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ABSTRACT

The stomach contents of common minke whales (*Balaenoptera acutorostrata*), sampled off Sanriku from April to May and Kushiro region from September to October by the Japanese Whale Research Program under Special Permit in the western North Pacific (JARPNII) were collected and examined. The main purpose of this study was to estimate the amount of fish resources consumed by the common minke whales, accounting for some uncertainties. Prey species of whales were identified by examining their stomach contents, and the amount of prey consumed in the research area was estimated by using information on prey consumption *per capita* and the numbers of whales distributed. In Sanriku region, the dominant prey species consisted of one krill (*Euphausia pacifica*) and two fishes (Japanese sandlance and Japanese anchovy). Based on the results obtained by three equations combined and Monte Carlo simulations, the daily prey consumptions *per capita* of common minke whales were 98kg and 106kg for immature male and female; and 166kg and 223kg for mature male and female, respectively. The CVs was around 0.3. The seasonal consumption of total prey by common minke whales were 4,234 tons, 1,822 tons and 850 tons in 2005, 2006 and 2012 seasons, respectively. The CVs was around 0.2. The seasonal consumption of Japanese sandlance were 3,709 tons, 1,522 tons and 656 tons in 2005, 2006 and 2012 seasons, respectively. It corresponded to 30-40% of the fisheries catch on this fish resource in two years before the tsunami. In the Kushiro region, the daily prey consumptions *per capita* of common minke whales were 82kg and 81kg for immature male and female; and 116kg and 155kg for mature male and female, respectively. The CVs was around 0.2. The seasonal consumptions of total preys by common minke whales were in the range 782-3,469 tons during the period 2002-2012. The CVs were in the range 0.2-0.3. The seasonal consumptions of Pacific saury and walleye pollock were 0-843 tons and 85-1,546 tons, respectively. It corresponded to approximately 2-3% of the fisheries catch on these resources. These estimates on prey consumption will be useful as input data in ecosystem models.

KEYWORDS: COMMON MINKE WHALE; SANRIKU; KUSHIRO; 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 distributed mainly in the Sea of Japan - Yellow Sea - East China Sea (J stock) and the other 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 variety of prey species with flexible feeding habits. According to previous reports, they consumed several prey species such as pelagic schooling fish and zooplankton (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992; Tamura *et al*., 1998, Tamura and Fujise, 2002a).

The results of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) and JARPNII feasibility study showed that common minke whales fed on various prey species such as Pacific krill *Euphausia pacifica*, Japanese anchovy *Engraulis japonicus*, Pacific saury *Cololabis saira*, walleye pollock *Gadus chalcogrammus*, 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, 2002b). The estimated prey consumption by common minke whales was comparable to that of the commercial fisheries (Tamura and Fujise, 2000b, 2002c), indicating the some extend interaction between common minke whales and fisheries may occur in the coastal area from previous research results.

In order to cover the geographical and seasonal gaps of JARPN and JARPNII feasibility study, sampling of common minke whales in the coastal area using small type whaling catcher boats was planned in 2002 (Government of Japan, 2002).

The purpose of this study is to estimate the amount of fish resources consumed by the common minke whale off the Pacific coast of Sanriku and Kushiro, accounting for some uncertainties, and to evaluate the feeding impact by common minke whales on some fisheries resources. The study is based on JARPNII data and samples, and information from commercial fisheries.

MATERIALS AND METHODS

Research region, year, season and sample size

Sanriku region
The sampling area was within the 30 n.miles (maximum 50 n.miles) from the Ayukawa port (Figure 1). The researches were conducted in April and May since 2003 excluding 2004 and 2011. The sample size for the minke whale in the Sanriku component started with 50 animals in 2003. After 2005, the sample size changed to 60 animals to be taken in every spring (April and May). These surveys were described in detail by Kishiro *et al.* (2009a, 2016 (SC/F16/JR3)).The actual sampling number of whales between 2003 and 2013 is shown in Table 1.

Kushiro region
The study area was comprised north of 41°N and between longitude 143°E (Cape Erimo) and 146°E. The sampling area was within the 30 n.miles (maximum 50 n.miles) from the Kushiro port (Figure 1). The researches were conducted in September and October since 2002 excluding 2003. The sample size for the minke whale in the Kushiro component started with 50 animals in 2002. After 2004, the sample size changed to 60 animals to be taken in every autumn (September and October). These surveys were described in detail by Kishiro *et al*. (2009a, 2016 (SC/F16/JR3)). The actual sampling number of whales between 2002 and 2013 is shown in Table 1.

Sampling and treatment of stomach contents from minke whales

Baleen whales have four chambered stomach system (Hosokawa and Kamiya, 1971; Olsen *et al*., 1994). The stomach contents remain in the forestomach (1st. stomach) and fundus (2nd. stomach).

The stomach contents were removed from each compartments and weighed to the nearest 0.1kg at the land station. Then, contents were weighed to the nearest 0.1kg. A sub-sample (1-5kg) of stomach contents was removed and frozen and/or fixed with 10% formalin water for later analyses. The stomach contents were transferred to a system consisting of three sieves (20mm, 5mm and 1mm), which were applied in the Norwegian scientific research to filter off liquid from the rest of the material (Haug *et al*., 1995). The sub-sample (3-4kg) included all undigested fish skulls, free otoliths and squid beaks, which were kept frozen for later analyses in the laboratory.

Data analyses

Biological data
An estimate of the daily prey consumption requires the use of some additional biological and morphometric data. Body length of the whales was measured to the nearest 1cm from the tip of the upper jaw to the deepest part of the fluke notch in a straight line. Body weight was measured using large weighing machine to the nearest 50kg. Energy requirements and feeding habit are different for sexual maturity classes; therefore, estimations of the daily prey consumption in this study took into consideration information on sexual maturity. Sexual maturity of each whale was defined by testis weight and ovaries observation.

Prey species identification and stomach contents weight
In the laboratory prey species in the sub-samples were identified to the lowest taxonomic level as possible. Undigested preys were identified using morphological characteristic, based on different sources: copepods (Brodskii, 1950), euphausiacea (Baker *et al*., 1990), squids (Kubodera and Furuhashi, 1987) and fish (Masuda *et al*., 1988; Chihara amd Masuda, 1997). The otoliths and jaw plate were used to identify the fish with advanced stage of digestion (Morrow, 1979; Ohe, 1984; Kubodera and Furuhashi, 1987; Arai, 1993).

When undigested fish and squid were found, fork length, mantle length and the weights were measured to the nearest 1mm and 1g, respectively. This data were used for restoring their stomach contents with advanced stage of digestion.

The total number of each fish and squid species in the sub-sample were calculated by adding to the number of undigested fish or squid, undigested skulls and half the total number of free otoliths. The total weight of each prey species in the sub-sample was estimated by multiplying the average weight of fresh specimens by the number of individuals. The total number and weight of each prey species in the stomach contents were estimated by using the figures obtained from the sub-sample and the total weight of stomach contents.

Prey composition (W %) in each region and year

In order to simplify the comparison of feeding indices, prey species were divided as follows: Pacific krill, sandlance (*Ammodytes personatus*), Japanese anchovy, Japanese sardine (*Sardinops melanostictus*), Pacific saury, walleye pollock (*Gadus chalcogrammus*, formerly *Theragra chalcogramma*), mackerels (*Scomber japonicus*, *S. australasicus*), Japanese common squid and other fishes (Japanese pomfret (*Brama japonica*), Salmonidae).

The relative prey composition (%) in weight of each prey species (*RW*) in each month was calculated as follows:

$RW_i = (W_i / W_{all}) \times 100$

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

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

Estimation of daily and seasonal prey consumption in each whale species

Daily prey consumption

The amount of prey consumption consumed by common minke whales is estimated using theoretical energy requirement calculations. The uncertainties associated to the relevant parameters were treated by Monte Carlo simulations.

The daily prey consumption (D_{kg}) in each sexual maturity class was estimated from the standard metabolic rate (SMR_{kJ}) and energy deposit according to the following equations:

$D_{kg} = (SMR_{kJ} + ED_{kJ}) / (E_{KJ} * AE)$ (1)

Where D_{kg} is daily prey consumption (kg day^{-1}), SMR_{kJ} is the standard metabolic rate (kJ day^{-1}), ED_{KJ} is Energy deposition (kJ day^{-1}), E_{kJ} is the caloric value of prey species (kJ kg^{-1}), and *AE* is Assimilation efficiency (%). The details of these items are described as follows:

SMR (STANDARD METABOLIC RATE, ALLOMETRIC RELATIONSHIPS)

The uncertainty associated to several components involved in estimating the amounts and types of prey consumed by whales was assisted by a review by Leaper and Lavigne (2007) and Tamura *et al.* (2009). They considered that the appropriate consumption estimates is between the high end of Equation 1 and the low end of Equation 2 (see below). The estimate of consumption by Equation 3 was considered by the authors at the upper range of these reasonable values. Furthermore, Equation 4 is used by PICES for estimating prey consumption of marine mammals (Hunt *et al*., 2000).

Equation 1: $BMR = 0.42\ M^{0.67}$ (Innes *et al*., 1986) (2)

Equation 2: $SMR = 2{,}529.2\ M^{0.524}$ (Boyd, 2002) (3)

Equation 3: $SMR = 863.6M^{0.783}$ (Sigurjónsson and Víkingsson, 1997) (4)

Equation 3-1: $SMR = 690.36M^{0.783}$ (Sigurjónsson and Víkingsson, 1997) (5)

Equation 4: $SMR = 803.71M^{0.75}$ (Perez *et al*, 1990) (6)

SMR is the daily prey consumption (expressed by KJ day^{-1}) and *M* is body mass in kg. It should be noted here that the estimates from Equation 1 depend only on the body weight data (expressed in kg). The estimates from Equations 2, 3 and 4 require body weight data (expressed in kg) and energy content of prey (expressed in KJ kg^{-1}). Equation 3.1 excluded an *AE* value of 80% from Equation 3. In this study, three equations (Equations 2, 3-1 and 4) were used in the sensitivity analysis with 10,000 Monte Carlo simulations using the electronic software package (Oracle ® Crystal Ball: Release 11.1.2.3.). The details of these parameters are described as follows:

The mean caloric values of main prey species (krill, Japanese sandlance, Japanese anchovy, Japanese sardine, Pacific saury, mackerels, walleye pollock and Japanese common squid) were measured using bomb caloric meter (Table 2). These samples were obtained from the stomach contents of whales. The energy contents consumed by whales were calculated based on their prey composition in each region. Prey composition (Weight of %) of whales sampled were calculated in each region (Table 3). The energy contents consumed by whales were calculated based on their prey composition and energy contents of prey species in each region (Table 3). The distribution assumed a triangular distribution with minimum, maximum and average values.

Although an Assimilation Efficiency (*AE*) of 0.8 (80%) is commonly assumed, this will clearly vary with prey condition, size and species. The range of assimilation efficiency was assumed between 0.75 (75%) and 0.85 (85%), and used randomly in the sensitivity analysis. The distribution assumed a uniform distribution between 0.75 and 0.85.

Many baleen whales are generally known to migrate between the feeding ground in high latitudinal waters in summer and the breeding ground in low latitudinal waters in winter. There is some uncertainty in this parameter because the ratio of high feeding season and low feeding season (*r*) and the proportion (*P*) of the energy intake per year during high feeding season are assumed without actual data. For example, Lockyer (1981) indicated that around 83% of the annual energy intake in Southern Hemisphere balaenopterid species is ingested during the summer season. If the number of days of high feeding season (*HD*) was 120 and the rest of the days were considered low feeding season (*LD*), *r* become 0.10. Leaper and Lavigne (2007) estimated the *r* to be from 0.34 (Antarctic minke whales) to 0.62 (North Atlantic minke whales) based on other literatures.

The *r* was calculated as following:

$$r = (365(1-P)) / (365-HD))/ (365P/HD) \qquad (7)$$

P is the proportion of amount during high feeding season per annual energy intake assumed.

The daily prey consumption of high feeding season was assumed to be the feeding index of high feeding season (*H index*). If the *HD* was 150days and the proportion of amount during high feeding season per annual energy intake assumed 80% (0.8), *H index* was 1.95. *HF* is the feeding index as a multiplicative factor greater than one. The *H index* was calculated as following:

$$H\ index = 365P / HD \qquad (8)$$

The range of *H* index was assumed between 1.42 and 2.74 and used randomly in the sensitivity analysis (Table 4). The distribution assumed a triangular distribution with minimum, maximum and average values (1.95).

Based on this assumption, the daily and seasonal prey consumption of high feeding season was calculated using Equations 2, 3-1, 4 and *H index.*

$$SMR \text{ of high feeding season} = H\ index * SMR \qquad (9)$$

The body mass (M) of each sex and reproductive status of whales

The body mass data (*M*) were obtained directly by using the large electronic weighing system (track scale system) in JARPNII. With regard to the measurement of body weight, little uncertainty is assumed. The average body mass is shown in Table 5.

The composition of maturity stages of whales sampled is also shown in Table 5. Males of minke whales were defined as sexually mature by testis weight (larger side) of more than 290g (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. These criteria are practical ones and confirmed biologically (Bando *et al*, per com.).

The number of common minke whales distributed in Sanriku and Kushiro region

The number of whales distributed in each region and year was estimated by Hakamada *et al*. (2009) and Hakamada and Matsuoka (2016: SC/F16/JR11) (Table 6). The number of whales distributed in each sex, reproductive status in each region and year were calculated using Tables 5 and 6.

Prey species abundance and fisheries catch information

In Sanriku region, the prey survey was conducted since 2003 excluding 2004 and 2011. In Kushiro region, the prey survey was conducted between 2004 and 2007. The details of the results were described in each cruise reports (Bando *et al*, 2008, 2011; Goto *et al*., 2007; Kishiro *et al*., 2003, 2005, 2006, 2008, 2010, 2012, 2014; Yasunaga *et al.*, 2009, 2010, 2012, 2013, 2014; Yoshida *et al*., 2004, 2006, 2007, 2009a, 2011, 2013, 2015).

The information on abundance and occurrence of prey species in Kushiro region is summarised in appendix 3, based on the information from the Fisheries Research Agency of Japan (FRA), and Kushiro Fisheries Research Institute.

Fisheries catch information in Sanriku region is shown in Table 7 and Figure 2, and annual trend of the index of Japanese sandlance abundance is summarised in Appendix 2. This information was based on the data from Miyagi Prefecture Fisheries Technology Institute.

Fisheries catch information of Japanese sardine, mackerels, Pacific saury and walleye pollock in Kushiro are shown in Table 7 and Figure 2, based on the data from the Marine Net Hokkaido constructed by the Hokkaido Research Organization, Fisheries Research Department.

RESULTS

Diversity of prey species

Sanriku region
A total of three main preys, including one species of euphausiids, two of fishes were identified in 486 stomachs of minke whales (Table 8).

Kushiro region
A total of seven main preys, including one species of euphausiids, one of squid and five of fishes were identified in 589 stomachs of minke whales (Table 8).

Feeding habit of common minke whales

Sanriku region
Table 3 shows the prey composition (*W* %) of common minke whales sampled in each year. The dominant prey was sandlance, it did not change since 2003 (Figure 3).

Kushiro region
Table 3 shows the prey composition (*W* %) of common minke whales sampled in each year. The dominant prey changed from Japanese anchovy in 2002-2011 to Japanese sardine in 2012-2013. In Kushiro region, long term information for prey composition was obtained from the past commercial whaling, and reported by Kasamatsu and Tanaka (1992). Figure 3 shows this information together with the results of JARPN and JARPNII surveys. Until 1976, the dominant pelagic prey species of common minke whales was Chub mackerel. After that, the dominant prey species were switched from Chub mackerel to Japanese sardine in 1977, from Japanese sardine to Pacific saury in 1996, and from Pacific saury to Japanese sardine and mackerels in 2012.

The size distribution of main prey species consumed by minke whales

Sanriku region
The size distributions of Japanese sandlance in the stomach of common minke whales, and in the environment, in each survey year are shown in Figure 4. Common minke whale feed on both of juvenile and matured sandlance. The size difference of sandlance consumed by the common minke whale in Sanriku region seems to depend on the size of sandlance distributed in the area. It seems that the common minke whales have not prey size selectivity.

Kushiro region
The size distributions of walleye pollock found in immature whale stomachs and in the environment were similar, showing a clear mode between 34 and 52cm in fork length (Figure 5). Sizes of Pacific saury in both stomachs of mature whales and the environment mainly ranged from 28 to 31cm in knob length. However, immature whales fed mainly on Pacific saury of from 25 to 28cm in knob length, which was smaller than the main size of Pacific saury found in the stomachs of mature whales and in the environment (Figure 5). Japanese anchovy mainly ranged in size from 11 to 14cm in scale length in the stomachs of immature and mature whales, and in the environment (Figure 5).

The daily prey consumption estimates *per capita* of each sex and reproductive status in three equations combined model

The daily prey consumption estimates *per capita* of each sex and reproductive status in three equations combined model were shown in Table 9 and Appendix 1.

Sanriku region
The daily prey consumption *per capita* was 98kg and 106kg for immature males and females, respectively; and 166kg and 223kg for mature males and females, respectively. The CVs was around 0.3.

Kushiro region
The daily prey consumption *per capita* was 82kg and 81kg for immature males and females, respectively; and 116kg and 155kg for mature males and females, respectively. The CVs was around 0.2.

The seasonal prey consumption by common minke whales in each region and season

The seasonal prey consumption estimates by common minke whales in each region and season were shown in Table 10 and Appendix 1.

Sanriku region
The seasonal prey consumptions in 2005, 2006 and 2012 were 4,234 tons, 1,822 tons and 850 tons, respectively. The CVs was around 0.2 (Table 10).

Kushiro region
The seasonal prey consumptions during 2002 to 2012 were between 782 and 3,469 tons. The CVs were in the range 0.2-0.3 (Table 10).

DISCUSSION

Different in feeding habits between Sanriku and Kushiro

Sanriku region
The dominant prey species of common minke whales sampled off Sanriku region in April and May were Japanese sandlance, followed by Japanese anchovy and Pacific krill. This result was similar to that of previous report (Kasamatsu and Tanaka, 1992; Yoshida *et al.*, 2009b). Kasamatsu and Tanaka (1992) examined the yearly change of prey species of common minke whale off Sanriku during 1948 to 1987 based on commercial whaling data. 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 sandlance and *iwashi* (Japanese sardine and/or Japanese anchovy, but main was Japanese sardine). They pointed out that the yearly change of Japanese sardine occupancy in stomach contents were similar to the yearly trend of fisheries catch of Japanese sardine in this area.

Some sandlance 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 (< 50m depth) (Kobayashi *et al*., 1991). So, Japanese sandlance as prey of common minke whale off Sanriku region is presumably available only from February to June through a year.

Kushiro region
Kasamatsu and Tanaka (1992) examined the yearly change of prey species of common minke whale off Kushiro region during 1948 to 1987 based on commercial whaling data. Commercial whaling was made from April to October with peaks from July to September. After 1982, two peaks were observed in July and September. The dominant prey species were krill, *iwashi* (Japanese sardine and/or Japanese anchovy, but main was Japanese sardine), chub mackerel, walleye pollock, Pacific saury and Japanese common squid. They pointed out that the yearly change of Japanese sardine in the stomach contents were similar to the yearly trend of abundance of Japanese sardine in this area. The JARPNII revealed that the variety of the prey species in recent 2000th was almost same as previous report, and the similar change in the dominant prey species was occurred again in recent years (Kishiro *et al*, 2009b, Tamura *et al,* 2016: SC/F16/JR24).

The similarity in the yearly trends of abundance and occurrence of prey species in the waters and density of the whales migrated in the waters suggested that common minke whale was thought to be migrated into the Kushiro waters according to the amount and availability of the pelagic preys resources, and such kind of migration was thought to be triggered the direct conflict between the whales and local fisheries through the overlapping of local fishing grounds and whale feeding grounds (see appendix 3).

Prey consumption of common minke whales in Sanriku and Kushiro
The daily prey consumption *per capita* and seasonal prey consumption by common minke whales in each region could be estimated with appropriate level of statistical precision (CVs were in the range 0.2-0.3) at this stage. The uncertainty derived from the use of different energetic models seems to be appropriately captured in the Monte Carlo simulation.

The feeding impact by common minke whales on fisheries resources

Sanriku region
Sandlance is targeted for commercially and it is important one in Sanriku region during spring. It is mainly caught by stick held dip net fisheries. The catches of sandlance in Sanriku region were several thousand tons since 2002. However, in 2011 and 2012, the fisheries efforts decreased by the effect of a tsunami in 2011 (Table 7).

Based on results of the sand lance consumption by common minke whales and the degree of overlap between fisheries ground of Japanese sandlance and sighting position of common minke whales, it is conceivable that the possibility with direct interaction between common minke whale and Japanese sandlance fisheries occurs. The fisheries season of Japanese sandlance is from February to May, and common minke whales also feed on Japanese sandlance in the latter half of the season. Furthermore, sighting positions of common minke whales were overlapped with fisheries ground of Japanese sandlance. With the decrease of the sandlance resources, the density of common minke whales showed a decreasing trend (Figure 6). Catch data of important commercial fish were provided from the Miyagi Prefecture Fisheries Technology Institute. Some minke whales attack and feed on the school of sandlance when fishermen attracted fishes around boat, causing dispersion of the schools of Japanese sandlance. The catch quota and season of Japanese sandlance off the Sanriku region (around the Sendai Bay) is regulated by the fisheries conference in order to protect the resources of Japanese sandlance and price control.

The consumptions of sandlance by common minke whales in 2005, 2006 and 2012 were estimated in 3,709 tons, 1,522 tons and 656 tons, respectively. It was equivalent to 48.7% and 5.4% of the 2005 and 2006 sandlance resources based on echosounder data (Murase *et al*., 2009; Wada *et al*, 2016: SC/F16/JR19). It was also equivalent to 42.7% and 28.7% of the 2005 and 2006 fisheries catch (Tables 7 and 10).

Therefore, consumption by common minke whales should be taken into account for fishery management of Japanese sandlance off Sanriku region. The ecosystem model (*e.g.* Okamura *et al.*, 2009, Kitakado *et al.*, 2016 (SC/F16/JR29)) will make clear the interaction between common minke whales and sand lance in next step.

Kushiro region

The change of prey species of common minke whales were corresponded with a change of the dominant species taken by commercial fisheries in the same area (Figures 2 and 3). Annual trend of a total catch of fishes (Japanese sardine, anchovy, mackerels, Pacific saury, and walleye pollock in Table 7) by the fisheries, and the density of common minke whales are shown in Figure 6. Catch trend was similar to those of whale's density, and there were no negative relationships such as increasing density with decreasing catch or vice versa.

As the case in Pacific saury, Tamura and Fujise (2002c) noted that most of the common minke whales sightings in sub-area 7W occurred close to fishing grounds of Pacific saury in JARPN (Figure 7). The fisheries season of Pacific saury is from August to October, and common minke whales feed on Pacific saury in the same season. Some fishermen indicate the fishing operation have interfered by common minke whales as same as the case in Japanese sandlance in Sanriku region.

The prey consumptions of economically important Pacific saury and walleye pollock by common minke whales during 2002 to 2012 were calculated as 0–843 tons and 85–1,546 tons, respectively. It was equivalent to 0.0-1.75% and 0.13-2.83%, respectively (Tables 7 and 10). The biomass of prey species in this region could not be estimated, because of logistical reasons. Though, it is difficult to evaluate the interaction between whales and fisheries, quantitatively at this stage.

The fisheries catch is made by several kinds of fisheries in Kushiro region. For instance, Pacific saury is mainly caught by stick held dip net fisheries, walleye pollock is mainly caught by otter trawl fisheries and Danish seine fisheries, Japanese anchovy, Japanese sardine, and mackerels are caught by purse seine fisheries, and Japanese common squid is caught by quid jigging fisheries (Appendix 3).

Modelling works

The ecosystem model is one of the useful methods to examine the effect of the consumption to the fish resources and those fisheries. In Sanriku region, some modelling works could progress (Okamura *et al.*, 2009, Kitakado *et al.*, 2016 (SC/F16/JR29)). To improve the ecosystem model in Sanriku region will make clear the interaction between common minke whales and sandlance in future. On the other hand, in Kushiro region, the actual and interesting circumstances of the complexity could be revealed such as a lot of kinds of prey species, decadal change of the prey compositions, and many type of fisheries engaged. These complexities preclude applying the simple model analyses. For fisheries management in Kushiro region, model works will be considered the structure of ecosystem and application in the future. It is needed the data of the number of common minke whales distributed and the biomass of prey species yearly basis, especially for evaluating the interaction between whales and fisheries in detail.

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Table 1. Numbers of whales sampled in each region.

Sanriku

Year	Number
2003	50
2005	60
2006	60
2007	57
2008	60
2009	60
2010	45
2012	60
2013	34
Total	486

Kushiro

Year	Number
2002	50
2004	59
2005	60
2006	35
2007	50
2008	50
2009	59
2010	60
2011	60
2012	48
2013	58
Total	589

Table 2. Results of caloric value of dominant prey species in Sanriku and Kushiro region.

Sanriku

Species	Analyzed	Energy contents (KJ/kg)	
	Number	Avegage	S.D
Krill (*Euphausia pacifica*)	2	4,117	1,685
Sand lance	4	4,663	2,098
Japanese anchovy	2	6,942	942

Kushiro

Species	Analyzed	Energy contents (KJ/kg)	
	Number	Avegage	S.D
Krill (*Euphausia pacifica*)	2	3,449	325
Japanese anchovy	3	6,762	735
Japanese sardine	1	5,272	-
Pacific saury	2	12,343	1,124
Mackerels	1	13,836	-
Walleye pollock	5	6,106	568
Japanese common squid	1	6,611	-

Table 3. Prey composition (%) of common minke whales and average energy values of stomach contents sampled off Sanriku and Kushiro region

Sanriku

Year	Numeber (N)	Prey composition (%) Krill	Sand lance	Anchovy	Energy contents (KJ/kg)
2003	50				0.0
Immature male	12	72.6	27.4	0.0	100.0
Immature female	9	64.3	35.7	0.0	100.0
Mature male	20	0.0	100.0	0.0	100.0
Mature female	9	56.4	43.6	0.0	100.0
2005	60				0.0
Immature male	15	3.9	77.1	19.0	100.0
Immature female	23	0.0	94.4	5.6	100.0
Mature male	8	0.0	100.0	0.0	100.0
Mature female	14	17.9	82.1	0.0	100.0
2006	60				0.0
Immature male	14	0.0	52.9	47.1	100.0
Immature female	31	0.0	85.4	14.6	100.0
Mature male	12	0.0	94.2	5.8	100.0
Mature female	3	0.0	100.0	0.0	100.0
2007	57				0.0
Immature male	11	0.0	67.2	32.8	100.0
Immature female	29	0.0	52.9	47.1	100.0
Mature male	10	0.0	44.9	55.1	100.0
Mature female	7	0.0	82.0	18.0	100.0
2008	60				0.0
Immature male	19	0.0	100.0	0.0	100.0
Immature female	28	0.0	100.0	0.0	100.0
Mature male	4	0.0	100.0	0.0	100.0
Mature female	9	3.6	96.4	0.0	100.0
2009	60				0.0
Immature male	26	3.6	96.4	0.0	100.0
Immature female	32	7.4	88.6	4.0	100.0
Mature male	1	0.0	100.0	0.0	100.0
Mature female	1	0.0	100.0	0.0	100.0
2010	45				0.0
Immature male	12	33.0	66.2	0.8	100.0
Immature female	26	20.1	79.9	0.0	100.0
Mature male	6	0.0	45.2	54.8	100.0
Mature female	1	0.0	100.0	0.0	100.0
2012	60				0.0
Immature male	27	6.8	82.3	10.9	100.0
Immature female	28	24.4	75.1	0.5	100.0
Mature male	2	0.0	0.0	100.0	100.0
Mature female	3	0.0	100.0	0.0	100.0
2013	34				0.0
Immature male	15	0.0	100.0	0.0	100.0
Immature female	17	0.0	98.0	2.0	100.0
Mature male	2	0.0	0.0	100.0	100.0
Mature female	0				0.0

Table 3. Continued.

Kushiro

Year	Numeber	Average depth	Prey composition (%)							Energy contents
	(N)	(m)	Krill	Anchovy	Sardine	Saury	Mackerel	Pollock	Squid	(KJ/kg)
2002	50									
Immature male	16	187	48.5	23.1	0.0	0.2	0.0	28.3	0.0	4,979
Immature female	11	197	7.1	35.0	0.0	0.0	0.0	57.8	0.0	6,147
Mature male	16	379	0.0	19.2	0.0	42.1	0.0	1.9	36.9	9,041
Mature female	7	159	0.0	4.3	0.0	0.0	0.0	19.5	76.2	6,519
2004	59									
Immature male	15	832	10.1	65.0	0.0	19.1	0.0	5.8	0.0	7,457
Immature female	10	479	0.0	63.0	0.0	16.5	0.0	20.5	0.0	7,546
Mature male	32	934	0.0	49.7	0.0	50.3	0.0	0.0	0.0	9,570
Mature female	2	417	0.0	58.9	0.0	41.1	0.0	0.0	0.0	9,057
2005	59									
Immature male	15	291	13.9	6.5	0.0	0.0	0.0	79.6	0.0	5,780
Immature female	14	329	69.6	9.6	0.0	0.0	0.0	20.8	0.0	4,319
Mature male	29	549	9.8	8.6	0.0	1.2	0.0	68.3	12.1	6,035
Mature female	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Unidentified	1	503	0.0	0.0	0.0	0.0	0.0	100.0	0.0	6,106
2006	35									
Immature male	12	409	2.4	88.6	0.0	0.0	0.0	9.0	0.0	6,624
Immature female	8	271	0.0	22.6	0.0	0.0	0.0	77.4	0.0	6,254
Mature male	11	579	0.0	50.0	0.0	28.2	0.0	0.0	21.8	8,302
Mature female	2	647	0.0	100.0	0.0	0.0	0.0	0.0	0.0	6,762
Unidentified	2	669	0.0	100.0	0.0	0.0	0.0	0.0	0.0	6,762
2007	50									
Immature male	17	296	10.4	40.0	0.0	1.5	0.0	48.1	0.0	6,186
Immature female	17	243	1.4	56.2	0.0	0.0	0.0	42.5	0.0	6,439
Mature male	14	423	3.1	35.2	0.0	61.7	0.0	0.0	0.0	10,104
Mature female	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Unidentified	2	231	0.0	3.5	0.0	0.0	0.0	0.0	96.5	6,616
2008	50									
Immature male	32	374	8.2	37.0	0.0	0.0	0.0	54.8	0.0	6,131
Immature female	15	287	0.0	11.1	0.0	0.0	0.0	88.9	0.0	6,179
Mature male	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Mature female	3	568	0.0	2.8	0.0	0.0	0.0	0.0	97.2	6,615
2009	59									
Immature male	24	334	45.3	12.3	0.0	0.0	0.0	42.4	0.0	4,983
Immature female	23	273	18.9	15.8	0.0	0.0	0.0	65.3	0.0	5,708
Mature male	12	560	54.1	45.9	0.0	0.0	0.0	0.0	0.0	4,971
Mature female	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2010	60									
Immature male	32	211	0.0	13.9	0.0	0.0	0.0	86.1	0.0	6,197
Immature female	19	196	0.0	20.6	0.0	0.0	0.0	79.4	0.0	6,241
Mature male	9	374	0.0	62.3	0.0	0.0	0.0	37.7	0.0	6,515
Mature female	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2011	60									
Immature male	19	225	8.4	32.9	0.0	0.0	0.0	58.7	0.0	6,098
Immature female	22	173	0.0	31.5	0.0	0.0	0.0	68.5	0.0	6,313
Mature male	16	238	14.7	47.6	0.0	0.0	0.0	37.7	0.0	6,028
Mature female	3	90	0.0	100.0	0.0	0.0	0.0	0.0	0.0	6,762
2012	48									
Immature male	21	479	0.0	0.0	27.2	0.0	1.6	71.2	0.0	6,000
Immature female	17	343	0.0	0.2	41.7	0.0	16.0	42.0	0.0	6,999
Mature male	6	712	52.3	0.0	6.8	0.0	1.8	27.7	11.3	4,859
Mature female	4	441	0.0	0.1	3.6	0.0	0.0	0.0	96.4	6,563
2013	58									
Immature male	41	527	11.1	0.0	37.7	0.0	3.8	47.4	0.0	5,792
Immature female	10	405	0.0	0.0	14.7	0.0	6.1	79.2	0.0	6,458
Mature male	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Mature female	7	432	0.0	0.0	45.0	0.0	0.0	17.5	37.5	5,920

Table 4. The values of the *H index* for the estimation of daily consumption.

H index (Residence days)	*P* (Percentage of annual prey consumption) 70	80	90
120	2.13	2.43	2.74
150	1.70	1.95	2.19
180	1.42	1.62	1.83

Table 5. The average of body mass (kg) and the sexual maturity composition (%) of whales sampled.

Sanriku

Average body mass (kg)

Year	IM	IF	MM	MF
2005	2,439	2,333	3,820	5,362
2006	1,894	2,169	3,971	5,920
2012	1,520	1,690	4,441	4,854

Sexual maturity composition (%)

Year	Number	IM	IF	MM	MF
2003	50	26.0	40.0	16.0	18.0
2005	60	25.0	38.3	13.3	23.3
2006	60	25.4	50.8	18.6	5.1
2007	57	19.6	51.8	16.1	12.5
2008	60	32.2	49.2	6.8	11.9
2009	60	43.3	53.3	1.7	1.7
2010	45	26.7	57.8	13.3	2.2
2012	60	45.0	46.7	3.3	5.0
2013	34	44.1	50.0	5.9	0.0
Average	54	31.9	48.7	10.6	8.9

Kushiro

Average body mass (kg)

Year	IM	IF	MM	MF
2002	1,765	1,955	4,607	6,266
2004	2,543	2,142	4,939	5,341
2005	1,961	1,949	4,651	-
2006	2,298	2,020	5,109	6,520
2007	2,134	1,927	4,977	-
2012	2,337	1,936	5,036	6,793

Sexual maturity composition (%)

Year	Number	IM	IF	MM	MF
2002	50	32.0	22.0	32.0	14.0
2004	59	25.4	16.9	54.2	3.4
2005	60	25.4	25.4	49.2	0.0
2006	35	34.3	22.9	37.1	5.7
2007	50	36.0	34.0	30.0	0.0
2008	50	44.0	30.0	20.0	6.0
2009	59	40.7	39.0	20.3	0.0
2010	60	26.7	36.7	31.7	5.0
2011	60	31.7	36.7	26.7	5.0
2012	48	43.8	35.4	12.5	8.3
2013	58	24.1	17.2	46.6	12.1
Average	54	33.1	28.7	32.8	5.4

Table 6. Estimated numbers of whales distributed in each region (Hakamada *et al.* (2009; 2016 (SC/F16/JR 11)).

Sanriku

Year	Estimates	CV	95% CI LL	95% CI UL
2004	260	0.517	100	675
2005	401	0.300	226	713
2006	216	0.311	119	392
2012	124	0.371	61	251
2003-2013	252	0.385	121	521

Kushiro

Year	Estimates	CV	95% CI LL	95% CI UL
2002	551	0.350	283	1,073
2003	888	0.406	413	1,909
2004	338	0.352	173	660
2005	290	0.350	149	565
2006	221	0.351	113	431
2007	130	0.553	47	358
2012	433	0.542	160	1,171
2002-2013	407	0.415	187	889

Table 7. Fisheries catch data of major prey species off the Pacific coast of Sanriku and Kushiro (Iwashi* include Japanese anchovy and Japanese sardine).

Sanriku

(tons)

Year	Krill	Sand lance
2002	20,585.0	2,668.6
2003	22,385.0	6,677.4
2004	20,941.0	6,908.0
2005	20,278.0	8,679.3
2006	19,094.0	5,294.8
2007	19,011.0	1,789.0
2008	18,629.0	9,191.2
2009	14,602.0	2,253.9
2010	17,693.0	3,909.5
2011	0.0	166.6
2012	7,155.0	478.9
2013	13,025.0	2,823.0

Kushiro

(tons)

Year	Iwashi*	Mackerels	Saury	Pollock
1965	1.0	76,858.0	7,946.0	62,817.0
1966	1,475.0	42,854.0	26,035.0	85,826.0
1967	6.0	48,071.0	19,702.0	109,013.0
1968	0.0	96,740.0	14,972.0	205,407.0
1969	0.0	113,637.0	9,599.0	301,145.0
1970	3.0	197,525.0	22,670.0	272,363.0
1971	0.0	116,956.0	46,977.0	310,803.0
1972	0.0	170,930.0	19,006.0	380,384.0
1973	0.0	174,175.0	89,773.0	557,645.0
1974	292.0	235,283.0	19,532.0	577,889.0
1975	509.0	202,497.0	54,584.0	488,950.0
1976	237,875.0	21,456.0	15,098.0	498,019.0
1977	374,555.0	20,111.0	29,058.0	387,189.0
1978	328,812.0	21,515.0	66,677.0	199,281.0
1979	423,068.0	413.0	59,500.0	163,657.0
1980	371,811.0	6.0	24,195.0	167,430.0
1981	494,038.0	7.0	21,549.0	220,112.0
1982	620,185.0	28.0	24,717.0	191,952.0
1983	801,655.0	193.0	32,789.0	181,116.0
1984	979,206.0	377.0	31,402.0	195,467.0
1985	925,592.0	23.0	44,393.0	177,238.0
1986	920,175.0	25.0	27,106.0	194,290.0
1987	1,063,054.0	44.0	27,908.0	384,597.0
1988	1,031,377.0	18.0	42,967.0	387,709.0
1989	793,349.0	18.0	31,953.0	251,348.0
1990	875,483.0	2.0	50,896.0	146,888.0
1991	607,406.0	0.0	30,246.0	181,205.0
1992	123,452.0	0.0	33,669.0	123,562.0
1993	3,092.0	1,654.0	40,950.0	138,201.0
1994	783.0	0.0	31,462.0	165,937.0
1995	1.0	0.0	60,066.0	113,671.0
1996	0.0	0.0	41,682.0	103,400.0
1997	0.0	18.0	53,281.0	99,860.0
1998	53,465.0	0.0	24,017.0	116,140.0
1999	25,621.0	1.0	25,219.0	103,305.0
2000	0.0	0.0	43,724.0	118,729.0
2001	53.0	0.0	59,743.0	61,720.0
2002	55,235.0	0.0	55,594.0	52,524.0
2003	69,251.0	0.0	59,984.0	75,041.0
2004	85,851.0	0.0	48,403.0	65,186.0
2005	4,639.0	3,364.0	58,528.0	54,628.0
2006	50,410.0	1,688.0	61,895.0	56,582.0
2007	508.0	794.0	69,629.0	51,088.0
2008	1,362.0	0.0	64,115.0	65,086.0
2009	17,254.0	0.0	60,885.0	56,718.0
2010	36,345.0	260.0	35,149.0	64,710.0
2011	9,115.0	40.0	58,824.0	70,700.0
2012	11,788.0	2,416.0	49,550.0	59,061.0
2013	27,073.0	2,696.0	30,529.0	66,317.0

Table 8. Prey species of common minke whales sampled off Sanriku and Kushiro region.

Sanriku

Species		
Main prey		
Krill	*Euphausia pacifica*	
Pisces	*Engraulis japonicus*	Japanese anchovy
	Ammodytes personatus	Sand lance
Miner prey		
Pisces	*Theragra chalcogramma*	Walleye pollocke
	Sardinops melanostictus	Japanese sardine

Kushiro

Species		
Main prey		
Krill	*Euphausia pacifica*	
Pisces	*Engraulis japonicus*	Japanese anchovy
	Sardinops melanostictus	Japanese sardine
	Cololabis saira	Pacific saury
	Scomber japonicus	Chub mackerel
	Gadus chalcogrammus	Walleye pollocke
	(formerly *Theragra chalcogramma*)	
Squids	*Todarodes pacificus*	Japanese common squid
Miner prey		
Pisces	*Paralepis atlantica*	Duckbill barracudina
	Brama japonica	Japanese pomfret
	Oncorhynchus gorbuscha	Pink salmon
	O. keta	Chum salmon

Table 9. Daily prey consumption estimates (kg) *per capita* of each sex and reproductive status.

Sanriku

Maturity stage	Consumption	CV	95% CI LL	95% CI UL
Immature male	98	0.25	56	149
Immature female	106	0.26	60	162
Mature male	166	0.26	91	249
Mature female	223	0.30	112	356

Kushiro

Maturity stage	Consumption	CV	95% CI LL	95% CI UL
Immature male	82	0.19	53	115
Immature female	81	0.19	53	112
Mature male	116	0.22	69	168
Mature female	155	0.23	91	225

Table 10. Prey consumption by common minke whales sampled off Sanriku and Kushiro region.

Sanriku

Year	Numbers of whales	Consumption (tons)	CV	95% CI LL	95% CI UL
2005	401	4,234	0.16	3,066	5,767
2006	216	1,822	0.18	1,293	2,588
2012	124	850	0.20	599	1,325
Average	247	2,302	0.18	1,653	3,227

Year	Prey consumption (tons)		
	Krill	Sandlance	Anchovy
2005	302	3,709	223
2006	–	1,522	300
2012	118	656	76
Average	210	1,962	199

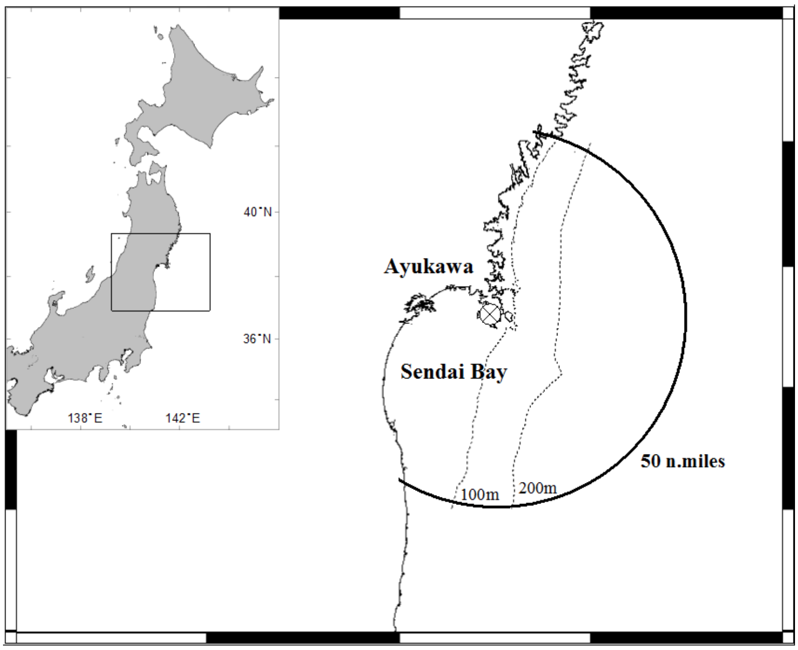
Table 10. Continued.

Kushiro

Year	Numbers of whales	Consumption (tons)	CV	95% CI LL	95% CI UL
2002	551	3,469	0.17	2,747	5,436
2003	888	–	–	–	–
2004	338	2,182	0.23	1,436	3,446
2005	290	2,601	0.23	1,569	3,757
2006	221	1,596	0.19	1,128	2,370
2007	130	782	0.25	568	1,515
2012	433	3,264	0.22	2,408	5,838
Average	407	2,316	0.21	1,643	3,727

Year	Prey consumption (tons)						
	Krill	Anchovy	Sardine	Saury	Mackerels	Pollock	Squid
2002	488	665	0	460	0	791	1,066
2003	–	–	–	–	–	–	–
2004	49	1,204	0	843	0	85	0
2005	627	220	0	18	0	1,546	190
2006	11	971	0	198	0	264	153
2007	41	338	0	170	0	233	0
2012	409	2	724	0	154	1,421	554
Average	271	567	121	282	26	723	327

Sanriku



Kushiro

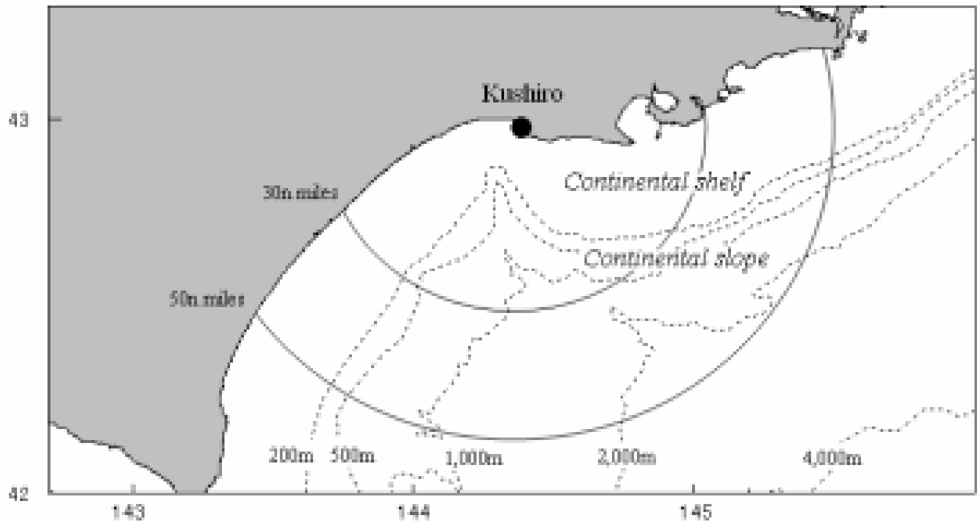
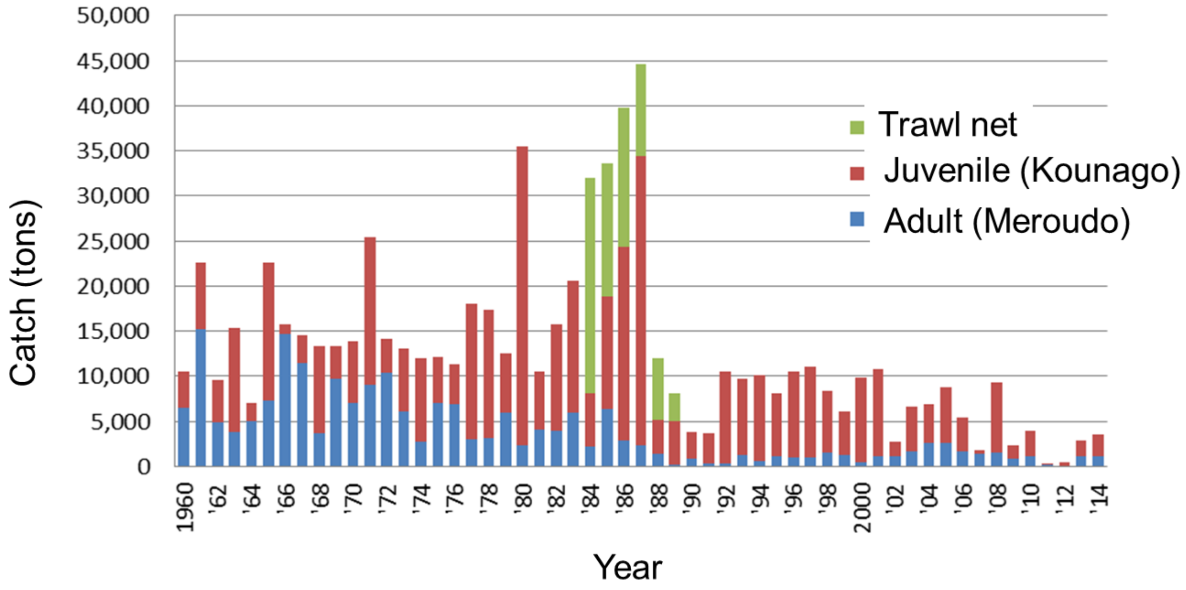


Figure 1. Research area off Sanriku and Kushiro regions.

(A) Sanriku



(B) Kushiro

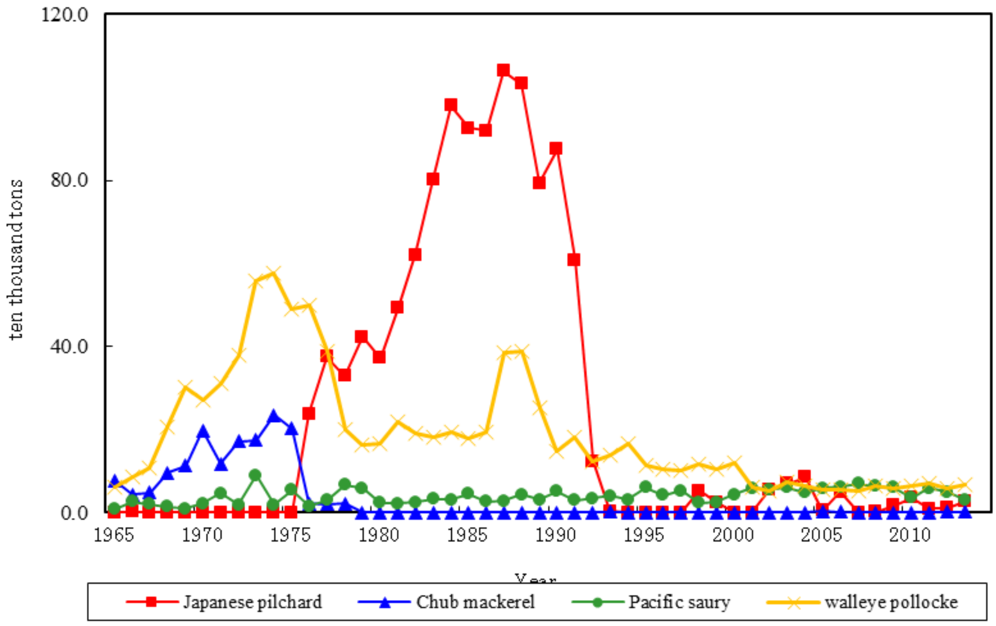
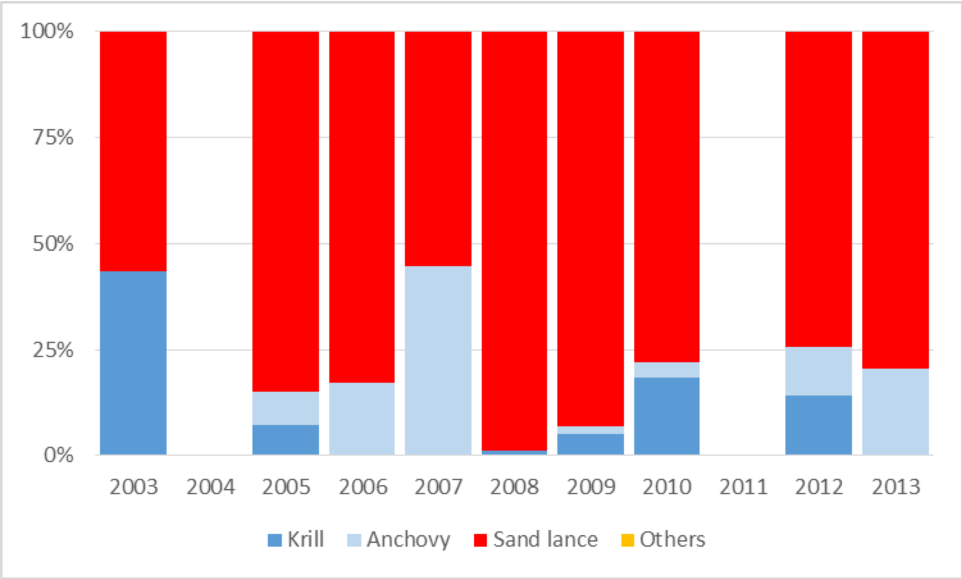


Figure 2. Catch information of fisheries off the Pacific coast of Sanriku (A) and Kushiro (B) (from Miyagi Prefecture Fisheries Technology Institute, Hokkaido Research Organization, Fisheries Research Department, Marine Net Hokkaido and Kishiro *per com.*)

(A) Sanriku



(B) Kushiro

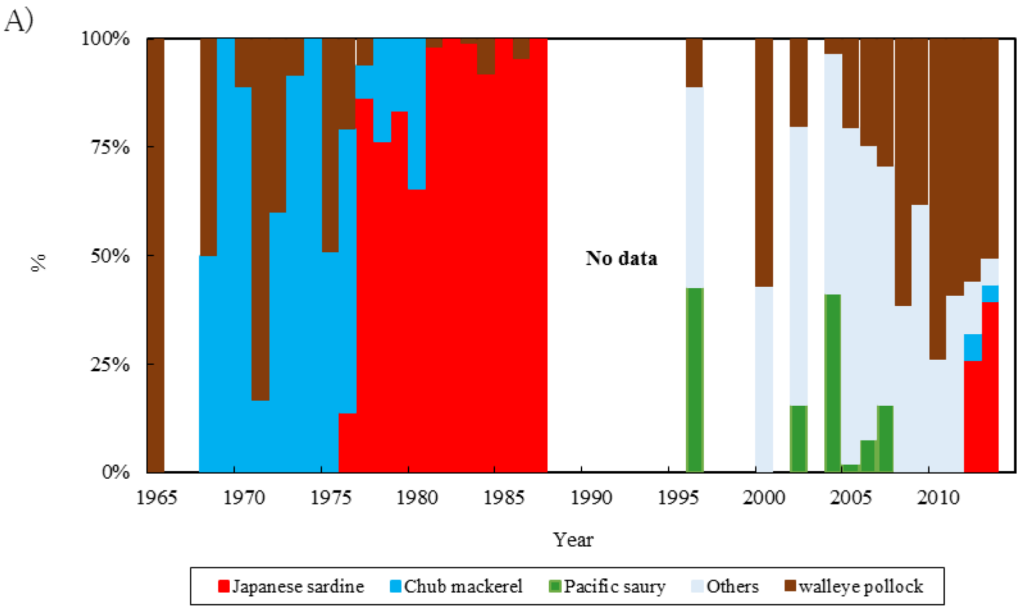


Figure 3. Yearly change of dominant prey species of common minke whales sampled off Sanriku (A) and Kushiro (B) (from Kasamatsu and Tanaka, 1992; JARPN data set (1996); in this study (since 2000))

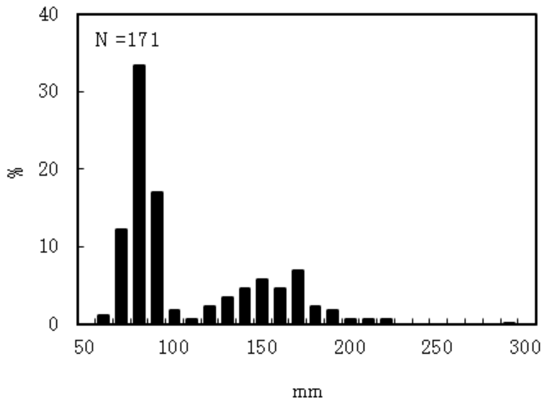
Sanriku

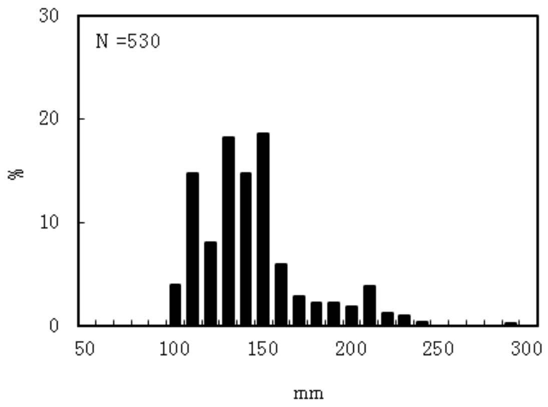
(a) Sand lance

In environment

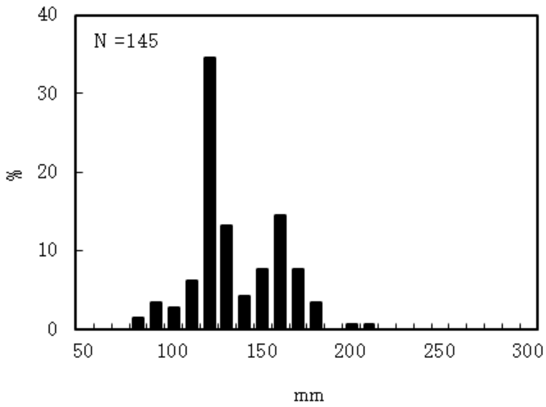
In whale stomach contents

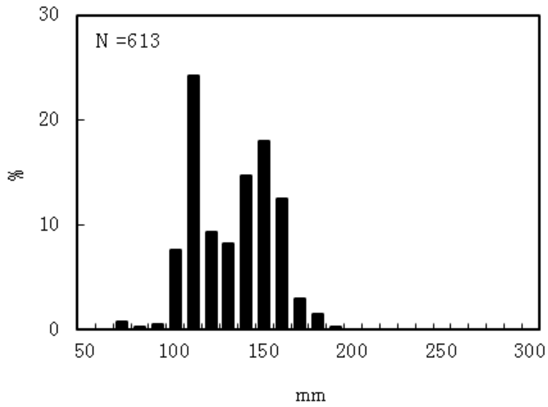
2005 survey



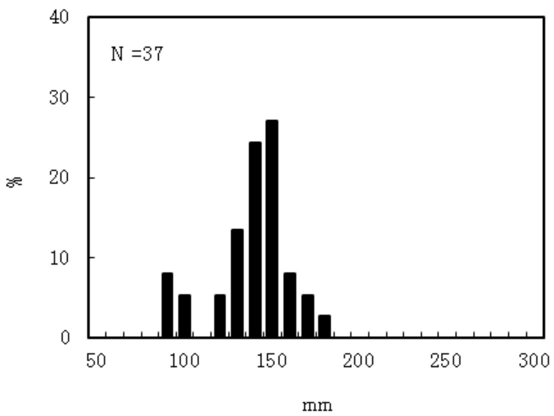


2006 survey





2007 survey



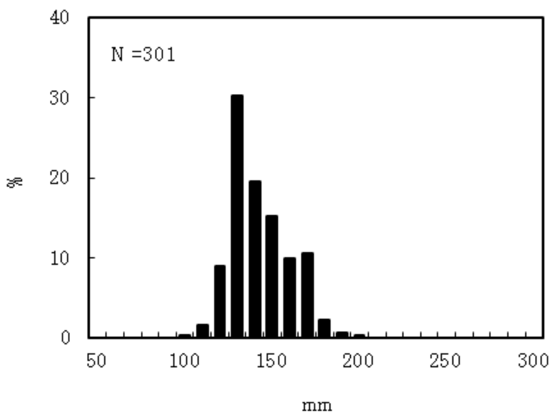
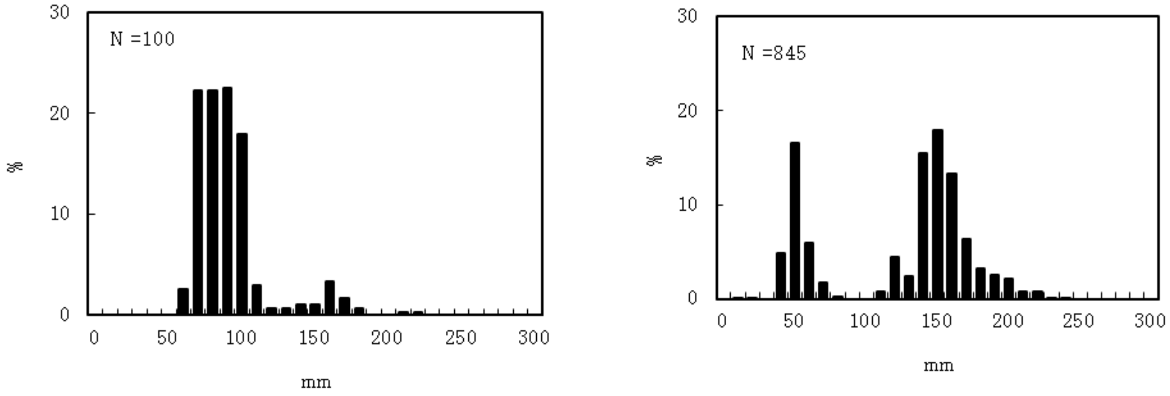


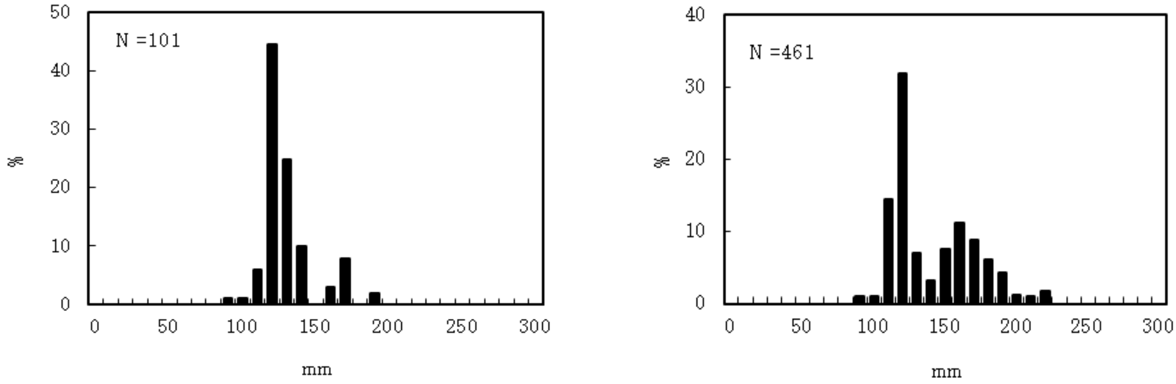
Figure 4. The size distribution of sand lance in the stomach contents of common minke whales and in the environment in Sanriku region

In environment In whale stomach contents

2008 survey



2009 survey



2010 survey

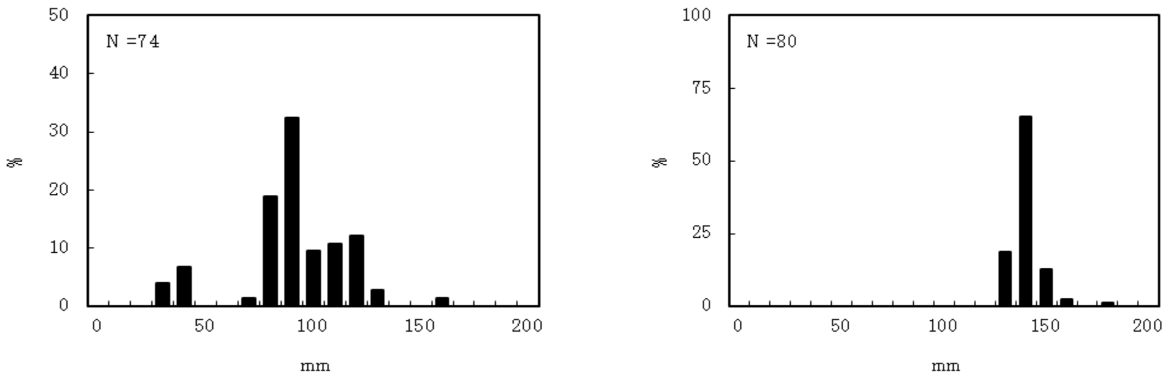
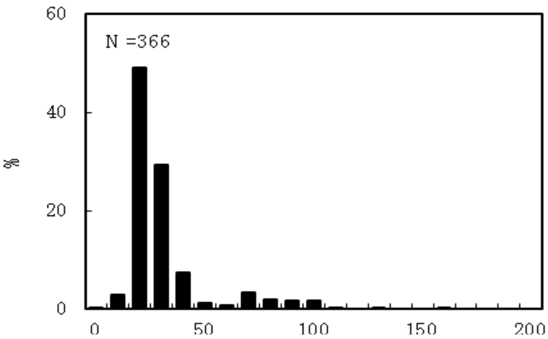


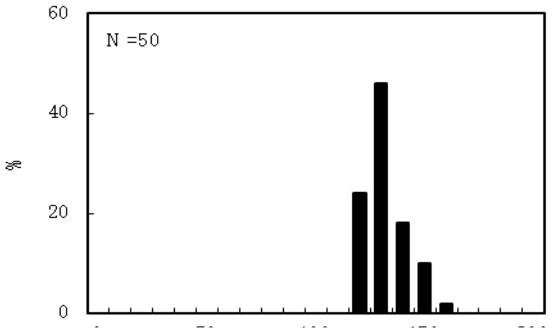
Figure 4. Continued.

In environment

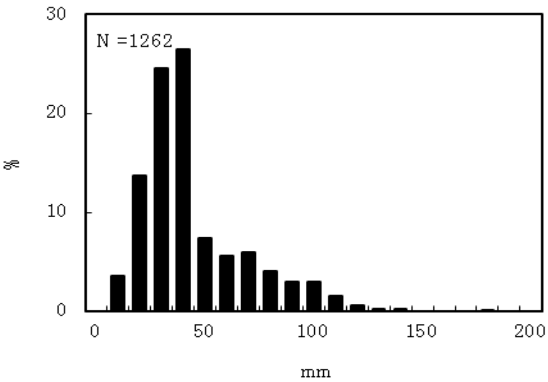
In whale stomach contents

2012 survey





2013 survey



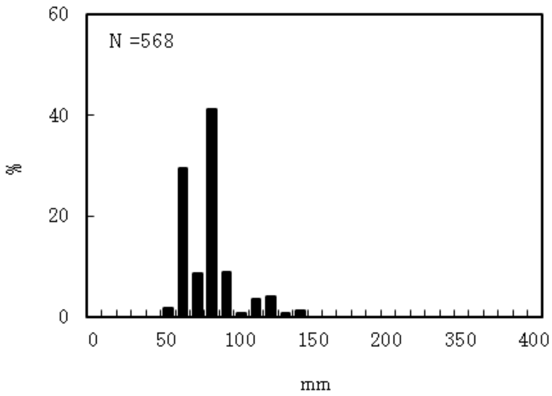


Figure 4. Continued.

Kushiro

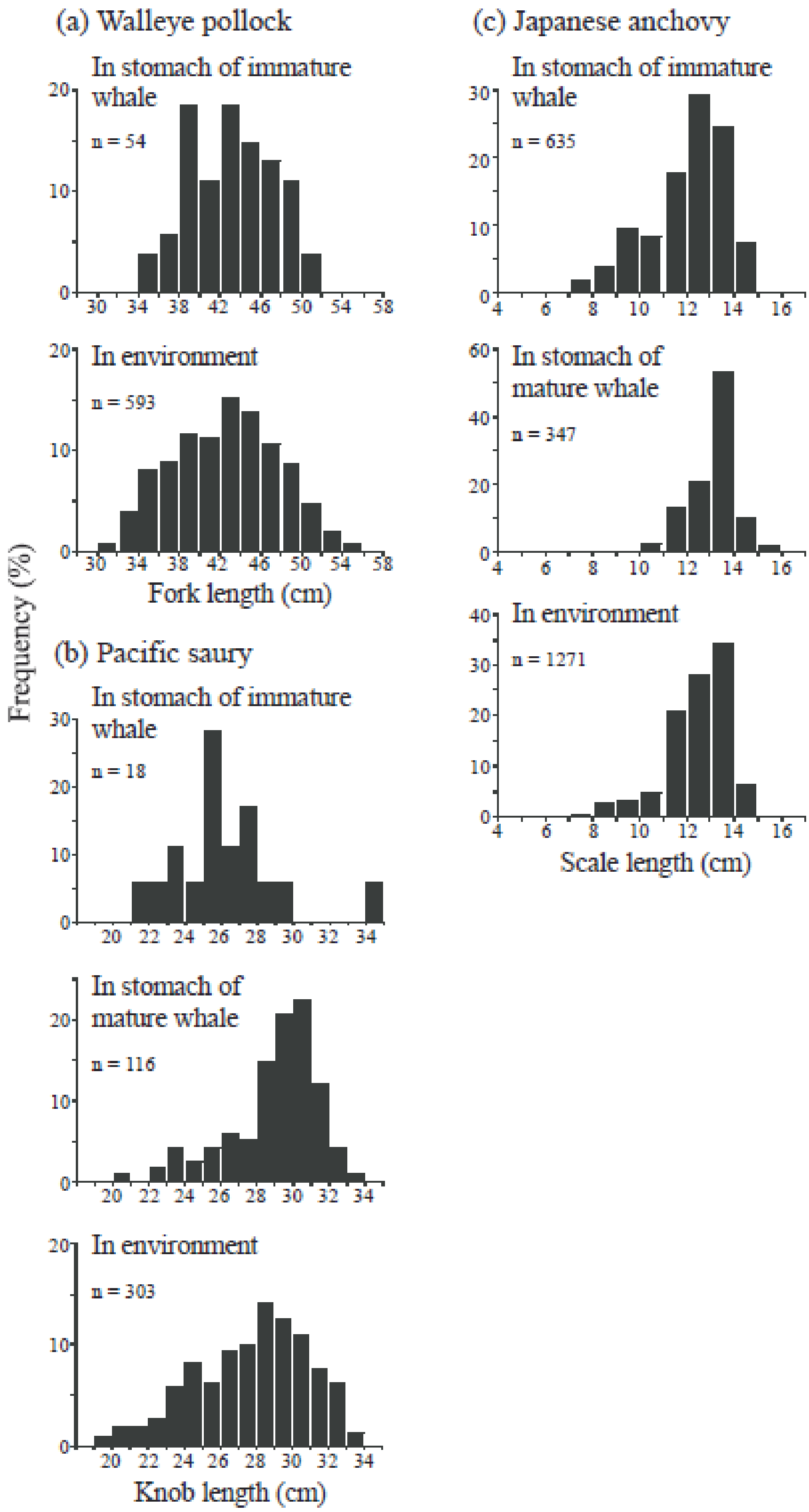
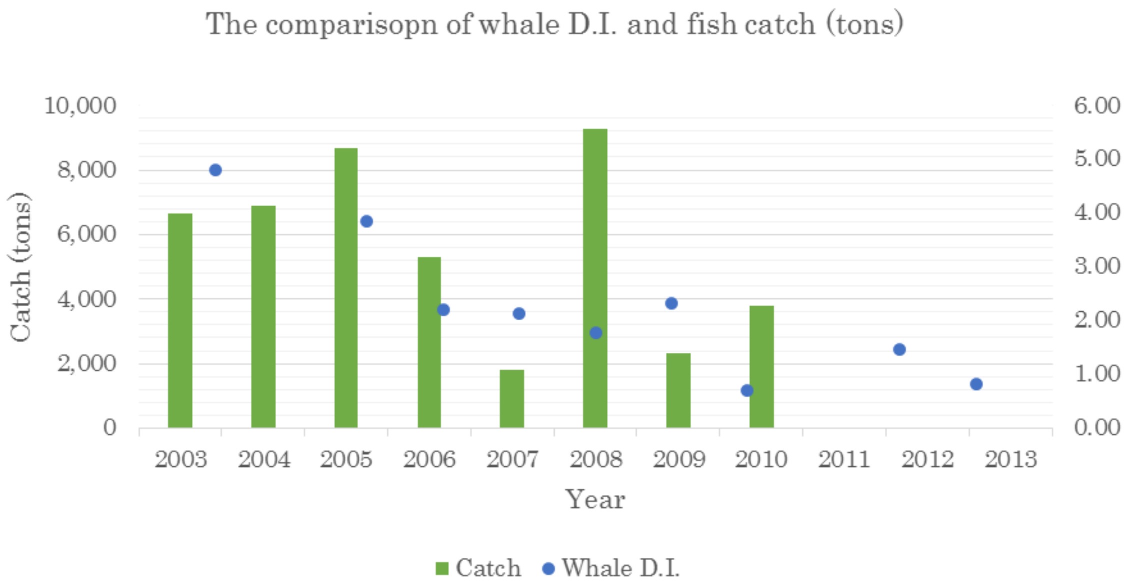


Figure 5. The size distribution of walleye pollock, Pacific saury, Japanese anchovy in the stomach contents of common minke whales and in the environment in Kushiro region.

(A) Sanriku

Sand lance



(B) Kushiro

Japanese anchovy, sardine, Pacific saury, mackerels, and walleye pollock

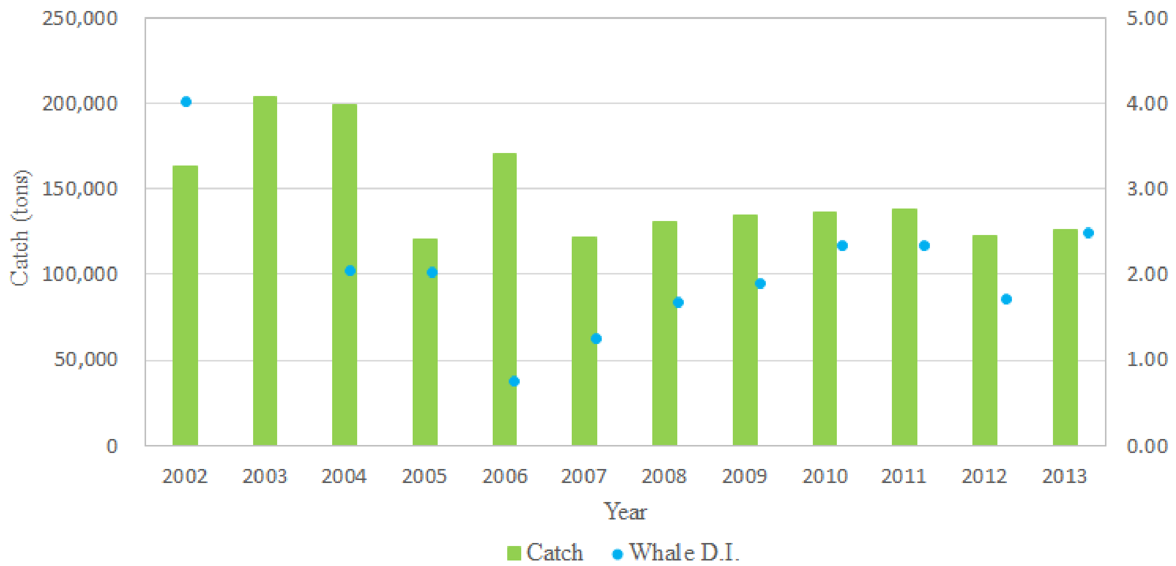


Figure 6. The relationship of minke whale's D.I. (no. of ind. / 100n. miles searched) and (A) Sanriku, sand lance catch (tons) in Sanriku region (B) Kushiro, total catch (tons) of Japanese anchovy, Japanese sardine, Pacific saury, mackerels, and walleye pollock in Kushiro region

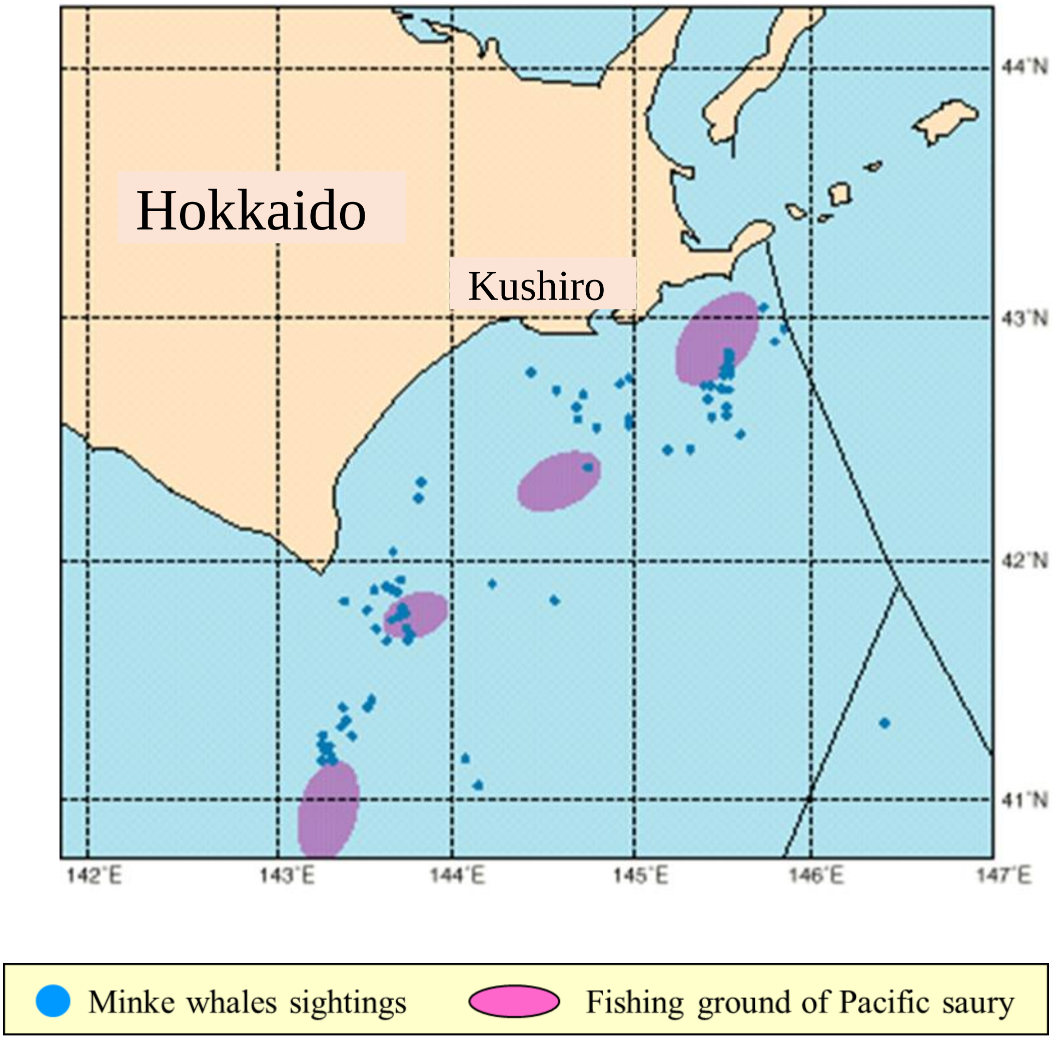


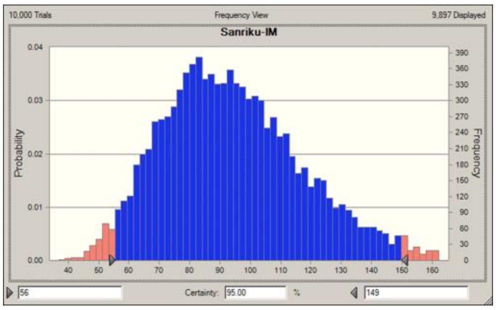
Figure 7. Relationship between minke whale sightings (dot) and the fishing ground (shaded portion) of Pacific saury in the sub-area 7W during 22 July and 8 September 1996. The information of the fishing grounds was obtained from the telex Nos. 27 - 33 on fishing grounds off the Pacific coast of eastern Hokkaido by the Fishing Information Service Center in Japan (Redrawn from Fujise *et al.* 1997).

Appendix 1. The results of simulations

Daily prey consumption (kg) consumed by whales *per capita*

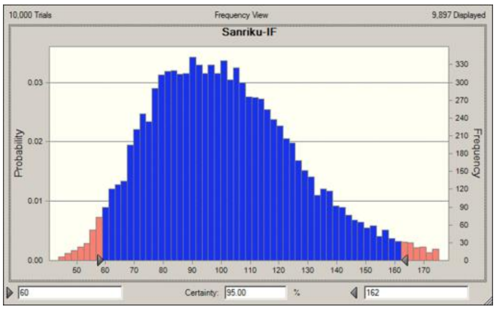
Sanriku

- Immature male



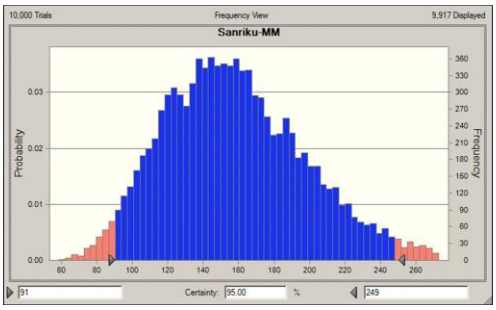
Forecast: Sanriku-IM	
Statistic	Forecast values
Trials	10,000
Base Case	98
Mean	95
Median	92
Mode	'---
Standard D	24
Variance	576
Skewness	0.6592
Kurtosis	3.55
Coeff. of V	0.2532
Minimum	37
Maximum	212
Mean Std.	0

- Immature female



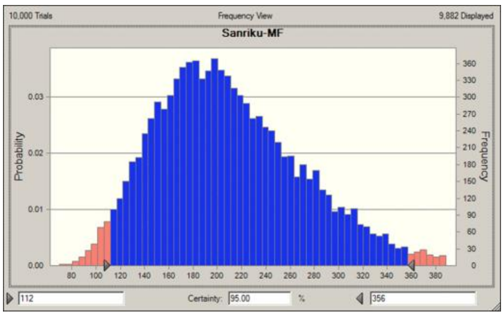
Forecast: Sanriku-IF	
Statistic	Forecast va
Trials	10,000
Base Case	106
Mean	102
Median	99
Mode	'---
Standard D	26
Variance	684
Skewness	0.6612
Kurtosis	3.52
Coeff. of V	0.2565
Minimum	44
Maximum	228
Mean Std.	0

- Mature male



Forecast: Sanriku-MM	
Statistic	Forecast va
Trials	10,000
Base Case	166
Mean	159
Median	155
Mode	'---
Standard D	41
Variance	1,661
Skewness	0.5418
Kurtosis	3.24
Coeff. of V	0.2571
Minimum	59
Maximum	339
Mean Std.	0

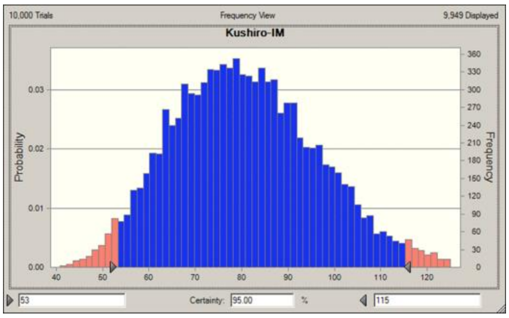
- Mature female



Forecast: Sanriku-MF	
Statistic	Forecast va
Trials	10,000
Base Case	223
Mean	212
Median	203
Mode	'---
Standard D	63
Variance	3,976
Skewness	0.7399
Kurtosis	3.64
Coeff. of V	0.2977
Minimum	70
Maximum	527
Mean Std.	1

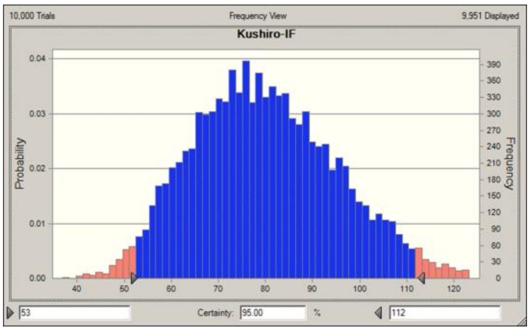
Kushiro

- Immature male



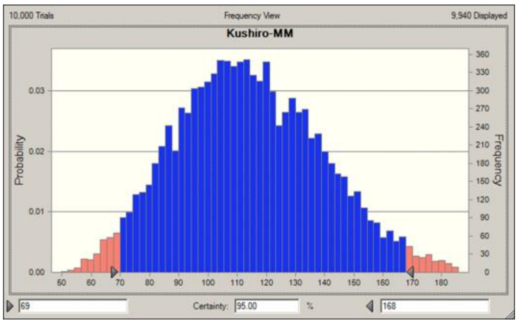
Forecast: Kushiro-IM	
Statistic	Forecast va
Trials	10,000
Base Case	82
Mean	81
Median	80
Mode	'---
Standard D	16
Variance	247
Skewness	0.3475
Kurtosis	2.9
Coeff. of V	0.1942
Minimum	41
Maximum	146
Mean Std.	0

- Immature female



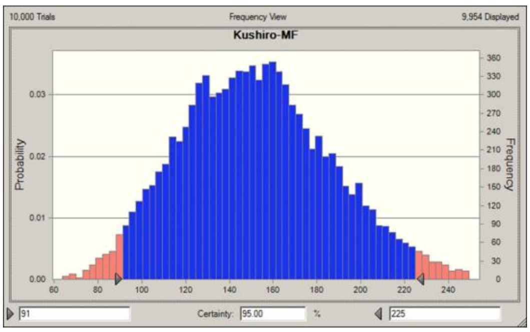
Forecast: Kushiro-IF	
Statistic	Forecast va
Trials	10,000
Base Case	81
Mean	80
Median	79
Mode	'---
Standard D	15
Variance	237
Skewness	0.3306
Kurtosis	2.86
Coeff. of V	0.1923
Minimum	37
Maximum	139
Mean Std.	0

- Mature male



Forecast: Kushiro-MM	
Statistic	Forecast va
Trials	10,000
Base Case	116
Mean	115
Median	113
Mode	'---
Standard D	25
Variance	645
Skewness	0.3276
Kurtosis	2.93
Coeff. of V	0.2216
Minimum	50
Maximum	207
Mean Std.	0

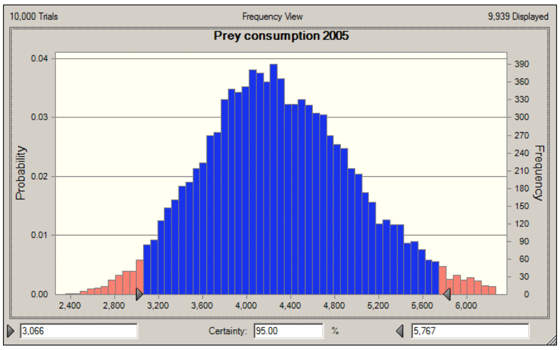
- Mature female



Forecast: Kushiro-MF	
Statistic	Forecast va
Trials	10,000
Base Case	155
Mean	152
Median	151
Mode	'---
Standard D	35
Variance	1,196
Skewness	0.3006
Kurtosis	2.84
Coeff. of V	0.2268
Minimum	64
Maximum	281
Mean Std.	0

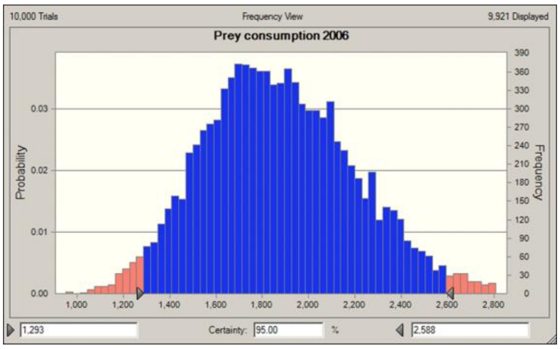
Seasonal prey consumption by minke whales in Sanriku region (From April to May)

- 2005 season



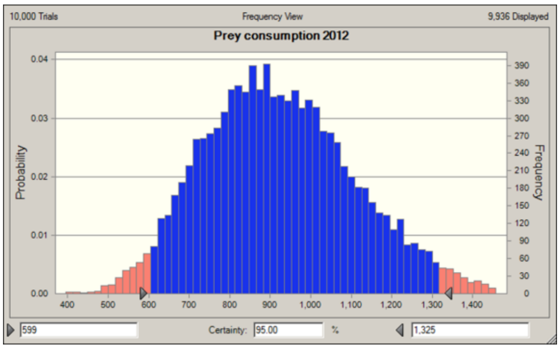
Forecast: Prey consumption 2005	
Statistic	Forecast values
Trials	10,000
Base Case	4,234
Mean	4,308
Median	4,261
Mode	'---
Standard D	696
Variance	484,903
Skewness	0.3386
Kurtosis	3.11
Coeff. of V	0.1617
Minimum	2,132
Maximum	7,320
Mean Std.	7

- 2006 season



Forecast: Prey consumption 2006	
Statistic	Forecast values
Trials	10,000
Base Case	1,822
Mean	1,879
Median	1,854
Mode	'---
Standard D	331
Variance	109,479
Skewness	0.3865
Kurtosis	3.08
Coeff. of V	0.176
Minimum	911
Maximum	3,174
Mean Std.	3

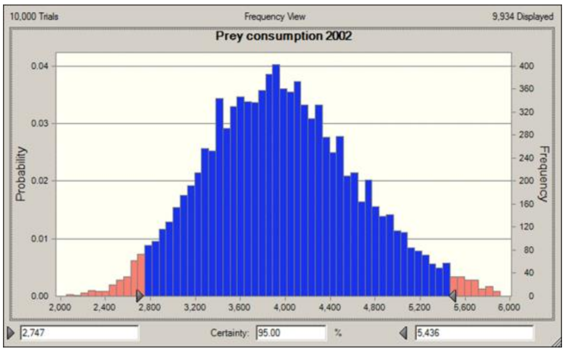
- 2012 season



Forecast: Prey consumption 2012	
Statistic	Forecast values
Trials	10,000
Base Case	850
Mean	926
Median	911
Mode	'---
Standard D	189
Variance	35,798
Skewness	0.4035
Kurtosis	3.11
Coeff. of V	0.2043
Minimum	383
Maximum	1,835
Mean Std.	2

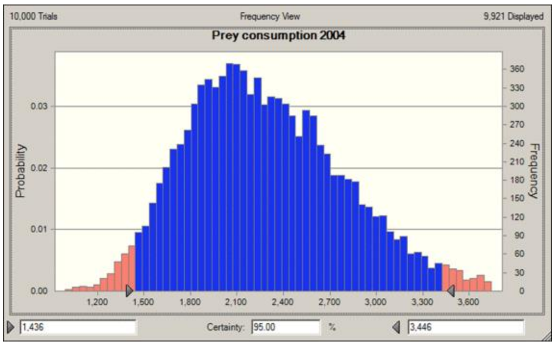
Seasonal prey consumption by minke whales in Kushiro region (From September to October)

- 2002 season



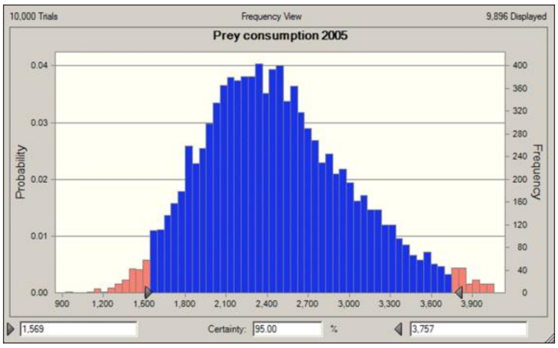
Forecast: Prey consumption 2002	
Statistic	Forecast values
Trials	10,000
Base Case	3,469
Mean	3,981
Median	3,941
Mode	'---
Standard D	688
Variance	473,510
Skewness	0.3575
Kurtosis	3.15
Coeff. of V	0.1728
Minimum	1,905
Maximum	7,170
Mean Std.	7

- 2004 season



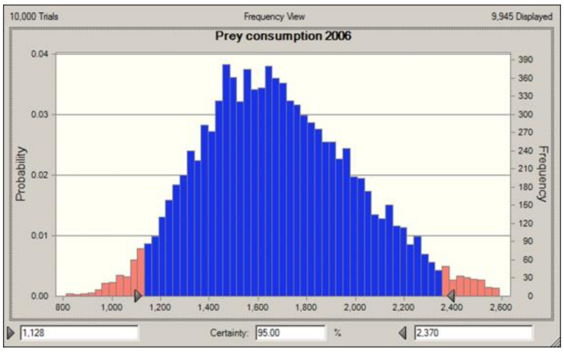
Forecast: Prey consumption 2004	
Statistic	Forecast values
Trials	10,000
Base Case	2,182
Mean	2,293
Median	2,235
Mode	'---
Standard D	517
Variance	266,860
Skewness	0.5279
Kurtosis	3.15
Coeff. of V	0.2253
Minimum	993
Maximum	4,401
Mean Std.	5

- 2005 season



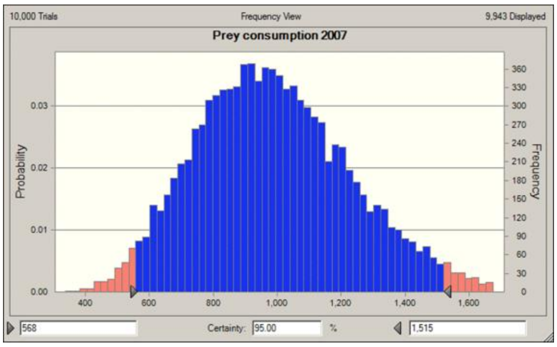
Forecast: Prey consumption 2005	
Statistic	Forecast values
Trials	10,000
Base Case	2,601
Mean	2,486
Median	2,426
Mode	'---
Standard D	559
Variance	312,968
Skewness	0.6307
Kurtosis	3.51
Coeff. of V	0.225
Minimum	928
Maximum	5,098
Mean Std.	6

- 2006 season



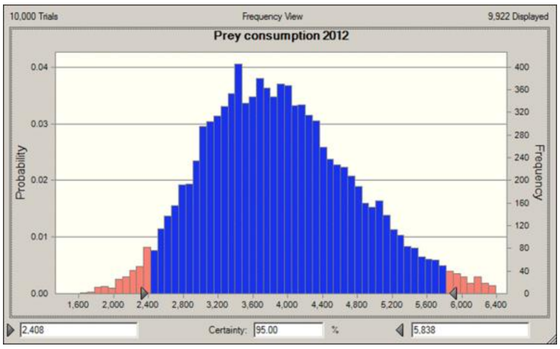
Forecast: Prey consumption 2006	
Statistic	Forecast values
Trials	10,000
Base Case	1,596
Mean	1,687
Median	1,660
Mode	'---
Standard D	322
Variance	103,933
Skewness	0.4082
Kurtosis	3.08
Coeff. of V	0.1911
Minimum	814
Maximum	3,131
Mean Std.	3

- 2007 season



Forecast: Prey consumption 2007	
Statistic	Forecast values
Trials	10,000
Base Case	782
Mean	991
Median	973
Mode	'---
Standard D	244
Variance	59,488
Skewness	0.3934
Kurtosis	2.99
Coeff. of V	0.2462
Minimum	339
Maximum	1,965
Mean Std.	2

- 2012 season



Forecast: Prey consumption 2012	
Statistic	Forecast values
Trials	10,000
Base Case	3,264
Mean	3,918
Median	3,847
Mode	'---
Standard D	880
Variance	774,894
Skewness	0.4672
Kurtosis	3.15
Coeff. of V	0.2247
Minimum	1,343
Maximum	7,505
Mean Std.	9

Appendix 2.

Information of prey species in the coastal waters off Sanriku

MITSUHIRO SAEKI AND KEIICHI ONODERA

Miyagi Prefecture Fisheries Technology Institute, 97-6 Sodenohama, Watanoha, Ishinomaki, Miyagi 986-2135, Japan

Japanese sand lance

R/V *Takuyo Maru* (120GT), Miyagi Prefecture Fisheries Technology Institute

Research period: every year in January

Research area: Sendai Bay

Methods: Bongo net by *Takuyo Maru* (120GT)

Index: CPUE (no. of individuals per m^3)

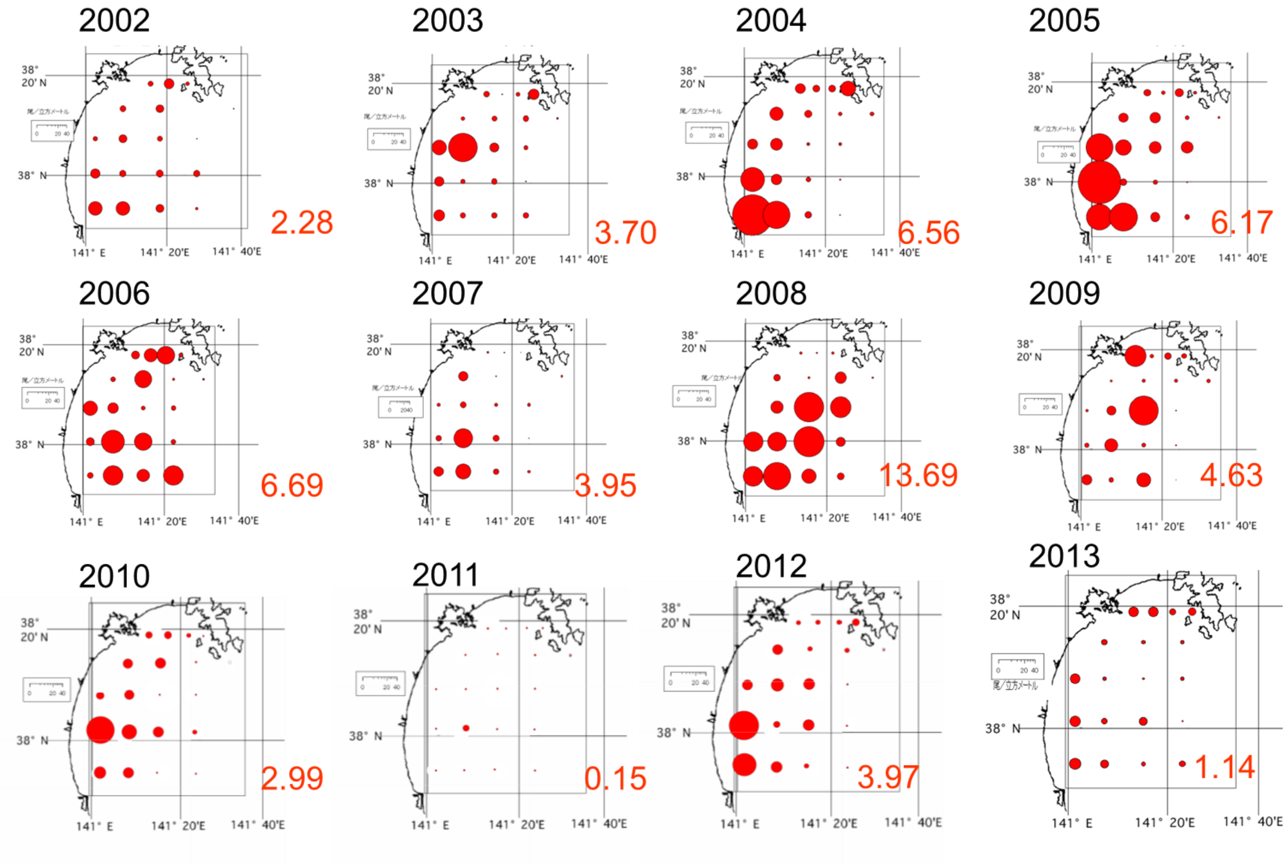


Figure 1. Occurrence of sand lance (juvenile) in January around Sendai Bay (ind./m^3).

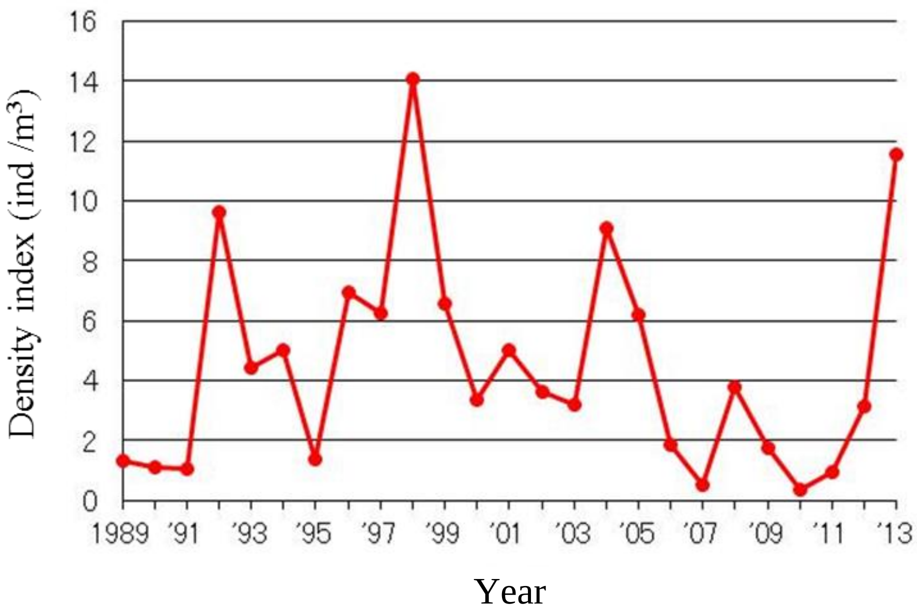


Figure 2. Yearly change of Density Index (ind./m^3) of sand lance in the estivation period around Sendai Bay.

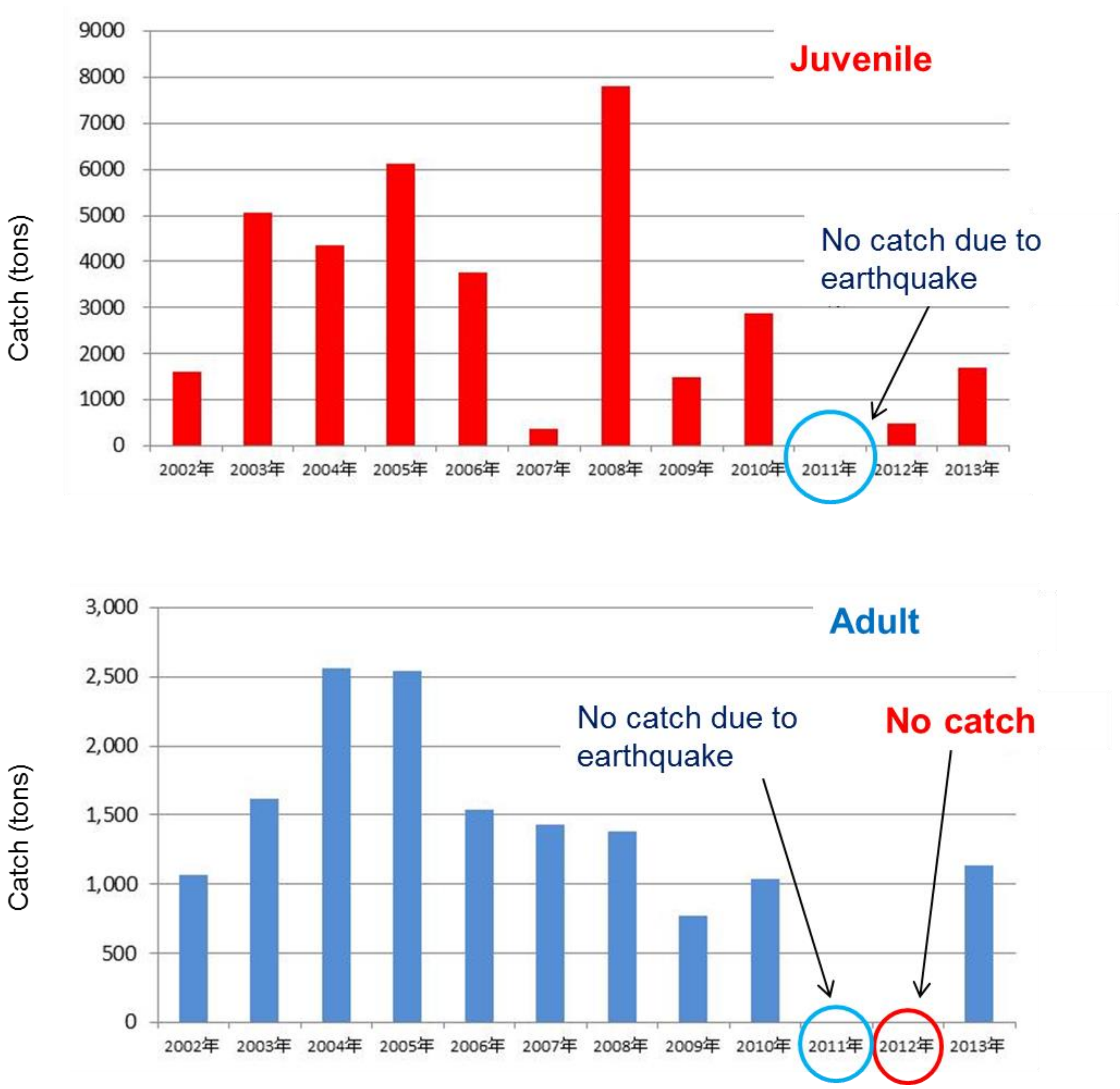


Figure 3. Catch information of Sand lance (Juvenile (kounago) and adult (meroudo)) in Sendai Bay.

Appendix 3.

Information on distributed abundance of prey species taken by common minke whales off Kushiro, with regard to the migration and feeding habit of the whales in the coastal waters off Kushiro

TOSHIYA KISHIRO[1], HIDEYOSHI YOSHIDA[1], MASAKI MITSUHASHI[2], YUUHO YAMASHITA[3] AND TETSUICHIRO FUNAMOTO[3]

[1]*National Research Institute of Far Seas Fisheries, 2-12-4 Fukuura, Yokohama, Kanagawa, 236-8648, Japan*
[2]*Kushiro Fisheries Research Institute, Fisheries Research Department, Hokkaido Research Organization, 2-6, Hama-cho, Kushiro, Hokkaido 085-0024, Japan*
[3]*Hokkaido National Fisheries Research Institute, 116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan*

ABSTRACT

This paper summarized the information on distributed abundance of five fish stocks (Japanese anchovy, Japanese sardine, Pacific saury, mackerels, and walleye pollock) and one squid stock (Japanese common squid) dominantly taken by common minke whales off Kushiro, during the research periods of the JARPNII coastal component off Kushiro in 2002 and afterwards, and made some discussion about migration, feeding habit, and feeding impact of common minke whales off Kushiro. The annual trends of the stock abundance and occurrence of prey species in the Kushiro waters were apparently different among the species, i.e. during the survey periods, Japanese anchovy and Pacific saury were decreased and Japanese sardine and mackerels were increased. In walleye pollock and Japanese common squid, no apparent increasing and/or decreasing trends were observed. The yearly changes in the occurrence of common minke whales feed on pelagic prey species were similar to those in the abundance and occurrence of the corresponded species, and apparent change of the dominant prey species from Japanese anchovy to Japanese sardine with linked to the change of the availability in the environment for each prey species were observed. These results and yearly change in the migration of the whales into the waters suggested that common minke whales migrated into the Kushiro waters according to the amount and availability of the pelagic preys resources in the waters regardless of the respective species (Japanese anchovy, sardine, Pacific saury and mackerels). This kind of migration manner of the whales was thought to be triggered the direct conflict between the whales and local fisheries through the overlapping of local fishing grounds and whale feeding grounds. The ratio of the estimated consumption by the whales migrated in the Kushiro waters to total abundance of the prey was about 0.01 to 0.1%, but these values were only parts of the total consumption by the whale population to the prey resources. To examine the final effects on the prey species populations from predation by the whales, including the information on the other areas and other season to cover the whole populations, and population dynamics studies through developing the ecosystem models will be needed.

INTRODUCTION

The first JARPNII coastal component off Kushiro was carried out in 2002, and the surveys have been conducted in every year since 2004 (Kishiro *et al*., 2016: SC/F16/JR3). Main objective of this component is the JARPNII objective 1: feeding ecology and ecosystem studies, and especially related to direct and/or indirect interaction between the whales and local fisheries (and targeted fish resources). In this regards, the dedicated prey species surveys by echo sounder-trawler survey vessels was conducted in the Kushiro waters from 2002 to 2007 (Watanabe *et al*., 2009a), and those results were submitted to the the first Expert Workshop to review the JARPNII in 2009 (Watanabe *et al*., 2009b). But, the survey was logistically restricted by the vessel availability, ability of the research equipment, and human resources, and difficult to continue in long term periods. Due to these problem, dedicated prey species surveys in the Kushiro waters was suspended in 2008. However, in the coastal waters off Kushiro, fish resources have been independently and diligently studied and surveyed by the dedicated fisheries research organizations outside of the JARPNII for their targeted fish resources and fisheries management. The information from these studies and surveys are valuable and useful to grasp the prey species environment in the coastal waters off Kushiro.

In cooperation with those research institutes, this paper summarised information of stocks and migration index of five fish and one squid species dominantly taken by common minke whales off Kushiro during the research periods of the JARPNII coastal component off Kushiro in 2002 and afterwards, and made some discussion about migration, feeding habit, and feeding impact of common minke whales off Kushiro.

MATERIALS AND METHODS

Prey species taken by common minke whales off Kushiro

Based on the stomach contents analyses of the coastal component off Kushiro, following species was identified as dominant prey for common minke whales in the Kushiro waters (Tamura *et al*., 2016: SC/F16/JR17): krill (*Euphausia pacifica*), Japanese anchovy (*Engraulis japonicus*), Japanese sardine (*Sardinops melanostictus*), Pacific saury (*Cololabis saira*), walleye pollock (*Gadus chalcogrammus*, formerly *Theragra chalcogramma*), chub mackerel

(*Scomber japonicus*), and Japanese common squid (*Todarodes pacificus*). All of those species except for krill are targeted by commercial fisheries off Kushiro, and studied by the dedicated research institutes. Thus, this paper summarised information for above five fish and one squid resources.

Information of the stocks and abundance of prey species

Stocks structures and abundance of fish and squid resources around Japan have been well studied by the several institutes of the Fisheries Research Agency of Japan (FRA) by cooperation with local fisheries research Institutes and Fisheries Agency of Japan, and published for the stock assessment and coastal fisheries managements (Fisheries Agency and Fisheries Research Agency of Japan, 2015). Basically, abundance of each stock was estimated by the cohort analyses with fisheries data and survey data. Among them, information of the stocks which was distributed and targeted by the whales in the Kushiro waters were extracted and summarised.

Migration index of prey species into the Kushiro waters

To examine the annual trends of the prey species migration into the Kushiro waters, results of the several surveys in the south eastern coastal waters of Hokkaido (including Kushiro waters) conducted by the Kushiro Fisheries Research Institute, Fisheries Research Department, Hokkaido Research Organization, and the Hokkaido National Fisheries Research Institute, the Fisheries Research Agency of Japan were used. Basically, catch per unit efforts data (CPUE) obtained from the dedicated surveys or commercial fisheries were used as an index of migration into the waters. Detail of each survey is described in each section below.

Information of common minke whales

Density index (Number of primary sightings per 100 nautical miles searched) obtained from the whale sampling surveys in the coastal component off Kushiro was used to examine the annual trends of the whales into the waters. Detail of the whale sampling surveys was described in Kishiro *et al.*, 2016: SC/F16/JR3). Number of animals in the waters estimated by dedicated sighting surveys (Hakamada *et al.*, 2016: SC/F16/JR11) were also used as a reference information. The occurrence of the prey species in the whale stomach was calculated annually as the ratio of the number of the whales dominantly feed on corresponded species for the total number of the whales caught in corresponded years, and the estimated amount of consumption by the whales was obtained from Tamura, *et al.* (2016: SC/F16/JR17).

RESULTS

Stocks and abundance of prey species targeted by common minke whales off Kushiro

Japanese anchovy: Pacific stock (Kamimura et al., 2015)

Individuals migrated to the coastal waters off Kushiro is classified as the Pacific stock, and distributed along the pacific side of Japan to the offshore waters in the western North Pacific. Main commercial fisheries taking this stock in the south eastern coastal waters of Hokkaido (including Kushiro waters) are purse seine fisheries. Estimated abundance of this stock was quite high (around 1,400 thousand tons) in 2003 but gradually decreased, and about 600 thousand tons in recent years.

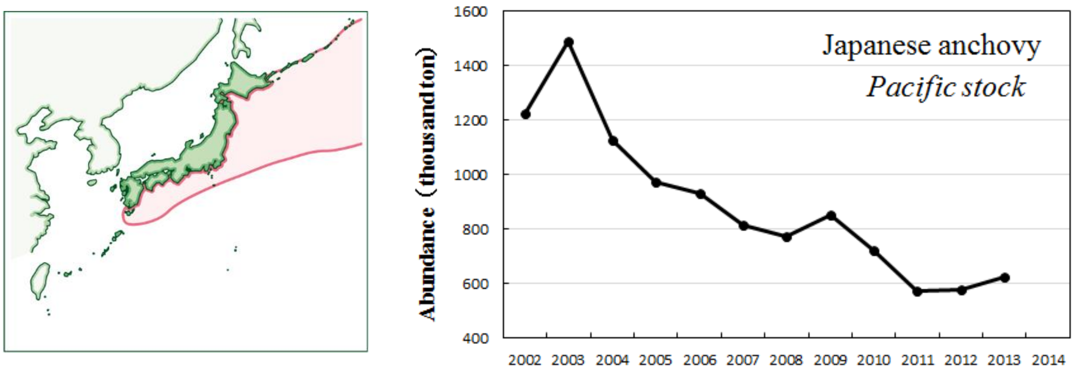


Figure 1. Distribution and annual trend of the estimated abundance of Japanese anchovy, Pacific stock.

Japanese sardine: Pacific stock (Kawabata *et al*., 2015a)

Individuals migrated to the coastal waters off Kushiro is classified as the Pacific stock, and distributed along the pacific side of Japan to the offshore waters in the western North Pacific. As same as Japanese anchovy, main commercial fisheries taking this stock are purse seine fisheries. Estimated abundance of this stock was low (below 200 thousand tons) but rapidly increased in 2010 and afterwards, and about 800 thousand tons in 2014.

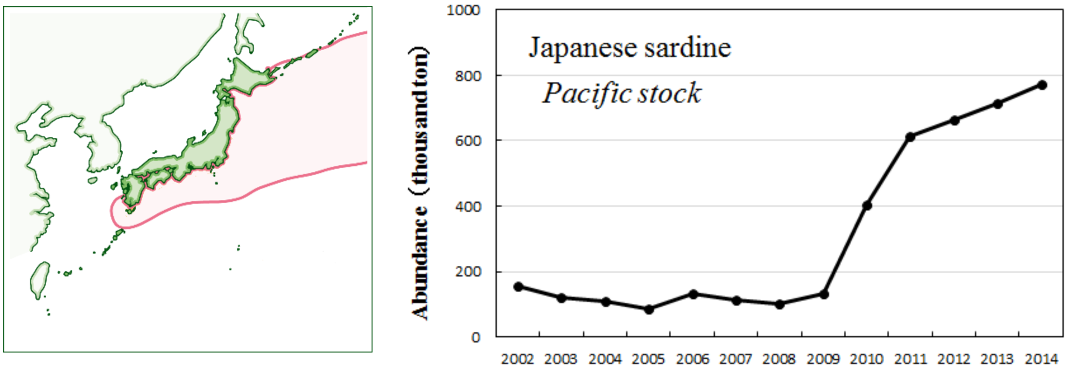


Figure 2. Distribution and annual trend of the estimated abundance of Japanese sardine, Pacific stock.

Pacific saury: Northwest Pacific stock (Nakagami *et al.*, 2015)
Individuals migrated to the coastal waters off Kushiro is classified as the Northwest Pacific stock, and widely distributed around Japan, including East China Sea, Sea of Japan, Okhotsk Sea, and western North Pacific. Main commercial fisheries taking this stock are stick held dip net fisheries. Estimated abundance of this stock was around 5,000 thousand tons in 2003, but gradually decreased, and below 3,000 thousand tons in recent years.

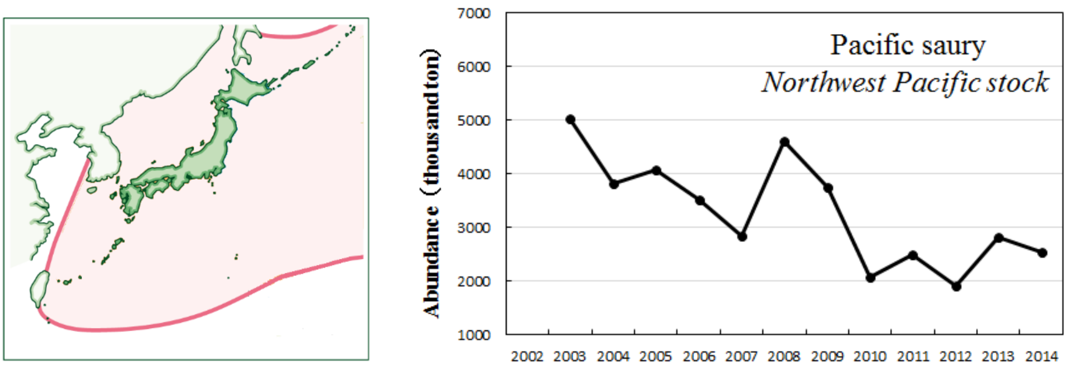


Figure 3. Distribution and annual trend of the estimated abundance of Pacific saury, Northwest Pacific stock.

Mackerels: Pacific stock (Kawabata *et al.*, 2015b; 2015c)
Mackerels distributed around Japan includes two species; *Scomber japonicus*, and *S. australasicus*. Both species migrated to the coastal waters off Kushiro are classified as the Pacific stock, and distributed along the pacific side of Japan to the offshore waters in the western North Pacific. Main commercial fisheries taking these stocks are purse seine fisheries. Estimated abundance of these stocks were low (around 500 thousand tons) in 2002 but gradually increased to over 2,500 thousand tons in 2014.

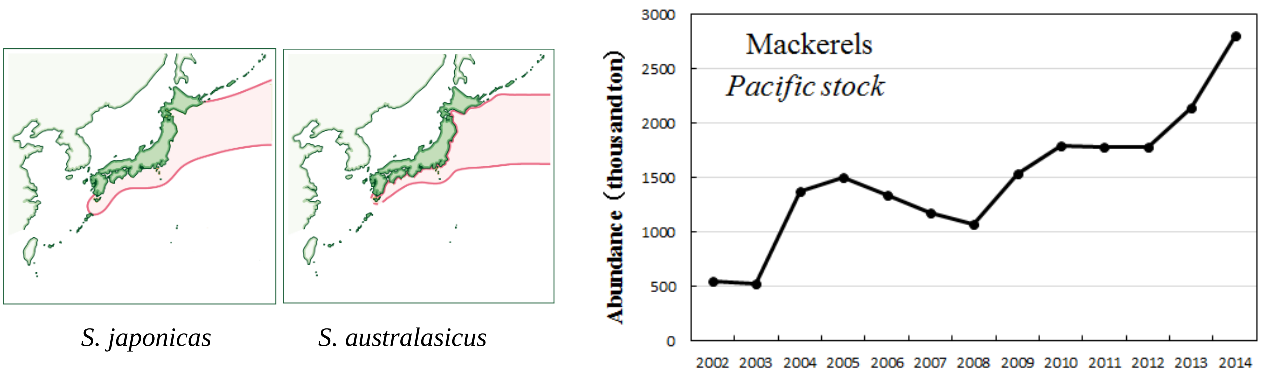


Figure 4. Distribution and annual trend of the estimated abundance of Mackerels, Pacific stock.

Walleye pollock: Japanese Pacific stock (Funamoto *et al*., 2015)

Individuals migrated to the coastal waters off Kushiro is classified as the Japanese Pacific stock. Distribution of this stock is narrow and restricted in the coastal waters off the pacific side of northern Japan. Main commercial fisheries taking this stock in the south eastern coastal waters of Hokkaido (including Kushiro waters) are offshore otter trawl fisheries and Danish seine fisheries. Estimated abundance of this stock is around 1,100 thousand tons and relatively stable compared with other fish stocks, though some fluctuations are observed.

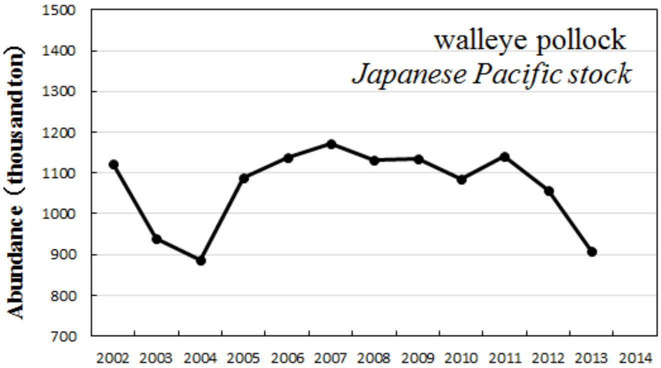


Figure 5. Distribution and annual trend of the estimated abundance of walleye pollock, Japanese Pacific stock.

Japanese common squid: winter spawning stock (Yamashita *et al*., 2015)

Japanese common squids distributed around Japan are divided into two stocks; autumn spawning stock and winter spawning stock, and individuals migrated to the coastal waters off Kushiro is classified as the winter spawning stock, which spawns in the East China Sea in December to March, and migrated in around Japan. Main commercial fisheries taking this stock are quid jigging fisheries. Estimated abundance of this stock is fluctuated from 600 to 1,200 thousand tons, and no apparent increasing and/or decreasing trends are observed.

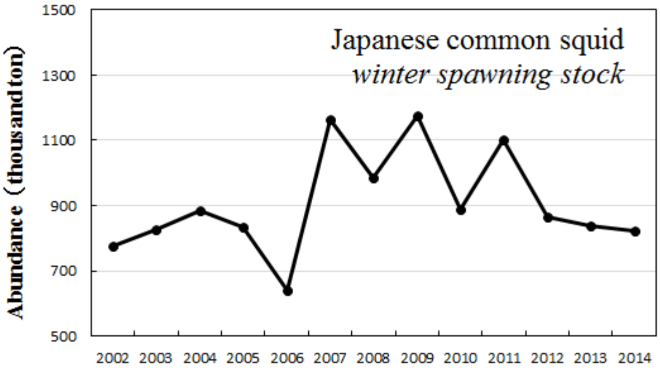


Figure 6. Distribution and annual trend of the estimated abundance of Japanese common squid: winter spawning stock.

Migration of common minke whales into the Kushiro waters

Figure 7 shows yearly change in density index (number of primary sightings per 100 nautical miles searched) of common minke whales obtained from the whale sampling vessels in the coastal component off Kushiro (September to October), and Figure 8 shows the number of common minke whales estimated by the dedicated whale sighting surveys in the south eastern coastal waters of Hokkaido, including Kushiro waters (Hakamada *et al*., 2016: SC/F16/JR11) in the same season. Research areas for sampling and sighting surveys is shown in Figure 9.

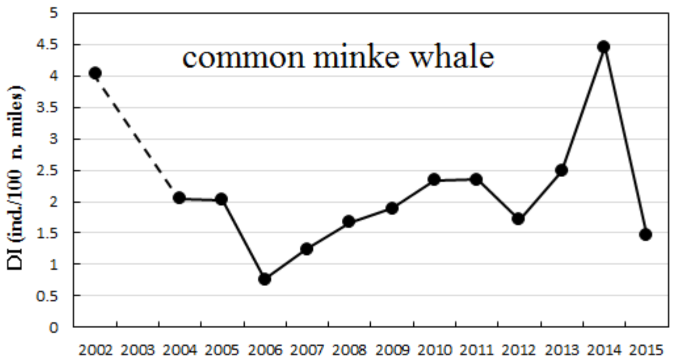


Figure 7. Yearly change in DI (no. of ind./100 n. miles searched)

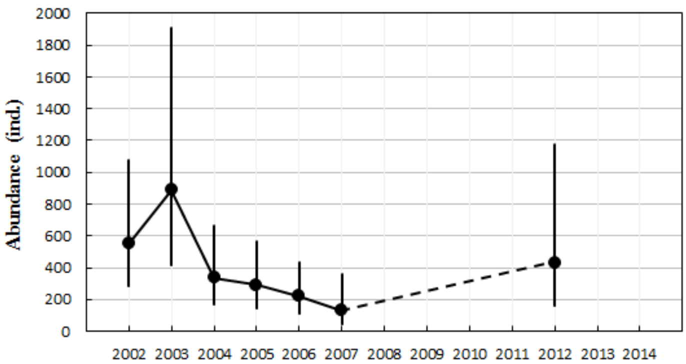


Figure 8. Estimated abundance by sighting surveys by whale sampling surveys (Hakamada *et al.*, 2016: SC/F16/JR11).

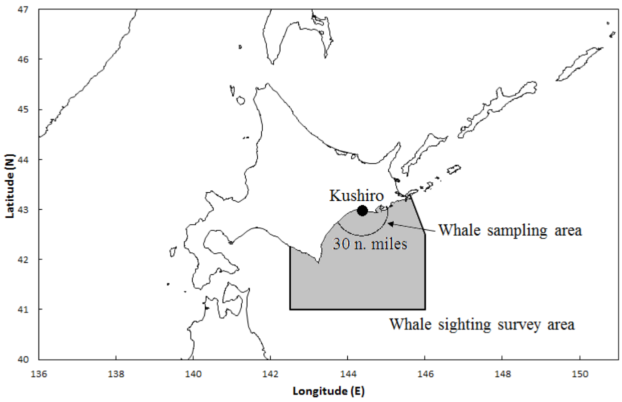


Figure 9. Research areas for whale sampling, and dedicated sighting surveys.

As shown in Figure 9, common minke whale sampling was made in the waters within a 30 nautical miles from the Kushiro port, and the DI in Figure 7 indicates index of the migration into the narrow coastal areas off Kushiro. Although the estimated number of animals in Figure 8 was obtained from wider areas than the whale sampling surveys, both the DI and the estimated number of animals were high in 2002 to 2003, decreased through 2004 to 2006 or 2007, and then increased in 2007 and afterwards. These results suggested that the migration of common minke whales into the coastal waters off Kushiro in autumn season was frequently occurred in early 2000th, decreased in mid-2000th, and increased again in recent years.

Migration of prey species into the Kushiro waters, and occurrence of the prey in the whale stomach

The migration of common minke whales into the Kushiro waters might be affected by the environmental change in the prey in those waters. Thus, the annual trends of the prey species migration into the Kushiro waters in almost same season were examined. These data were obtained from the independent dedicated fisheries surveys as follows:

Japanese anchovy, *sardine*, *Pacific saury*, *and Mackerels*
Information was obtained from the experimental Drifting Gill Nets surveys, conducted by the Kushiro Fisheries Research Institute, Fisheries Research Department, Hokkaido Research Organization.

Research vessel: R/V *Hokushin Maru* (216GT)

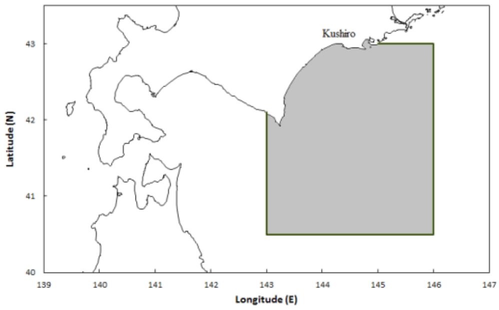
Research period: every year in September (9 to 10 days)

Research area: 41°30’N-43°00’N, 143°00E-146°00’E

Methods: Experimental fishing by drifting gill nets

(5 to 8 research points)

Index: CPUE (no. of individuals per one research)



Japanese common squid
Information was obtained from the experimental Squid Jigging surveys, conducted by the Kushiro Fisheries Research Institute, Fisheries Research Department, Hokkaido Research Organization.

Research vessel: R/V *Hokushin Maru* (216GT)

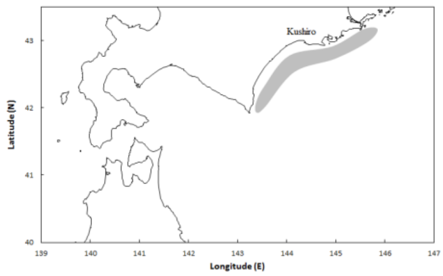
Research period: every year in late August (5 to 8 days)

Research area: along the coast line

Methods: Experimental fishing by squid fishing machine

(8 to 10 research points)

Index: CPUE (no. of individuals per one hour)



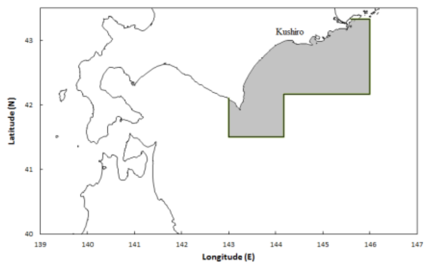
Walleye pollock
Information was obtained from the trawl fisheries catch and effort data, analysed by the Fisheries Management Division, Hokkaido National Fisheries Research Institute, Fisheries Research Agency.

Source: commercial otter trawl fisheries

Area: South eastern coastal waters of Hokkaido (*Dohto area)*

Statistics period: September and October

Index: CPUE (catch (ton) per trawl cast)



The annual trends on the occurrence (CPUE) of Japanese anchovy and Japanese sardine in the Kushiro waters, with the frequency of the whales dominantly feed on those species are shown in Figure 10. The same figures for Pacific saury and Mackerels are shown in Figure 11. The yearly changes in the occurrence of these pelagic fish species in the Kushiro waters were similar to those in the estimated abundance of each fish stock (see above section), and also similar to those in the occurrence of the whales feed on corresponded prey species, though some time lags were observed. These results suggested that common minke whales migrated into the Kushiro waters in autumn season utilized these pelagic fish resources according to the availability and amount of the prey in the respective environment of the waters. These data also indicated apparent change of dominant prey species from Japanese anchovy to Japanese sardine, linked to the change of the availability for each prey species.

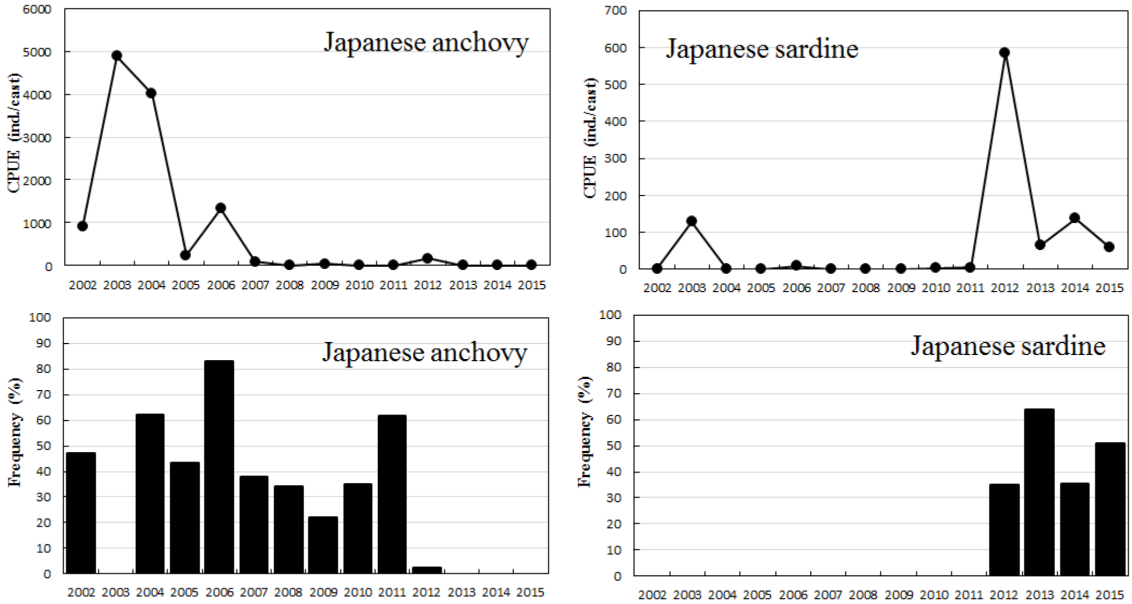


Figure 10. Annual trends on the CPUEs (upper) of Japanese anchovy and sardine, and the frequency of the common minke whales dominantly feed on corresponded species (lower) in the Kushiro waters.

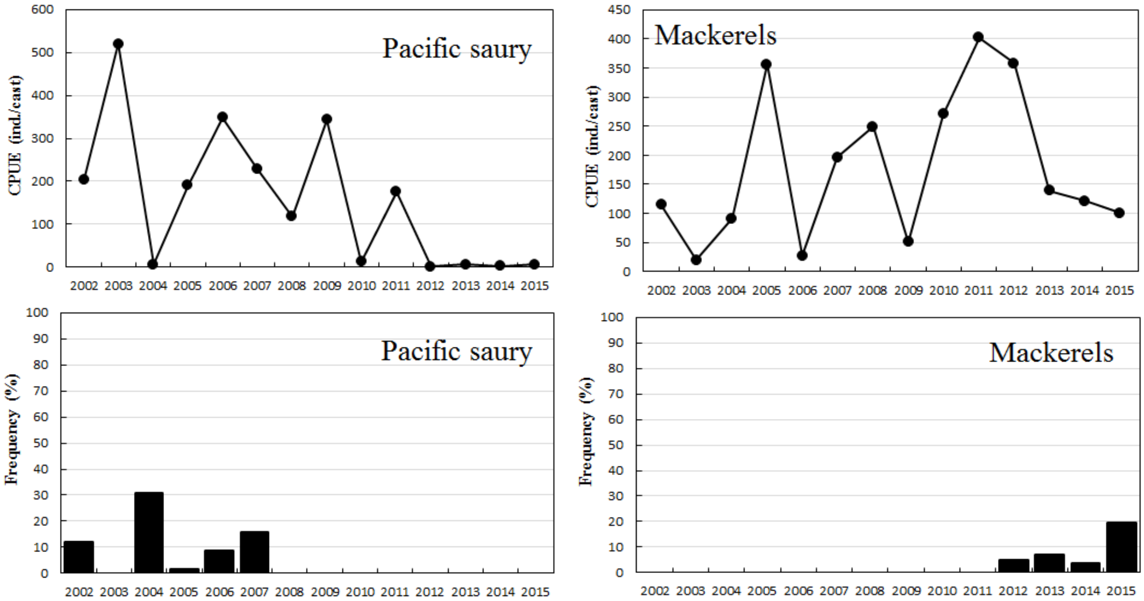


Figure 11. Annual trends on the CPUEs (upper) of Pacific saury and Mackerels, and the frequency of the common minke whales dominantly feed on corresponded species (lower) in the Kushiro waters.

Figure 12 shows the annual trends on the occurrence (CPUE) of walleye pollock and Japanese common squid in the Kushiro waters, with the frequency of the whales dominantly feed on those species. As well as the pelagic fish species, the yearly changes in the occurrence of walleye pollock in environment were similar to those in the whales feed on this species. This suggested that common minke whales also utilized mesopelagic species according to the availability in the environment. On the other hand, frequency of the whales feed on Japanese common squids were quite low, and no apparent relationship between the occurrence in environment with occurrence of the whales was observed.

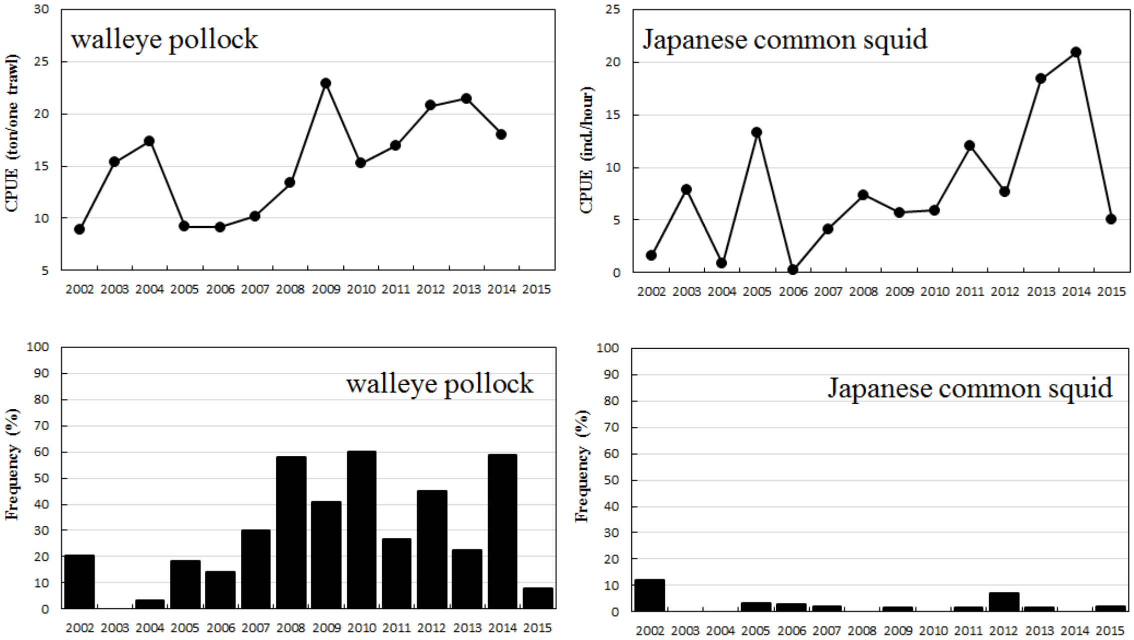


Figure 12. Annual trends on the CPUEs (upper) of walleye pollock and Japanese common squid, and the frequency of the common minke whales dominantly feed on corresponded species (lower) in the Kushiro waters.

Feeding impact of common minke whales off Kushiro to abundance of the prey species stocks

Tamura *et al*. (2016: SC/F16/JR17) estimated consumption of each prey species by common minke whales distributed in the coastal waters off Kushiro in autumn season, based on the individual metabolic rate (energy requirement), number of animals distributed, and prey species composition in the stomach. Among them, the number of animals was based on the sighting surveys in the areas covered the south eastern coastal waters of Hokkaido as shown in Fig.9, and prey species composition was based on the results of whale sampling surveys in the waters within a 30 nautical miles from the Kushiro port. Table 1 shows the respective values of the estimated amount of consumptions with a total abundance of the corresponded prey species stock. The ratio of consumption to the abundance of stock was 0.0003 to 0.11% in Japanese anchovy, 0.11% in Japanese sardine, 0.0004 to 0.02% in Pacific saury, 0.01% in Mackerels, 0.01 to 0.14% in walleye pollock, and 0.02 to 0.14% in Japanese common squid. These results suggested that the feeding impact of the whales distributed in the Kushiro waters in autumn season was about 0.01 to 0.1% of the total abundance of the respective stock, and there was no distinct difference among the prey species.

Table 1. Estimated total abundance of the prey stocks and consumption by common minke whales in the Kushiro waters.

Year	Japanese anchovy			Japanese sardine			Pacific saury		
	Abundance (tons)	Consumption in Kushiro waters (tons)	Ratio (%)	Abundance (tons)	Consumption in Kushiro waters (tons)	Ratio (%)	Abundance (tons)	Consumption in Kushiro waters (tons)	Ratio (%)
2002	1,226,000	665	0.05	157,000	0	0.00	Not available	460	-
2004	1,125,000	1,204	0.11	109,000	0	0.00	3,828,000	843	0.02
2005	974,000	220	0.02	87,000	0	0.00	4,073,000	18	0.0004
2006	929,000	971	0.10	132,000	0	0.00	3,516,000	198	0.01
2007	815,000	338	0.04	113,000	0	0.00	2,831,000	170	0.01
2012	577,000	2	0.0003	665,000	724	0.11	1,920,000	0	0.00

Year	Mackerels			Walleye pollock			Japanese common squid		
	Abundance (tons)	Consumption in Kushiro waters (tons)*	Ratio (%)	Abundance (tons)	Consumption in Kushiro waters (tons)*	Ratio (%)	Abundance (tons)	Consumption in Kushiro waters (tons)*	Ratio (%)
2002	551,000	0	0.00	1,121,322	791	0.07	777,000	1,066	0.14
2004	1,378,000	0	0.00	887,771	85	0.01	883,000	0	0.00
2005	1,499,000	0	0.00	1,087,373	1,546	0.14	833,000	190	0.02
2006	1,335,000	0	0.00	1,139,077	264	0.02	641,000	153	0.02
2007	1,172,000	0	0.00	1,172,962	233	0.02	1,162,000	0	0.00
2012	1,777,000	154	0.01	1,058,631	1,421	0.13	864,000	554	0.06

*: Values of consumption was from Tamura *et al.*, 2016 (SC/F16/JR17)

DISCUSSION

The annul trend of the abundance of prey species stock was apparently different among the species, i.e. Japanese anchovy and Pacific saury were decreased and Japanese sardine and mackerels were increased. Similar trends were observed in the migration index of respective species in the Kushiro waters, and suggested that migration of these species into the Kushiro waters was reflected by the current of those populations. The oceanographic conditions might be influenced to the fluctuation of the population and local migration in these species. In a long term viewpoint, the oceanographic decadal oscillation observed in the Pacific Ocean (Okazaki *et al*., 2016a: SC/F16/JR5) may arouse the regime shift of climate and marine ecosystem change and/or the alternation of the fish species (Schwartzlose *et al*., 1999), as observed in this study. From a local point of view, yearly variations of the oceanographic conditions in the Kushiro waters (Okazaki *et al*., 2016b: SC/F16/JR6) may affect the migration of prey species into the waters, and such variations is thought to be one of the reasons for the time lag of the trends observed between the stock abundance and the local migration index.

The JARPNII coastal component of Kushiro in 2002 and afterwards revealed that the migration of common minke whales into the Kushiro waters was also fluctuated, and suggested that the migration of the whales into these waters in autumn season was frequently occurred in early 2000th, decreased in mid-2000th, and increased again in recent years. From the migration index of respective prey species, the relative abundance of the pelagic prey species in these waters in the same season was thought to be also high in early 2000th (Japanese anchovy and Pacific saury), decreased in mid-2000th, and increased again (Japanese sardine and mackerels) in recent years. These implied that the whales migrated into the Kushiro waters according to the amount and availability of the pelagic preys regardless of the respective species (at least among Japanese anchovy, sardine, Pacific saury and mackerels) in the waters. In general, common minke whales are thought to be opportunistic feeders with flexible feeding habit (Tamura *et al*., 2016: SC/F16/JR17), and the similarity on the trends between the occurrence of these pelagic fish species in the waters and the occurrence of the whales feed on corresponded prey species observed in this study supported this point.

From the viewpoint of the interaction with fisheries, this kind of migration can be triggered the direct conflict between the whales and local fisheries, because both the whales and fishermen flock around the place where their resources are abundantly distributed, and local feeding areas of the whales are overlapped with local fishing grounds. To resolve these problems, further information on the fisheries such as the methods and tactics of the fishing operations including fishing gears, time of operations, and detailed positions on the fishing grounds will be needed.

In context of the indirect interaction between the whales and fisheries, ratio of the estimated consumption by the whales in the Kushiro waters to total abundance of the prey was about 0.01 to 0.1%, and feeding impact of the whales in the Kushiro waters is not so large to the targeted fish populations. However, these values are only parts of the total consumption by the whale stock to the prey resources. To examine the final effects on the prey species populations through the mortality caused by predation, both the whales and prey species should be considered as a population level. In this regards, including the information on the other areas and other season to cover the whole populations, gathering the knowledge on distribution gap caused by the difference of seasonal migration between the populations, and population dynamics studies through developing the ecosystem models will be needed.

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