.

The I index were 63 in Japanese sand lance (>10cm) and 5 in *E. pacifica*, respectively. Sighting positions of mink whales were overlapped fisheries ground of Japanese sand lance off Sanriku where rough sand bottom are dominant. (>10cm) (Fig. 3).

DISCUSSION

The present study indicates that there is large impact of predation by common minke whale on sand lances in Sendai Bay. To figure out how and how much impacts common minke whales to off Sanriku region ecosystem, Japanese sand lance is one of the most important key prey species off Sanriku region.

Some sand lance species in the world have specific habit, summer aestivation. (Robards *et al*, 1999). They hide themselves in near shore substrates every summer, when water temperature is high. In Sendai Bay, they hide during August and December, at mainly rough sand sediment in shallow water (< 50 m depth) (Kobayashi *et al*. 1991). So, Japanese sand lances as prey of common minke whale off Sanriku region are presumably available only from February to June through a year.

In 2003 coastal component of JARPN II, the dominant prey species of common minke whales sampled off Sanriku region in April and May were Japanese sand lance and krill *Euphausia pacifica*. This result was similar to that of previous report (Kasamatsu and Tanaka, 1992). They analysed the yearly change of prey species of common minke whale off Sanriku during 1948 to 1987. Commercial whaling had been made from January to September with peaks from April to June. After 1980, the peak of catch was observed in April. The dominant prey species were krill, Japanese sand lance and *iwashi* (Japanese sardine and/or Japanese anchovy). They pointed out that the yearly change of Japanese sardine in stomach contents were similar to the annual trend of abundance of Japanese sardine in this area.

The maximum stomach contents weight was 102.6 kg (2.0 % of body weight). Our daily estimated prey consumption was from 120 kg to 244 kg (from 3.8 % to 4.8 % of body weight). Common minke whale should take on prey at several times due to meet a demand for their energy requirement in a day. Based on diurnal change in feeding activity of common minke whale in the western North Pacific, Tamura and Fujise (2000c) pointed out that common minke whales feed on prey at several time throughout the day at the surface. Our results supported their consideration.

The seasonal consumption of 574 common minke whales distributed off Sanriku during April and May (60 days) was 5,500 tons. The total consumption of Japanese sand lance estimated 3,900 tons, equivalent to 63% of current commercial fisheries catch of Japanese sand lance.

Based on results of the sand lance consumption by common minke whales and the degree of overlap between fisheries ground of Japanese sand lance and sighting position of common minke whales, it is conceivable that the possibility with direct competition between common minke whale and Japanese sand lance fisheries occurs. The fisheries season of Japanese sand lance is from February to May, and common minke whales also feed on Japanese sand lance in the later half of the season. Furthermore, sighting positions of common minke whales were overlapped fisheries ground of Japanese sand lance (>10cm). The catch quota and season of Japanese sand lance off the Sanriku region (around the Sendai Bay) is regulated by the fisheries conference in order to protect the resources of Japanese sand lance and price control, however common minke whales feed on Japanese sand lance more than half of catch. Therefore, consumption by common minke whales should be taken into account for fishery management of Japanese sand lance off Sanriku region.

Furthermore, some fishermen indicate the fishing operation have interfered by common minke whales. Some minke whales attack and feed on the school of sand lance when fishermen attracted fishes around boat, causing dispersion of the schools of Japanese sand lance.

This preliminary analysis was based on the result of only once research in 2003. To evaluate the competition between common minke whale and Japanese sand lance fisheries, more information of accurate abundance in prey species and common minke whales, and the accurate resident period of common minke whale around the Sendai Bay are needed. It needs the long-term monitoring research in this area in future.

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Table 1. Sample size of common minke whale off Sanriku region.

Year	Month	Number	Empty	Broken
2003	April	49	0	2
	May	1	0	1

Table 2. Diet composition (*RW*: %) in the stomach contents of common minke whales off Sanriku region.

Month	Year	N	Sand lance	Krill	Anchovy
April	2003	47	70.7	29.3	<0.1

Table 3. Sex and maturity composition of common minke whales off Sanriku region.

Month	Sex and maturity	N	%
April-May	Immature male	13	26.0
	Immature female	20	40.0
	Mature male	8	16.0
	Mature female	9	18.0

Table 4. Estimated field metabolism and daily consumption during feeding period of common minke whales.

Sex and maturity	Body weight (kg)	Field metabolism (KJ/day)	Daily consumption (Feeding period: kg)
Immature male	2,500	395,000	120.1
Immature female	2,600	410,800	125.0
Mature male	4,800	600,000	182.5
Mature female	5,900	737,500	244.3

Table 5. Seasonal consumption by common minke whales off Sanriku region from April to May.

A. Japanese sand lance (>10cm)

Abundance of common minke whale (Individuals)		Consumption (tons)
574	Abundance estimate	3,885
191	Lower level of 95%CI	1,293
1,653	Upper level of 95%CI	11,187

B. Krill

Abundance of common minke whale (Individuals)		Consumption (tons)
574	Abundance estimate	1,610
191	Lower level of 95%CI	536
1,653	Upper level of 95%CI	4,636

Table 6. Fish catches of the Japanese sand lance (>10cm) and *Euphausia pacifica* in Sendai Bay from February to May.

A. Japanese sand lance (>10cm)

Year	Catch (t)
1990	4,218
1991	2,440
1992	4,375
1993	11,086
1994	5,665
1995	6,921
1996	10,094
1997	4,744
1998	8,642
1999	5,273
2000	376
2001	6,862
2002	6,026
2003	10,016
Average	6,196

B. *Euphausia pacifica*

Year	Catch (t)
1990	11,820
1991	27,836
1992	60,989
1993	31,794
1994	38,184
1995	30,565
1996	25,109
1997	31,174
1998	34,869
1999	21,409
2000	37,955
2001	24,183
2002	20,607
2003	
Average	30,500

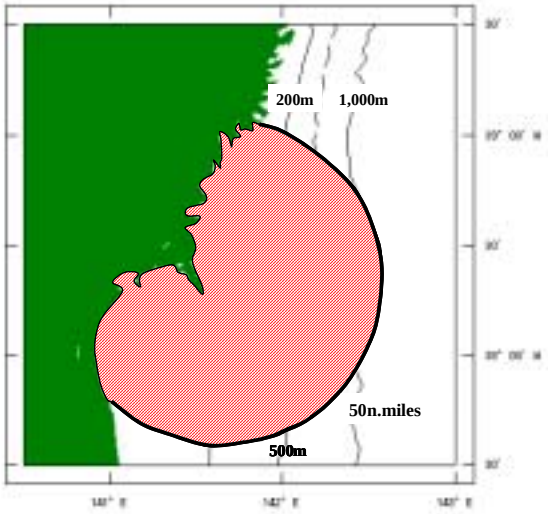

Fig1. Research area off the Sanriku, northeast Japan.

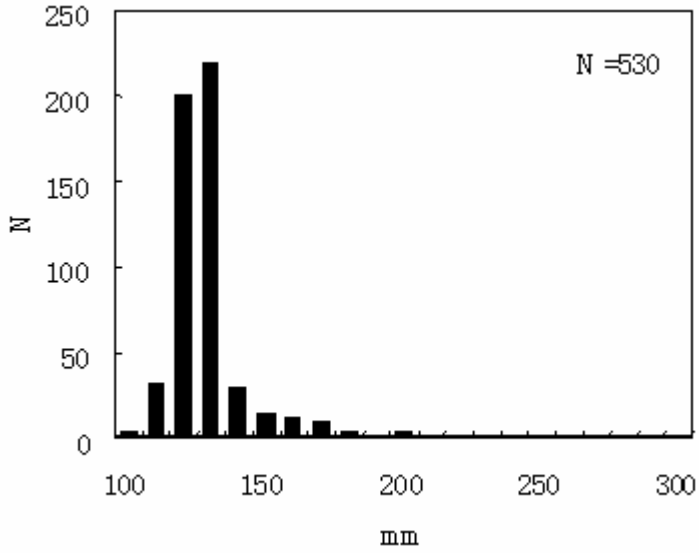

Fig. 2. Length distribution (*S.L.*) of Japanese sand lance in the stomachs of common minke whales.

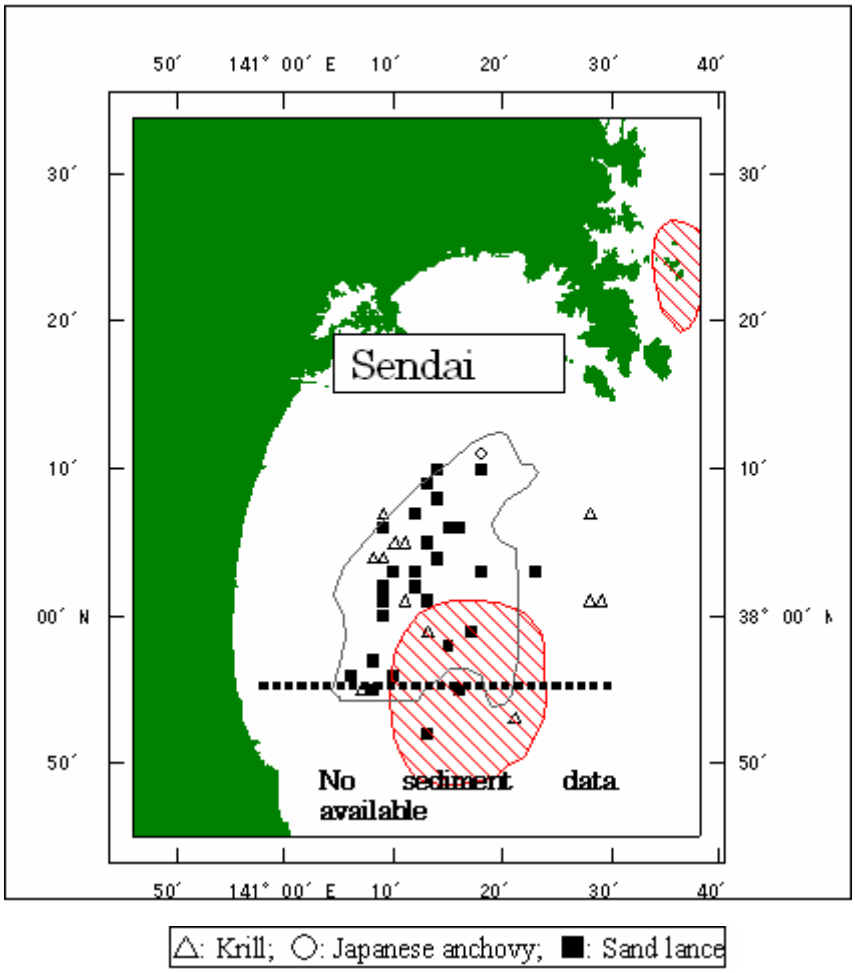

Fig.3: Sighting positions and stomach contents of common minke whales sampled in JARPNII 2003 (Fishing ground of Japanese sand lance (>10cm) shows ▨). Area of rough sand sediment redraws using the data from Kobayashi *et al.* 1991 (◯)