Prey consumption and feeding habits of common minke, sei and Bryde's whales in the western North Pacific

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ABSTRACT

The stomach contents of common minke whale *Balaenoptera acutorostrata*, sei whale *B. borealis* and Bryde's whale *B. edeni* sampled in the western North Pacific from May to September in 2000-2007 JARPN II were analyzed. The purposes of this study are to estimate the amount of fish resources consumed by the three whale species. Prey species of whales were identified by examining their stomach contents, and the amount of prey consumed in the research area was estimated by extrapolation using information on prey consumption per individuals and abundance of whales. The main prey species of common minke whale consisted of one copepod, two krill, two squids and eight fish. The main prey species of sei whale consisted of two copepods, three krill and four fish. The main prey species of Bryde's whale consisted of five krill, one squid and four fish. There were seasonal and geographical changes of prey species. The total prey consumption by three baleen whales during the feeding season was 1.6 million tons per year. The prey consumption of Japanese anchovy, mackerels and Pacific saury by three baleen whales were estimated as 739 thousands tons, 140 thousands tons and 43 thousands tons per year, respectively. The consumption of Japanese anchovy, mackerels and Pacific saury were equivalent to 15.4 %, 13.9 % and 1.0 % of their biomass, respectively. The consumption of Japanese anchovy, mackerels and Pacific saury were equivalent to 224.1 %, 33.3 % and 10.6 % of fisheries catch in each year by Japan, respectively.

KEYWORDS: COMMON MINKE WHALE; BRYDE'S WHALE, SEI WHALE, NORTH PACIFIC; SCIENTIFIC PERMIT

Introduction

Use of marine living resources must be done with sustainable way, so that people have responsibility to examine and evaluate the interactions between top predators and fisheries. However, historical fishery industry showed many cases of depletions in exploited species all over the world. Some species of large baleen whale are examples of the depleted resources by some countries, and then IWC has developed the RMP and RMS for sustainable commercial whaling without depletion. Recent ecosystem based management is alternative management procedure which conserve "ecosystem" not one species, therefore species interactions in management area are becoming important.

Baleen whales generally feed on variety size of prey from small zooplankton to fish, playing an important role in the food web in the Western North Pacific because of their large biomass (Hakamada in this meeting). The Second Phase of Japanese Whale Research Program in the Western North Pacific (JARPN II) conducted samplings of common minke, sei and Bryde's whales that abundantly occur off the coast of Japan and are important comportments of the ecosystem in their feeding grounds.

Although these three baleen whales occur in the JARPN II research area, their feeding habits and distribution differ. Minke whale feed on zooplankton to large sized fish such as Pacific saury, Japanese flying squid and mackerel, indicating wide range of prey size (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992; Tamura and Fujise, 2002).

The sei whale is known to feed on a wide spectrum of marine animals such as krill, Japanese anchovy, chub mackerel, Pacific saury and Japanese common squid. According to Nemoto (1962), sei whales feed mainly copepods in the northern part of the North Pacific, but they likely feed on fishes and squids off the Pacific coast of northern Japan. In the southern Aleutian waters, Pacific saury was also reported as important prey for sei whales (Nemoto, 1959; Kawamura, 1982).

The information of feeding in Bryde's whales was available from commercial whaling period, showing krill, Japanese anchovy (*Engraulis japonicus*) and Chub mackerel (*Scomber japonicus*), Japanese sardine (*Sardinops melanostictus*), and horse mackerel (*Trachurus japonicus*) as prey.

The overall goal of the JARPN II was to contribute to the conservation and sustainable use of marine living resources including whales in the western North Pacific, especially within Japan's EEZ. This study examined the prey consumption of common minke, Bryde's, sei whales which contribute to the objectives in JARPN II, using up-dated whale abundance estimates obtained by JARPN II sighting survey.

Material and Methods

Research area, year and sample size

The research area of the JARPN II was a part of sub-areas 7, 8 and 9, which were established by the IWC/SC (IWC, 1994) (Fig. 1). The survey months, years and sample size in each sub-area are shown in Table 1. A total of 740 minke whales, 489 sei whales and 393 Bryde's whales were examined in this study (Table 1).

Sampling and treatment of stomach contents from 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). Therefore, this study was based on contents from forestomach and fundus.

In the JARPN II surveys, the stomach contents were removed on the ship's flensing deck after capture. Then, contents were weighed to the nearest 0.1 kg. A sub-sample (1-5 kg) 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 (20 mm, 5 mm and 1 mm), 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 (3-4 kg) included all undigested fish skulls, free otoliths and squid beaks, which were kept frozen for later analyses in the laboratory.

Data analyses

Prey species identification and restoring 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, copepods (Brodskii, 1950), euphausiacea (Baker *et al*., 1990), squids (Kubodera and Furuhashi, 1987) and fish (Masuda *et al*., 1988; Chihara *et al*., 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 1 mm and 1 g, 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. The total weight of each zooplankton was estimated by using an assimilation efficiency of 84 % (Lockyer, 1981a).

Prey composition in each month and sub area

In order to simplify the comparison of feeding indices, prey species were divided into the following prey groups: copepods (*Neocalanus cristatus*, *N. plumchrus*, *Calanus* sp.), krill (*Euphausia pacifica*, *E. similes*, *E. gibboides*, *Thysanoessa gregaria*, *Nematoscelis difficilis*), Japanese flying squid (*Todarodes pacificus*), Japanese anchovy (*Engraulis japonicus*), Japanese sardine (*Sardinops melanostictus*), Pacific saury (*Cololabis saira*), walleye pollock (*Theragra chalcogramma*), Mackerels (*Scomber japonicus*, *S. australasicus*), Japanese pomfret (*Brama japonica*), Atka mackerel (*Pleurogrammus monopterygius*), oceanic lightfish (*Vinciguerria nimbaria*), minimal armhook squid (*Berryteuthis anonychus*), Salmonidae, other squids and other fishes.

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

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

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

The daily consumption of each prey species (*D*) by different maturity stages of minke, sei and Bryde's whale were calculated from the following equations (Sigurjónsson and Víkingsson, 1997):

$D = 206.25M^{0.783}$; $F = D/E$

D : Daily prey consumption (kcal day^{-1})
M: Mean body weight of whales (kg)
F : Daily prey consumption (kg day^{-1})
E : Caloric value of prey species (kcal kg^{-1})

The following assumptions were made for this method.

A: Mean body weight (*M*)
The mean body weight of 2,600 kg and 2,200 kg for immature male and female of minke whale were calculated, respectively. For mature male and female of minke whale were 4,900 kg and 6,500 kg, respectively. The mean body weight of 13,700 kg and 15,400 kg for immature male and female of sei whale were calculated, respectively. For mature male and female of sei whale were 19,900 kg and 24,800 kg, respectively. The mean body weight of 9,600 kg and 9,300 kg for immature male and female of Bryde's whale were calculated, respectively. For mature male and female of Bryde's whale were 15,500 kg and 17,800 kg, respectively. These weights were obtained from JARPN II survey data (Table 2).

B: Caloric value of prey species (*E*)
Stomach contents analyses show large variations in the diet of baleen whales in the western North Pacific

(Kasamatsu and Tanaka, 1992; Tamura *et al.*, 1998). In the North Atlantic, the energy contents of the prey species varies from 900 kcal kg^{-1} when feeding on *Parathemisto* spp. to as high as 3,000 kcal kg^{-1} when feeding on herring (Markussen *et al*., 1992). In this study, the mean caloric value of copepods, krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese flying squid were calculated using bomb caloric meter (Table 3).

C: Residence time in the western North Pacific

Many baleen whale generally known to migrate between the feeding ground in high latitudinal waters in summer and the breeding ground in low latitudinal waters in winter. Miyashita *et al.* (1995) fixed up the worldwide map of cetacean distribution based on Japanese sighting data (1964-1990). Unfortunately, there were few research activities during winter (from November to March) due to wrong weather condition for sighting research of cetaceans. It was assumed that the minke whales, sei whale and Bryde's whale spend about 150 days (research season) in the feeding areas in the western North Pacific. Lockyer (1981a) indicated that around 83% of the annual energy intake in southern Hemisphere balaenopterid species is ingested during the summer season, corresponding to approximately ten times higher feeding rates during feeding season of summer than non-feeding season of winter.

Based on this assumption, the average daily prey consumption during feeding season (*SF*) (From May to September), and during non-feeding season (*NF*) (From October to April) were made for the baleen whales by the following equations:

$$SF = 2.020\ F$$

$$NF = 0.289\ F$$

D: The total prey consumption during feeding period

The feeding period were divided up early period (May-June; 60days) and late period (July-September; 90days). The total prey consumption during feeding period per individual was estimated in each month and sub-area using the composition of prey species in JARPNII results.

E: The composition of maturity stages of whales

The composition of maturity stages of whales is shown in Table 4. Males of minke, Bryde's and sei whales were defined as sexually mature by testis weight (larger side) of more than 290g, 560g and 1,090g, respectively (Bando *et al*., unpublished data). Female were defined as sexually mature by the occurrence of at least one corpus luteum or albicans in their ovaries. The rate of mature males in minke whales was higher in each season and sub area. For sei whales, the rate of mature males and females were higher. The rate of mature females in Bryde's whales was higher than other in each season and sub area.

F: The seasonal abundance of whales in each sexual maturity stage and area

Based on the abundance of whales in each area and season by Hakamada *et al*. (2009) and the above composition of maturity stages of whales (Table 4), the seasonal abundance of whales in each sexual maturity stage and area is shown in Table5.

Results

Diversity of prey species

Minke whales

A total of fourteen prey species, including 1 copepods, 2 euphausiids, 2 squids and 9 fishes were identified in the 740 stomachs of minke whales (Table 6).

Sei whales

A total of twelve prey species, including 3 copepods, 3 euphausiids, 1 squid and 5 fishes were identified in the 489 stomachs of sei whales (Table 6).

Bryde's whales

A total of eighteen prey species, including 5 euphausiids, 1 squid and 12 fishes were identified in the 393 stomachs of Bryde's whales (Table 6).

Composition of prey species

Minke whales

Most minke whales (88 %) had fed upon one single prey species at a time. Animal of 11 % had fed upon two species and only 0.6 had more than two prey species in the stomach (Table 7-1).

Sei whales

Most sei whales (90 %) had fed upon one single prey species at a time. Animal of 10 % had fed upon two species in the stomach (Table 7-2).

Bryde's whales

Most Bryde's (92 %) had fed upon one single prey species at a time. Animal of 8 % had fed upon two species in the stomach (Table 7-3).

Geographical and seasonal changes in dominant prey species

Minke whales

In sub-area 7, Japanese anchovy was the dominant prey species, composing 85.7 and 71.3 % of the total weight ingested in May and July (Table 8-1). In May and June, minke whales consumed Japanese anchovy in the middle part of the research area (38 Nº – 40 Nº)(Fig. 2-1), while in July and August, minke whales consumed this species in the middle and northern part of the research area (38Nº – 42Nº) (Fig. 2-1). In September, Pacific saury was the dominant prey species, composing 79.3 % of the total weight ingested around Hokkaido (Table 8-1, Fig. 2-1).

In sub-area 8, the same trend of sub-area7, in early season (May and June), Japanese anchovy was the dominant prey species, composing 66.6 and 66.1 % of the total weight ingested, while in late season (from July and August), Pacific saury was the dominant prey species, composing 83.5 % and 92.4 % of the total weight ingested. In May and June, minke whales consumed Japanese anchovy in the middle part of the research area (36Nº – 40Nº)(Fig. 2-1), while in July and August, minke whales consumed this species and Pacific saury in the middle and northern part of the research area (40Nº – 45 Nº) (Fig. 2-1).

In sub-area 9, copepods and mackerels were the dominant prey species, composing 29.5 and 37.4 % of the total weight ingested in May and July (Table 8-1). Minke whales consumed these preys in the middle part of the research area (36Nº – 40Nº)(Fig. 2-1). From July to September, minke whales consumed Pacific saury in the middle and northern part of the research area (40Nº – 48Nº)(Fig. 2-1). In August, Minke whales fed on minimal armhook squid in the North eastern part of sub-area 9.

Sei whales

In sub-area 7, the samples were few numbers. Japanese anchovy was the dominant prey species, composing 100.0 % and 89.5 % of the total weight ingested in June and July (Table 8-2). Sei whales consumed Japanese anchovy in the middle part of the research area (36Nº – 40Nº)(Fig. 2-2).

In sub-area 8, in May, Mackerels and krill were the dominant prey species, composing 53.0 and 42.0 % of the total weight ingested. Sei whales consumed these preys in the southern part of research area (35 N º – 40 N º) (Fig. 2-2). While from June to September, Japanese anchovy and krill were the

dominant prey species. Sei whales consumed Japanese anchovy in the entire research area (35N° – 45N°)(Fig. 2-2).

In sub-area 9, in May, copepods and krill were the dominant prey species, composing 53.6 and 33.7 % of the total weight ingested. Sei whales consumed these preys in the southern part of research area (35N° – 40N°)(Fig. 2-2). While from June to September, Japanese anchovy was the dominant prey species. Sei whales consumed Japanese anchovy in the middle and northern part of research area (38N° – 45N°)(Fig. 2-2).

Bryde's whales

In sub-area 7, Krill was the dominant prey species, composing 88.9 and 75.3 % of the total weight ingested in May and June (Table 8-3). Bryde's whales consumed krill in the southern and middle part of the research area (35N° – 40N°)(Fig. 2-3), while from July to September, Bryde's whales consumed this species in the middle part of the research area (38N° – 41N°) (Fig. 2-3).

In sub-area 8, in June, Krill, Mackerels and Japanese anchovy were the dominant prey species, composing 37.0 %, 32.9 % and 30.1 % of the total weight ingested, respectively (Table 8-3). Bryde's whales consumed krill in the southern part of the research area (35N° – 38N°)(Fig. 2-3), while from July to August, Japanese anchovy was the dominant prey species, composing 65.3 % and 100.0 % of the total weight ingested (Table 8-3). Bryde's whales consumed krill in the southern part of the research area (35N° – 38N°)(Fig. 2-3).

In sub-area 9, from June to September, Japanese anchovy was the dominant prey species, composing from 64.5 and 100.0 % of the total weight ingested (Table 8-3). Bryde's whales consumed these preys in the southern part of research area (35N° – 40N°). In August, Bryde's whales fed on oceanic lightfish in the South eastern part of Area 9 (Fig. 2-3).

Yearly changes in dominant prey species

Minke whales

In sub-area 7, the dominant prey was almost Japanese anchovy except 2005 season. In early and late seasons of 2005, krill was dominant prey. In sub-area 8, Japanese anchovy, krill and Pacific saury were dominant prey species in early seasons, though in late seasons, Pacific saury was dominant prey species. In sub-area 9, there is same situation of sub-area 8. Japanese anchovy, krill and Pacific saury were dominant prey species in early seasons, though in late seasons, Pacific saury was dominant prey species except 2000 and 2005 seasons. In late seasons of 2000 and 2005, Japanese anchovy was dominant prey (Figs. 3-1)

Sei whales

In sub-area 7, the dominant prey was Japanese anchovy except early season of 2003. In sub-area 8, the dominant prey was also Japanese anchovy except 2005 and 2007 season. In 2005, krill was dominant prey. In 2007, mackerels was dominant prey in early season, copepods was dominant prey in late season. In sub-area 9, Japanese anchovy and copepods were dominant prey species in early seasons, though in late seasons, Japanese anchovy was dominant prey species except 2002 and 2005 seasons. In late seasons of 2002 and 2005, krill was dominant prey (Figs. 3-2).

Bryde's whales

In sub-area 7, the dominant preys were krill and Japanese anchovy in early season, though in late seasons, Japanese anchovy was dominant prey species except 2003 seasons. In late seasons of 2003, krill was dominant prey. In sub-area 8, the dominant prey was krill in early season except 2004. In early seasons of 2004, mackerels were dominant prey. In late season, Japanese anchovy was dominant prey. In sub-area 9, the dominant prey was krill in early season except 2004. In early seasons of 2004, Japanese anchovy was dominant prey. In late season, Japanese anchovy was

dominant prey except 2006 seasons. In late seasons of 2006, krill and oceanic light fish were dominant prey (Figs. 3-3).

The size distribution of three main fish sizes consumed by three baleen whales

Japanese anchovy

The size distributions of Japanese anchovy in the stomach of three baleen whales are shown in Fig. 4-1. Minke whale feed on most large sized anchovy, the fork length ranged from 54 to 155 mm with a single mode at 120-130 mm. The fork length of Japanese anchovy ingested by sei whales ranged from 24 to 143 mm with a single mode at 120 mm. The length of 120 mm of anchovy is mature size. Bryde's whale obviously feed on smaller size of anchovy than other whale's feeding. The fork length ranged from 20 to 153 mm with a single mode at 50-75 mm. The small size anchovy (B.L.<8cm) hatched in this year.

Pacific saury

The size distributions of Pacific saury in the stomach of three baleen whales are shown in Fig. 4-2. We didn't find Pacific saury from the stomach contents of Bryde's whale. We see two modal distributions (B.L: 200-230mm and 300 mm) in minke and sei whales, but minke whale fed on large sized saury.

Mackerels

The size distributions of mackerels in the stomach of three baleen whales are shown in Fig. 4-3. Minke whale fed on largest mackerels, the fork length ranged from 70 to 280 mm with a single mode at 240 mm. The small size mackerel fed by sei whale and Bryde's whales hatched in this year.

Daily and seasonal prey consumption by whales

Minke whales

The daily prey consumption weight of minke whales based on sexual maturity stage (IM, MM, IF and MF) were calculated to be 65-142 kg, 107-234 kg, 57-125 kg and 133-291 kg, respectively (Table 9-1).

The seasonal prey consumption of minke whales was calculated to be 130 thousands tons. The minke whales fed mainly on Japanese anchovy and Pacific saury. The consumption weight of these prey were 67 thousands tons and 28 thousands tons, respectively (Table 11).

Sei whales

The daily prey consumption weight of sei whales based on sexual maturity stage (IM, MM, IF and MF) were calculated to be 475-741 kg, 636-993 kg, 520-812 kg and 756-1,180 kg, respectively (Table 9-2).

The seasonal prey consumption of sei whales was calculated to be 813 thousands tons. The sei whales fed mainly on Japanese anchovy, copepods and krill. The consumption weight of these prey were 273 thousands tons, 269 thousands tons and 228 thousands tons, respectively (Table 11).

Bryde's whales

The daily prey consumption weight of Bryde's whales based on sexual maturity stage (IM, MM, IF and MF) were calculated to be 358-603 kg, 521-877 kg, 349-588 kg and 580-977 kg, respectively (Table 9-3).

The seasonal prey consumption of Bryde's whales was calculated to be 481 thousands tons. The Bryde's whales fed mainly on Japanese anchovy. The consumption weight of this prey was 400 thousands tons (Table 11).

The feeding impact of fisheries resources

Japanese anchovy

The consumption of Japanese anchovy by three baleen whales was estimated to be 739 thousands tons during May to September, equivalent to roughly 2.2 times the total estimated recent Japanese anchovy's catch in the western North Pacific. The biomass of this species is estimated 4.8 million tons (Fisheries agency of Japan, 2008). The consumption was equivalent to 15.4 % of their biomass.

Mackerels

The consumption of mackerels by three baleen whales was estimated to be 140 thousands tons during May to September, equivalent to roughly 33.3 % of the total estimated recent mackerel's catch in the western North Pacific. The biomass of this species is estimated 1.0 million tons (Fisheries agency of Japan, 2008). The consumption was equivalent to 13.9 % of their biomass.

Pacific saury

The consumption of Pacific saury by two baleen whales (minke and sei whales) was estimated to be 43 thousands tons during May to September, equivalent to roughly 10.6 % of the total estimated recent Pacific saury's catch in the western North Pacific. The biomass of this species is estimated 4.5 million tons (Fisheries agency of Japan, 2008). The consumption was equivalent to 1.0 % of their biomass.

Discussion

1. Prey species and feeding type

This study showed that the prey species of three baleen whale species in the western North Pacific during May and September from 2000 to 2007, included various pelagic species of zooplankton, squid and fishes. Prey species of three baleen whale species varied with both geographically and temporally. Minke whales in Northern Hemisphere consume various pelagic prey species of zooplankton, squid and fishes (Kasamatsu and Tanaka, 1992; Haug et al., 1995, 1996; Tamura, 1998; Tamura and Fujise, 2002). We confirmed that three baleen whale species in the western North Pacific are euryphagous, similar to those in Northeast Atlantic. Generally the baleen whales are grouped into two types on the feeding behaviour, that is, swallowing and skimming types (Nemoto, 1959). The former is the group of fin whales, blue whale and humpback whale and the latter is the group of right whale. This study showed most of stomach contents with fish were one single prey species, indicating the aggregation of fish is important factor for whale's feeding habits. Only a few whales had more than two prey species in each sub-area.

2. Geographical, seasonal changes and size difference of prey species

Our results showed that there was geographical and seasonal change of prey species.

In offshore area, minke whales fed on Japanese anchovy during May and June, and changed their prey to Pacific saury during July to September. For this reason, the finding position of minke whales fed on Pacific saury was rather north than whales fed on anchovy, so the movement of minke whale cause spatial overlap with Pacific saury. In the north east part of sub-area 9 over the Emperor Sea Mountains, minke whale abundantly fed on minimal armhook squid in August. This result suggested that the minke whale

use the feeding area near Emperor Seamounts where the minimal armhook squid occur in summer (Konishi and Tamura, 2007).

Minke whale also adapted to coastal areas where large whales rarely occur. In sub-area 7, walleye pollock was one of the important prey species in early summer for minke whale in addition to Pacific saury and anchovy off northern Japan. For the size of fish in the stomachs, minke whales fed on large-sized walleye pollock over the continental break and slope around 200-300m water depth.

Sei whale fed on Japanese anchovy and copepods dominantly during survey season in most of years. However they mostly fed on mackerels in 2005 season, and this indicated that sei whale feed on most aggregated prey species near surface. At the off shore area under the effects of Kuroshio-current extension, the prey species fed by large baleen whales depend on what the current carry in early summer.

The dominant prey species of Bryde's whale was Japanese anchovy and krill during May to September. There was seasonal change of prey species. In early season (May and June), the dominant prey species was krill. In late season (from July to September), the dominant prey species was Japanese anchovy/. In South eastern part of sub-area 9 in August, oceanic lightfish were also important prey species. Kawamura reported that this species was the dominant prey species of Bryde's whales in the North Pacific (Kawamura, 1980). This suggests that the Bryde's whale use the feeding area near Emperor Seamounts where the oceanic lightfish occur in summer.

For three baleen whale species, the most dominant prey species was Japanese anchovy in the JARPN II survey years. Japanese anchovy is distributed shallower than 30 m depth, where it feeds on copepods (Kondo, 1969). The anchovy are distributed widely in temperate waters of the western North Pacific. Japanese anchovy migrate to this research area to feed copepod from June through September (Kondo, 1969). Three baleen whale species probably feed on prey at the surface during their seasonal migration to the feeding area. Differences in the prey might reflect to local and seasonal changes in the relative abundance of these prey species in the research area.

Furthermore, our results showed that there was size difference of prey species. Common minke whale obviously fed on larger size of Japanese anchovy, Pacific saury and mackerels than other whale's feeding. The small size anchovy (B.L.<8cm) and mackerels (B.L.<25cm) hatched in this year. These fishes distributed the southern part of the research area. Differences in the prey size among the stomach contents of three baleen whales might reflect to geographical distribution of prey species in the research area.

3. Yearly change of prey species

Our results showed that there was yearly change of prey species.

For common minke whales, Tamura and Fujise (2001) noted that the Japanese anchovy was the most important prey species in May and June, while Pacific saury was the most important one in July and August in Offshore area. Our results was generally same, but in some seasons, another prey was dominant (*ex.* Krill in early season of 2005, Japanese anchovy in late season of 2000). Kasamatsu and Hata (1985) reported that Chub mackerel was the most important prey species of common minke whales in western Pacific (a northern part of sub-area 8) in August. However, in our surveys, the composition of mackerels was low. This result seems to reflected changes in the abundance of prey species in this area.

Nemoto (1959) reported that Bryde's whales fed on krill, Japanese anchovy and Chub mackerel in the Pacific coast of Japan. Our results were also same. In only some season, however, they fed mainly on mackerels and/or oceanic lightfish.

The sei whale is known to feed on a wide spectrum of marine animals such as krill, Japanese anchovy, chub mackerel, Pacific saury and Japanese flying squid. According to Nemoto (1959 and 1962) and Nemoto and Kawamura (1977), sei whales feed mainly copepods in the northern part of the North Pacific, but they likely feed on fishes and squids in the Sanriku and Hokkaido coastal waters of Japan. Our results were also same. In only some season, they fed mainly on mackerels and/or krill. The fluctuation of prey

species of sei whales seems to reflect that sei whales are opportunistic feeders with a broad diet and with flexible feeding habits.

4. Daily and seasonal prey consumption by whales

Our estimates of the daily prey consumption was similar to by Nordøy et al. (1995), which investigated the eastern North Atlantic minke whales and these obtained by Lockyer (1981a,b), which investigated the large baleen whales.

In western North Pacific, the prey consumption of Japanese anchovy by three baleen whale species was 739 thousands tons during May to September. This value was equivalent to roughly 2.2 times the total estimated recent Japanese anchovy's catch in the western North Pacific. The biomass of this species is estimated 4.8 million tons. The consumption was equivalent to 15.4 % of their biomass.

Mackerels were important fish of commercial catch in the western North Pacific. The prey consumption of mackerels by three baleen whale species was 140 thousands tons during May to September. This value was equivalent to roughly 33.3 % of the total estimated recent mackerels catch in the western North Pacific. The biomass of this species is estimated 1.0 million tons. The consumption was equivalent to 13.9 % of their biomass.

The consumption of Pacific saury by two baleen whales (minke and sei whales) was estimated to be 43 thousands tons during May to September, equivalent to roughly 10.6 % of he total estimated recent Pacific saury's catch in the western North Pacific. The biomass of this species is estimated 4.5 million tons. The consumption was equivalent to 1.0 % of their biomass.

Our results show, consumption by three baleen whales should be taken into account for fishery management of these fishes in the future.

It was occurred to replacement from Japanese sardine to Japanese anchovy from 1980's in Pacific region of Japan. Kasamatsu and Tanaka (1992) examined annual changes of prey species based on the catch records of small type whaling in the seven whaling grounds off Japan from 1948 to 1987. In Pacific coast of Hokkaido (a part of sub-area 7W) from April to October, prey species recorded were krill, squid, Japanese sardine, Japanese anchovy, chub mackerel, walleye pollock, cod, sand lance, Pacific saury and so on. They noted that the change of prey of common minke whales from Chub mackerel to Japanese sardine in 1977 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976. In addition, the change of prey species of common minke whales from chub mackerel to Japanese sardine in 1977, from Japanese sardine to Pacific saury in 1996 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976, 1996, respectively (Tamura and Fujise, 2001).

Night or dawn sampling in order to determine how long food remained in the stomach is important for estimate night feeding behavior, however this resolution is not easy physically. The seasonal movements of whales that affects total consumption in restricted area is also important, and this information can be achieved by spatial modelling in Konishi *et al*. (2009).

To evaluate the interaction between whale and fisheries, long-term information of accurate abundance in prey species and each whale, and the accurate resident period of each whale are needed. Furthermore, there is a need to understand the potential for each whale to have an impact on commercial fisheries, either directly or indirectly using simulation models for specific geographical regions.

FUTURE WORKS

The prey consumption of cetaceans was estimated by several studies for three decades. We estimated the prey consumption using the equation of Sigurjónsson and Víkingsson (1997). However, from a recent

comprehensive review of the estimates of consumption (Leaper and Lavigne, 2007), it was considered that the appropriate consumption should be between the high end by Innes *et al*. (1986: $R = 0.42\ M^{0.67}$) and the low end by Boyd (2002: $FMR = 2529.2\ M^{0.524}$). The estimate of consumption by the Sigurjónsson and Víkingsson (1997: $FMR = 863.6M^{0.783}$) was considered at the upper range of reasonable values. Reilly *et al*. (2004) regarded the revised Innes's model to be the most appropriate model form for large baleen whales ($R = 1.66M^{0.559}$). We will compare estimates among these different equations.

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REFERENCES

Arai, M. 1993. Usujiri shyuuhenkaiiki ni seisokusuru gyorui no jiseki no hikakukeitaigakuteki kenkyuu [Comparative study on morphological otoliths for several fishes of Usujiri and adjacent waters in Southern Hokkaido, Japan]. Graduation Thesis, Hokkaido University, 98 pp. [In Japanese].

Baker, A. de. C., Boden, B. P. and Brinton, E. 1990. A practical guide to the euphausiids of the world. Natural History Museum Publications: London, 96 pp.

Brodskii, K. A. 1950. Calanoida of the far eastern seas and polar basin of the USSR. Opred. Faune SSSR, 35: 1-442. [In Russian] (Transl: Israel Program for Scientific Translations, Jerusalem 1967).Government of Japan, 2002. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPN II). Paper SC/54/O2 presented to the IWC Scientific Committee, May 2002 (unpublished). 115pp.

Chihara, M. and Murano, M. (eds.) 1997. An illustrated guide to marine plankton in Japan. Tokai Univirsity Press, Tokyo, Japan, 1574 pp.

Fisheries Agency of Japan 2008. Wagaguni shuhen no suisannshigen no gennjyou, Fisheries Agency of Japan and Fisheries Research Agency, http://abchan.job.affrc.go.jp/digests20/index.html.

Hakamada, T., Matsuoka, K. and Miyashita, T. 2009. Distribution and the number of western North Pacific common minke, Bryde's, sei and sperm whales distributed in JARPN II Offshore component survey area for estimation of prey consumption by the whales. Paper SC/J09/JR9 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 17pp.

Haug, T., Gjøsæter, H., Lindstrøm, U. and Nilssen, K. T. 1995. Diets and food availability for northeast Atlantic minke whale *Balaenoptera acutorostrata* during summer 1992. *ICES Journal of Marine Science*, 52: 77-86.

Haug, T., Lindstrøm, U., K. T. Nilssen, K. T., Rottingen, I. and Skaug, H. J. 1996. Diet and food availability for Northeast Atlantic minke whales *Balaenoptera acutorostrata*. *Rep. int. Whal. Commn*. 46: 371-82.

Hosokawa, H. and Kamiya, T. 1971. Some observations on the cetacean stomachs, with special considerations on the feeding habits of whales. *Rep. Whales Res. Inst*, 23: 91-101.

International Whaling Commission. 1994. Report of the Working Group on North Pacific minke whale. *Rep. int. Whal. Commn*. 44: 120-44.

Kasamatsu, F and Hata, T. 1985. Notes on minke whales in the Okhotsk Sea -West Pacific area. *Rep. int. Whal. Commn*. 35:299-304.

Kasamatsu, F. and Tanaka, S. 1992. Annual changes in prey species of minke whales taken off Japan 1948-87. *Nippon Suisan Gakkaishi*. 58:637-51.

Kawamura, A. 1982. Food habits and prey distributions of three rorqual species in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 34:59-91.

Kondo, K. 1969. Ecological studies of life pattern of the Japanese anchovy, *Engraulis japonicus* (HOUTTUYN). *Bulletin Tokai Region Fishery Research Laboratory*, 60:29-81.

Konishi, K. and Tamura, T. 2007. Occurrence of the minimal armhook squids *Berryteuthis anonychus* (Cephalopoda:Gonatidae) in the stomachs of common minke whales Balaenoptera acutorostrata in the western North Pacific. *Fisheries Science* 73:1208-10.

Konishi, K., Kiwada, H., Matsuoka, K., Kitakado, T., Hakamada, T. and Tamura, T. 2009. Density prediction modeling and mapping of common minke, sei and Bryde's whales distribution in the North-western Pacific using JARPN II (2002-2007) data set. Paper SC/J09/JR19 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 22pp.

Kubodera, T. and Furuhashi, M. 1987. Inaiyoubutu tyuuno ikarui oyobi hadakaiwasikagyorui no syusateinikannsuru manyuaru [Guide to the identification of lantern fishes and cephalopods in the stomach contents]. Appendix document of the report on the modeling of ecosystem in northern North Pacific. Fisheries Agency of Japan, 65 pp. [In Japanese].

Lockyer, C. 1981a. Estimation of the energy costs of growth, maintenance and reproduction in the female minke whale, (*Balaenoptera acutorostrata*), from the southern hemisphere. *Rep. int. Whal. Commn* 31:337-43.

Lockyer, C. 1981b. Growth and energy budgets of large baleen whales from the Southern Hemisphere. *FAO Fish. Ser*. (5) [*Mammals in the Sea*] 3:379-487.

Markussen NH, Ryg M, Lydersen C. 1992. Food consumption of the NE Atlantic minke whale (*Balaenoptera acutorostrata*) population estimated with a simulation model. ICES J mar Sci 49:317-23.

Masuda, H., Amaoka, K., Araga, C., Uyeno, T. and Yoshino, T. (eds.) 1988. The fishes of the Japanese archipelago. Second edition. Tokai Univirsity Press, Tokyo, Japan, 378 pp.

Miyashita, T., Kato, H. and Kasuya, T (eds). 1995. Worldwide map of cetacean distribution based on Japanese sighting data (Volume 1). 140p.

Morrow, J. E. 1979. Preliminary keys to otoliths of some adult fishes of the gulf of Alaska, Bering Sea, and Beaufort Sea. NOAA Technical Report NMFS circular, 420: 32 pp.

Nemoto, T. 1959. Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst*. 14:149-290.

Nemoto, T., 1962. Food of baleen whales. *Geiken Sosho*, 4: 136pp. (In Japanese)

Nemoto, T. and Kawamura, A. 1977. Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. *Rep. Int. Whal.Commn* Special issue 1:80-7.

Nordøy, E.S., Folkow, L.P., Mårtensson, P.E. and Blix, A.S. 1995. Food requirements of Northeast Atlantic minke whales. pp. 307-17. In: A.S. Blix, L.Walløe and Ø. Ulltang (eds.) *Whales, seals, fish and man.* Elsevier. [*Developments in Marine Biology*] 4:720pp.

Ohe, F. 1984. Otoliths of the coastal fishes along Japanese Islands and of fishes of adjacent seas. Report of Bullten The senior High School attached to Aichi University of Education, 11: 183-220.

Olsen, M. A., Nordøy, E. S., Blix, A. S. and Mathiesen, S. D. 1994. Functional anatomy of the gastrointestinal system of Northeastern Atlantic minke whales (*Balaenoptera acutorostrata*). *Journal of Zoology, London*, 234: 55-74.

Sigurjónsson, J. and Víkingsson, G.A. 1997 Seasonal abundance of and estimated prey consumption by cetaceans in Icelandic and adjacent waters. *J. Northw. Atl. Fish. Sci*. 22:271-87.

Tamura, T. 1998. *The study of feeding ecology of minke whales in the Northwest Pacific and the Antarctic*. D. C. Thesis. Hokkaido University. 125pp. [In Japanese].

Tamura, T and Fujise, Y.2002. Geographical and seasonal changes of prey species of minke whale in the Northwestern Pacific. *ICES Journal of Marine Science*. 59:516-528.

Table 1. Sampling numbers of whales

Common minke whales (2000-2007)

Sub-area	Sampling number					
	May	June	July	August	September	Total
7	16	155	49	15	88	323
8	30	59	37	7	1	134
9	11	28	86	152	6	283
Total	57	242	172	174	95	740

Sei whales (2002-2007)

Sub-area	Sampling number					
	May	June	July	August	September	Total
7	0	4	12	0	0	16
8	31	42	59	0	3	135
9	27	103	114	68	26	338
Total	58	149	185	68	29	489

Bryde's whales (2000-2007)

Sub-area	Sampling number					
	May	June	July	August	September	Total
7	7	59	60	39	19	184
8	0	34	39	36	0	109
9	0	46	33	15	6	100
Total	7	139	132	90	25	393

Table 2. Mean body weight in each sexual maturity of whales

Whale species	Sexual maturity	Mean body weight (kg)
Common minke	IM	2,600
	MM	4,900
	IF	2,200
	MF	6,500
Sei	IM	13,700
	MM	19,900
	IF	15,400
	MF	24,800
Bryde's	IM	9,600
	MM	15,500
	IF	9,300
	MF	17,800
Sperm	IM	14,300
	MM	35,500
	IF	9,400
	MF	16,800

Table 3. Results of caloric value of dominant prey species in western North Pacific.

Species	Size	Body length	Body weight	**Energy Kcal/kg**
Copepoda (*Neocalanus cristatus*)				**920**
Krill（*Eupahusia pacifica*）				**850**
Sand lance				**1,840**
Japanese anchovy				
	Small	86 mm	7 g	**1,320**
	Large	125 mm	18 g	**1,530**
Pacific saury				
	Small	158 mm	16 g	**1,260**
	Large	300 mm	145 g	**3,140**
Walleye pollock		192 mm	66 g	**1,490**
		430 mm	624 g	**1,480**
Japanese flying squid		206 mm	200 g	**1,580**
Deep-sea squid		6,700 mm	6,930 g	**650**

Table 4. Results of sexual maturity composition of whales in western North Pacific.

Common minke

	Sub-area 7		Sub-area 8		Sub-area 9	
Sex maturity	Early	Late	Early	Late	Early	Late
IM	24.2	19.7	13.3	10.9	13.2	6.4
MM	64.0	61.4	75.9	80.4	73.7	86.8
IF	7.5	10.2	7.2	0.0	5.3	0.5
MF	4.3	8.7	3.6	8.7	7.9	6.4
N	186	127	83	46	38	220

Sei

	Sub-area 7		Sub-area 8		Sub-area 9	
Sex maturity	Early	Late	Early	Late	Early	Late
IM	25.0	16.7	15.1	10.3	15.4	14.6
MM	25.0	50.0	27.4	32.8	32.3	37.3
IF	50.0	8.3	8.2	13.8	14.6	13.7
MF	0.0	25.0	49.3	43.1	37.7	34.4
N	4	12	73	58	130	212

Bryde's

	Sub-area 7		Sub-area 8		Sub-area 9	
Sex maturity	Early	Late	Early	Late	Early	Late
IM	18.2	25.0	20.6	27.3	10.9	16.7
MM	9.1	26.7	20.6	24.7	23.9	16.7
IF	25.8	19.0	14.7	13.0	21.7	13.0
MF	47.0	29.3	44.1	35.1	43.5	53.7
N	66	116	34	77	46	54

Table 5. Results of abundance of whales in each sub-area.

Species	Period	Sex maturity	Area 7	Area 8	Area 9	Total
Minke	Early	IM	1,026	102	211	1,338
		MM	2,713	584	1,179	4,475
		IF	319	56	84	459
		MF	182	28	126	336
	Late	IM	112	25	305	441
		MM	348	182	777	1,307
		IF	58	0	285	343
		MF	49	20	718	787
Sei	Early	IM	143	353	728	1,224
		MM	143	641	1,530	2,314
		IF	285	192	692	1,169
		MF	0	1,154	1,785	2,939
	Late	IM	34	145	551	730
		MM	103	459	1,403	1,964
		IF	17	193	515	725
		MF	51	603	1,296	1,951
Bryde's	Early	IM	125	110	37	272
		MM	62	110	81	253
		IF	177	79	73	329
		MF	322	236	147	705
	Late	IM	659	796	632	2,087
		MM	705	720	632	2,056
		IF	500	379	491	1,370
		MF	773	1,023	2,035	3,831

Table 6. Prey species of whales sampled in JARPN II.

Minke

	Species	
Main prey		
Copepods	*Calanus* sp.	
Krill	*Euphausia pacifica*	
	Thysanoessa gregaria	
Pisces	*Engraulis japonicus*	Japanese anchovy
	Cololabis saira	Pacific saury
	Scomber japonicus	Chub mackerel
	Theragra chalcogramma	Walleye pollocke
	Brama japonica	Japanese pomfret
	Oncorhynchus gorbuscha	Pink salmon
	O. keta	Chum salmon
	Pleurogrammus monopterygius	Atka mackerel
Squids	*Todarodes pacificus*	Japanese flying squid
	Berryteuthis anonychus	Minimal armhook squid
Miner prey		
Pisces	*Paralepis atlantica*	Duckbill barracudina

Sei

	species	
Main prey		
Copepods	*Neocalanus cristatus*	
	N. plumchrus	
	Calanus sp.	
Krill	*Euphausia pacifica*	
	E. similis	
	Thysanoessa gregaria	
Pisces	*Engraulis japonicus*	Japanese anchovy
	Cololabis saira	Pacific saury
	Scomber japonicus	Chub mackerel
	S. australasicus	Spotted mackerel
Miner prey		
Pisces	*Sardinops melanostictus*	Japanese sardine
Squids	*Todarodes pacificus*	Japanese flying squid

Bryde's

	species	
Main prey		
Krill	*Euphausia pacifica*	
	E. similis	
	E. gibboides	
	Thysanoessa gregaria	
	Nematoscelis difficilis	
Pisces	*Engraulis japonicus*	Japanese anchovy
	Scomber japonicus	Chub mackerel
	S. australasicus	Spotted mackerel
	Vinciguerria nimbaria	Oceanic lightfish
	Auxis rochei	
Squids	*Todarodes pacificus*	Japanese flying squid
Miner prey		
Pisces	*Arothron firmamentum*	Starry toado
	Decapterus russelli	Russell's scad
	Diaphus theta	Lantern fish
	Tarletonbeania taylori	Lantern fish
	Starry toado	Arothron firmamentum
	Nemichthys scolopaceus	Snipe eel
	Lestidiops jayakari	

Table 7-1. Prey composition of common minke whales sampled in JARPN II.

Number of prey species	Prey species	7		8		9		Total	
		N	%	N	%	N	%	N	%
1	Copepoda	0	0.0	0	0.0	5	2.1	5	0.8
	Krill	38	14.1	12	11.2	7	2.9	57	9.2
	Japanese anchovy	162	60.0	40	37.4	30	12.3	232	37.4
	Pacific saury	13	4.8	39	36.4	157	64.6	209	33.7
	Walleye pollock	21	7.8	0	0.0	0	0.0	21	3.4
	Japanese flying squid	3	1.1	0	0.0	0	0.0	3	0.5
	Minimal armhook squid	0	0.0	0	0.0	12	4.9	12	1.9
	Japanese pomfret	0	0.0	0	0.0	2	0.8	2	0.3
	Atka mackerel	0	0.0	0	0.0	1	0.4	1	0.2
	Chub mackerel	1	0.4	3	2.8	2	0.8	6	1.0
	Total	238	88.1	94	87.9	216	88.9	548	88.4
2	Copepoda+Pacific saury	0	0.0	0	0.0	1	0.4	1	0.2
	Krill+Japanese anchovy	3	1.1	0	0.0	1	0.4	4	0.6
	Krill+Pacific saury	2	0.7	0	0.0	3	1.2	5	0.8
	Krill+Japanese flyong squid	1	0.4	0	0.0	0	0.0	1	0.2
	Krill+Barracudas	0	0.0	0	0.0	1	0.4	1	0.2
	Japanese anchovy+Krill	4	1.5	0	0.0	0	0.0	4	0.6
	Japanese anchovy+Pacific saury	1	0.4	2	1.9	3	1.2	6	1.0
	Japanese anchovy+mackerels	0	0.0	0	0.0	1	0.4	1	0.2
	Japanese anchovy+Walleye pollock	4	1.5	0	0.0	0	0.0	4	0.6
	Japanese anchovy+Japanese flying squid	1	0.4	0	0.0	0	0.0	1	0.2
	Japanese anchovy+Pink salmon	0	0.0	1	0.9	0	0.0	1	0.2
	Pacific saury+Copepoda	0	0.0	0	0.0	1	0.4	1	0.2
	Pacific saury+Krill	1	0.4	4	3.7	4	1.6	9	1.5
	Pacific saury+Japanese anchovy	2	0.7	2	1.9	2	0.8	6	1.0
	Pacific saury+Japanese flying squid	2	0.7	2	1.9	0	0.0	4	0.6
	Pacific saury+Minimal armhook squid	0	0.0	0	0.0	1	0.4	1	0.2
	Pacific saury+Japanese pomfret	0	0.0	0	0.0	1	0.4	1	0.2
	Pacific saury+Walleye pollock	0	0.0	0	0.0	1	0.4	1	0.2
	Pacific saury+Chum salmon	0	0.0	0	0.0	2	0.8	2	0.3
	Pacific saury+Other squid	0	0.0	1	0.9	0	0.0	1	0.2
	Japanese flying squid+Japanese anchovy	2	0.7	0	0.0	0	0.0	2	0.3
	Japanese flying squid+Pacific saury	2	0.7	1	0.9	0	0.0	3	0.5
	Japanese flying squid+Walleye pollock	1	0.4	0	0.0	0	0.0	1	0.2
	Minimal armhook squid+Pacific saury	0	0.0	0	0.0	1	0.4	1	0.2
	Walleye pollock+Krill	3	1.1	0	0.0	0	0.0	3	0.5
	Walleye pollock+Japanese anchovy	2	0.7	0	0.0	0	0.0	2	0.3
	Walleye pollock+Pacific saury	1	0.4	0	0.0	0	0.0	1	0.2
	Total	32	11.9	13	12.1	23	9.5	68	11.0
3	Krill+Pacific saury+Barracudas	0	0.0	0	0.0	1	0.4	1	0.2
	Japanese pomfret+Pacific saury+Japanese anchovy	0	0.0	0	0.0	1	0.4	1	0.2
	Chum salmon+Japanese pomfret+Pacific saury	0	0.0	0	0.0	1	0.4	1	0.2
	Pacific saury+Japanese pomfret+Minimal armhook squ	0	0.0	0	0.0	1	0.4	1	0.2
	Total	0	0.0	0	0.0	4	1.6	4	0.6
No. whales Observed		270		107		243		620	

Table 7-2. Prey composition of sei whales sampled in JARPN II.

Number of prey species	Prey species	7		8		9		Total	
		N	%	N	%	N	%	N	%
1	Copepoda	2	15.4	5	5.6	118	46.3	125	35.0
	Krill	1	7.7	32	36.0	33	12.9	66	18.5
	Japanese anchovy	8	61.5	37	41.6	48	18.8	93	26.1
	Pacific saury	0	0.0	0	0.0	20	7.8	20	5.6
	Mackerels	0	0.0	11	12.4	6	2.4	17	4.8
	Total	11	84.6	85	95.5	225	88.2	321	89.9
2	Copepoda+Krill	1	7.7	0	0.0	1	0.4	2	0.6
	Copepoda+Pacific saury	1	7.7	1	1.1	7	2.7	9	2.5
	Copepoda+Japanese anchovy	0	0.0	0	0.0	4	1.6	4	1.1
	Krill+Copepoda	0	0.0	0	0.0	2	0.8	2	0.6
	Krill+Japanese anchovy	0	0.0	1	1.1	1	0.4	2	0.6
	Krill+Pacific saury	0	0.0	0	0.0	1	0.4	1	0.3
	Krill+Japanese flyong squid	0	0.0	0	0.0	2	0.8	2	0.6
	Japanese anchovy+Japanese sardine	0	0.0	0	0.0	1	0.4	1	0.3
	Japanese anchovy+mackerels	0	0.0	1	1.1	5	2.0	6	1.7
	Pacific saury+Copepoda	0	0.0	0	0.0	1	0.4	1	0.3
	Pacific saury+Krill	0	0.0	1	1.1	2	0.8	3	0.8
	Pacific saury+Japanese anchovy	0	0.0	0	0.0	1	0.4	1	0.3
	Pacific saury+mackerels	0	0.0	0	0.0	1	0.4	1	0.3
	Mackerels+Copepoda	0	0.0	0	0.0	1	0.4	1	0.3
	Total	2	15.4	4	4.5	30	11.8	34	10.1
No. whales Observed		13		89		255			

Table 7-3. Prey composition of Bryde's whales sampled in JARPN II.

Number of prey species	Prey species	7		8		9		Total	
		N	%	N	%	N	%	N	%
1	Krill	73	43.2	14	26.9	16	24.2	103	35.9
	Japanese anchovy	89	52.7	30	57.7	30	45.5	149	51.9
	Mackerels	1	0.6	4	7.7	0	0.0	5	1.7
	Oceanic lightfish	0	0.0	0	0.0	8	12.1	8	2.8
	Total	163	96.4	48	92.3	54	81.8	265	92.3
2	Krill+Oceanic lightfish	0	0.0	0	0.0	1	1.5	1	0.3
	Japanese anchovy+Krill	5	3.0	2	3.8	1	1.5	8	2.8
	Japanese anchovy+mackerels	0	0.0	1	1.9	8	12.1	9	3.1
	Mackerels+Krill	1	0.6	0	0.0	0	0.0	1	0.3
	Mackerels+Japanese anchovy	0	0.0	0	0.0	2	3.0	2	0.7
	Japanese flying squid+Japanese anchovy	0	0.0	1	1.9	0	0.0	1	0.3
	Total	6	3.6	4	7.7	12	18.2	22	7.7
No. whales Observed		169		52		66		287	

Table 8-1. Prey composition (% of weight) and stomach contents weight (average ±S.D.) of common minke whales sampled in each sub-area.

Sub-area 7

	May			June			July			August			September		
Number	N=52			N=47			N=15			N=3			N=31		
	Broken		8	Broken		5	Broken		2	Broken		0	Broken		5
	Empty		2 (3.8%)	Empty		1 (2.1%)	Empty		0 (0.0%)	Empty		0 (0.0%)	Empty		1 (3.2%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Copepods	-	-	-	-	-	-	1	0.01	0.01	-	-	-	-	-	-
Krill	4	14.3	47.98±76.92	15	16.7	28.58±30.93	-	-	-	1	59.7	29.85	4	1.9	4.70 ± 1.31
Anchovy	40	85.7	30.15±32.49	26	24.4	24.15±21.36	7	71.3	16.78±18.51	-	-	-	9	12.5	13.89 ± 13.61
B.L < 80 mm			0.0%			0.0%			0.0%						2.8%
B.L > 80 mm			100.0%			100.0%			100.0%						97.2%
Saury	-	-	-	-	-	-	1	0.05	0.08	2	39.4	9.85±12.34	17	79.3	46.61 ± 70.15
Mackerels	-	-	-	-	-	-	1	18.4	30.3	-	-	-	-	-	-
Walleye pollock	-	-	-	7	58.9	216.60±521.70	5	10.3	3.39±4.04	-	-	-	-	-	-
Japanese flying squid	-	-	-	-	-	-	-	-	-	-	-	-	5	6.3	12.65 ± 8.89
Sardine	1	0.01	0.09	-	-	-	1	0.01	0.02	-	-	-	1	0.02	0.18
Other fish	-	-	-	-	-	-	-	-	-	1	0.9	0.44	-	-	-

Sub-area 8

	May			June			July			August			September		
Number	N=30			N=59			N=37			N=7			N=1		
	Broken		4	Broken		7	Broken		6	Broken		1	Broken		1
	Empty		5 (16.7%)	Empty		0 (0.0%)	Empty		1 (3.2%)	Empty		0 (0.0%)	Empty		0 (0.0%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Copepods	-	-	-	1	0.3	2.26	-	-	-	-	-	-	-	-	-
Krill	7	24.9	8.57±11.15	4	0.6	1.26±1.26	4	2.2	3.96±1.61	-	-	-	-	-	-
Anchovy	14	66.6	11.89±19.30	29	66.1	18.59±25.19	5	12.8	18.94±13.69	-	-	-	-	-	-
B.L < 80 mm			0.0%			0.0%			0.0%						
B.L > 80 mm			100.0%			100.0%			100.0%						
Saury	2	1.3	1.59±0.99	23	32.8	11.65±12.30	25	83.5	24.68±19.60	6	92.4	36.69±38.34	-	-	-
Mackerels	1	5.4	12.93	2	0.1	0.32±0.42	-	-	-	-	-	-	-	-	-
Japanese flying squid	-	-	-	-	-	-	1	1.3	9.70	2	7.6	9.08±6.78	-	-	-
Sardine	-	-	-	1	0.01	0.04	-	-	-	-	-	-	-	-	-
Salmonids	1	1.9	4.49	-	-	-	-	-	-	-	-	-	-	-	-
Other fish	-	-	-	-	-	-	1	0.2	1.32	-	-	-	-	-	-
Other squid	-	-	-	1	0.1	1.06	-	-	-	-	-	-	-	-	-

Sub-area 9

	May			June			July			August			September		
Number	N=11			N=28			N=86			N=152			N=6		
	Broken		0	Broken		1	Broken		9	Broken		24	Broken		0
	Empty		1 (9.1%)	Empty		4 (14.3%)	Empty		0 (0.0%)	Empty		0 (0.0%)	Empty		0 (0.0%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Copepods	2	29.5	1.01±1.38	1	6.8	42.68	-	-	-	-	-	-	-	-	-
Krill	3	7.7	2.58±2.32	2	2.3	7.17±10.10	13	10.5	18.15±20.75	6	0.8	5.69±4.80	-	-	-
Anchovy	-	-	-	6	31.0	32.59±57.66	2	0.4	4.72 ± 6.57	33	24.9	33.62±58.14	1	8.5	19.37
B.L < 80 mm						0.0%						5.4%			
B.L > 80 mm						100.0%						94.6%			
Saury	2	18.6	2.44±0.55	17	59.9	22.22±25.96	72	85.1	26.46±26.74	94	56.8	27.00±27.08	5	91.5	41.73 ± 47.54
Mackerels	1	37.4	9.82	-	-	-	-	-	-	5	0.2	1.90±3.53	-	-	-
Walleye pollock	-	-	-	-	-	-	1	0.1	1.68	1	0.01	0.40	-	-	-
Japanese flying squid	-	-	-	-	-	-	-	-	-	1	0.002	0.10	-	-	-
Sardine	-	-	-	-	-	-	-	-	-	1	0.001	0.02	-	-	-
Pacific pomfret	-	-	-	-	-	-	3	3.7	27.69±8.43	3	0.4	5.87±7.11	-	-	-
Salmonids	1	5.6	1.47	-	-	-	-	-	-	2	0.5	10.35±7.91	-	-	-
Min. armed squi	-	-	-	-	-	-	-	-	-	16	15.6	43.41±27.87	-	-	-
Attka mackerel	-	-	-	-	-	-	-	-	-	1	0.8	36.30	-	-	-
Other fish	2	1.3	0.17 ± 0.08	-	-	-	5	0.2	0.92 ± 1.00	1	0.1	3.97	-	-	-

Table 8-2. Prey composition (% of weight) and stomach contents weight (average ±S.D.) of sei whales sampled in each sub-area.

Sub-area 7

	May			June			July			August			September		
Number	N=0			N=4			N=12			N=0			N=0		
	Broken		0	Broken		0	Broken		0	Broken		0	Broken		0
	Empty		0 (0.0%)	Empty		1 (25.0%)	Empty		4 (33.3%)	Empty		0 (0.0%)	Empty		0 (0.0%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Copepods	-	-	-	-	-	-	3	9.7	18.32±13.32	-	-	-	-	-	-
Anchovy	-	-	-	3	99.99	332.32±250.94	5	89.5	101.77±211.55	-	-	-	-	-	-
B.L < 80 mm	-	-	-			99.0%			100.0%	-	-	-	-	-	-
B.L > 80 mm	-	-	-			1.0%			0.0%	-	-	-	-	-	-
Sardine	-	-	-	1	0.01	0.03	-	-	-	-	-	-	-	-	-
Saury	-	-	-	-	-	-	2	0.8	2.34 ± 1.07	-	-	-	-	-	-
Mackerels	-	-	-	1	0.003	0.10	-	-	-	-	-	-	-	-	-

Sub-area 8

	May			June			July			August			September		
Number	N=31			N=42			N=59			N=0			N=3		
	Broken		2	Broken		0	Broken		3	Broken		0	Broken		0
	Empty		5 (17.2%)	Empty		11 (26.2%)	Empty		18 (30.5%)	Empty		0 (0.0%)	Empty		1 (33.3%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Copepods	1	0.1	3.79	4	2.1	16.37±14.96	2	2.8	65.82±12.00	-	-	-	-	-	-
Krill	9	42.0	226.78±160.27	8	25.1	96.17±163.96	20	53.3	125.72±136.51	-	-	-	-	-	-
Anchovy	4	4.8	58.61±115.27	19	70.1	113.14±115.10	15	43.2	135.86±158.30	-	-	-	2	100.0	398.40±562.55
B.L < 80 mm						23.5%			0.0%	-	-	-			4.0%
B.L > 80 mm						76.5%			100.0%	-	-	-			96.0%
Saury	1	0.1	2.44	2	0.8	12.27±15.83	3	0.7	11.34±19.33	-	-	-	-	-	-
Mackerels	12	53.0	216.00±201.59	1	1.9	56.91	-	-	-	-	-	-	-	-	-
Japanese flying squid	-	-	-	-	-	-	1	0.01	0.46	-	-	-	-	-	-

Sub-area 9

	May			June			July			August			September		
Number	N=27			N=103			N=110			N=68			N=26		
	Broken		1	Broken		8	Broken		7	Broken		6	Broken		1
	Empty		11 (42.3%)	Empty		22 (21.4%)	Empty		19 (17.3%)	Empty		7 (10.3%)	Empty		19 (76.0%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Copepods	11	53.6	73.41±68.02	51	30.8	63.97±97.05	35	16.7	35.54±81.29	24	11.4	22.17±26.18	5	69.7	4.30 ± 3.58
Krill	2	33.7	253.78±49.02	8	6.8	89.75±104.42	20	30.1	112.36±155.37	8	11.8	69.10±106.32	-	-	-
Anchovy	3	4.9	24.72±42.72	12	58.7	518.08±811.70	24	44.5	138.48±240.82	14	62.0	207.45±257.19	1	1.3	0.39
B.L < 80 mm									9.3%			0.1%			
B.L > 80 mm									90.7%			99.9%			
Sardine	-	-	-	-	-	-	-	-	-	1	1.1	53.05	-	-	-
Saury	1	0.1	1.24	8	2.9	38.12±57.33	13	2.9	16.66±22.03	16	13.7	40.11±70.95	-	-	-
Mackerels	3	7.7	38.53±34.71	2	0.6	31.99±45.19	7	5.4	57.42±110.16	-	-	-	1	29.0	8.95
Japanese flying squid	-	-	-	1	0.3	27.38	1	0.5	34.95	-	-	-	-	-	-

Table 8-3. Prey composition (% of weight) and stomach contents weight (average ±S.D.) of Bryde's whales sampled in each sub-area.

Sub-area 7

	May			June			July			August			September		
Number	N=7			N=59			N=60			N=39			N=19		
	Broken	0		Broken	0		Broken	5		Broken	2		Broken	2	
	Empty	2 (28.6%)		Empty	18 (30.5%)		Empty	19 (34.5%)		Empty	11 (28.2%)		Empty	8 (42.1%)	
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Krill	4	88.9	86.10±92.87	33	75.3	83.09±97.20	18	35.0	70.18±105.42	3	6.5	95.39±77.95	2	5.6	89.50 ± 52.56
Anchovy	1	11.1	43.09	7	22.0	121.24±91.41	20	61.6	111.07±233.85	17	93.5	313.77±285.15	6	94.4	379.30 ± 312.28
B.L < 80 mm					77.4%			55.6%			45.1%			90.8%	
B.L > 80 mm					22.6%			44.4%			54.9%			9.3%	
Mackerel	-	-	-	1	2.8	107.15	1	3.4	123.19	-	-	-	-	-	-

Sub-area 8

	May			June			July			August			September		
Number	N=0			N=34			N=39			N=36			N=0		
	Broken	0		Broken	1		Broken	0		Broken	1		Broken	0	
	Empty	0 (0.0%)		Empty	14 (42.4%)		Empty	11 (28.2%)		Empty	5 (14.3%)		Empty	0 (0.0%)	
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Krill	-	-	-	9	37.0	53.56±65.75	5	34.6	96.10±86.20	-	-	-	-	-	-
Anchovy	-	-	-	10	30.1	39.20±76.61	23	65.3	39.45±64.52	30	100.0	187.92±238.26	-	-	-
B.L < 80 mm					95.6%			71.8%			53.0%				
B.L > 80 mm					4.4%			28.2%			47.0%				
Mackerel	-	-	-	3	32.9	142.61±158.56	1	0.1	1.13	-	-	-	-	-	-
Japanese flying squid	-	-	-	1	0.002	0.03	-	-	-	-	-	-	-	-	-

Sub-area 9

	May			June			July			August			September		
Number	N=0			N=46			N=32			N=16			N=6		
	Broken	0		Broken	2		Broken	6		Broken	0		Broken	0	
	Empty	0 (0.0%)		Empty	7 (15.9%)		Empty	3 (11.5%)		Empty	5 (31.3%)		Empty	5 (83.3%)	
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Krill	-	-	-	12	17.7	88.05±120.01	5	4.9	30.77±40.45	1	6.9	39.75	-	-	-
Anchovy	-	-	-	23	73.2	190.26±181.85	19	95.1	157.15±167.28	3	64.5	98.11±138.97	1	100.0	42.28
B.L < 80 mm					46.0%			58.3%			1.0%				
B.L > 80 mm					54.0%			41.8%			99.0%				
Mackerel	-	-	-	10	9.1	54.49±78.66	-	-	-	-	-	-	-	-	-
Oceanic lightfish	-	-	-	3	0.02	0.32±0.22	-	-	-	6	28.7	27.69±34.32	-	-	-

Table 9-1. Daily prey consumption (kg) of common minke whales sampled in each month, sexual maturity stage and sub-area.

Sub-area 7

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Copepods	-	-	-	-	-	-	-	-	0.01	0.02	0.01	0.03	-	-	-	-	-	-	-	-
Krill	20	32	17	40	23	38	20	48	-	-	-	-	67	110	59	137	1	2	1	3
Anchovy																				
B.L < 80 mm																	0.2	0.4	0.2	0.5
B.L > 80 mm	118	193	103	241	36	59	32	74	92	151	81	188					8	14	7	17
Saury	-	-	-	-	-	-	-	-	0.06	0.1	0.06	0.1	44	72	39	90	55	91	49	113
Mackerels	-	-	-	-	-	-	-	-	24	39	21	48	-	-	-	-	-	-	-	-
Walleye pollock	-	-	-	-	82	135	72	169	13	22	12	27	-	-	-	-	-	-	-	-
Japanese flying squid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	7	4	9
Sardine	0.01	0.02	0.01	0.03	-	-	-	-	0.01	0.02	0.01	0.03	-	-	-	-	0.01	0.02	0.01	0.03
Other fish	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	2	-	-	-	-
Total	137	225	120	281	142	233	124	290	129	212	113	264	112	184	98	229	70	115	61	143

Sub-area 8

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Copepods	-	-	-	-	0.3	0.4	0.2	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Krill	35	58	31	72	0.6	1.0	0.5	1.2	1	2	1	3	-	-	-	-	-	-	-	-
Anchovy	95	156	83	194	63	104	56	130	9	14	8	18	-	-	-	-	-	-	-	-
B.L < 80 mm																				
B.L > 80 mm	95	156	83	194	63	104	56	130	9	14	8	18								
Saury	2	3	2	4	31	52	28	64	57	94	50	118	60	99	53	123	60	99	53	123
Mackerels	8	13	7	16	0.07	0.1	0.06	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Japanese flying squid	-	-	-	-	-	-	-	-	1	1	1	2	5	8	4	10	5	8	4	10
Sardine	-	-	-	-	0.005	0.008	0.004	0.010	-	-	-	-	-	-	-	-	-	-	-	-
Salmonids	3	4	2	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other fish	-	-	-	-	-	-	-	-	0.1	0.2	0.1	0.3	-	-	-	-	-	-	-	-
Other squid	-	-	-	-	0.1	0.2	0.1	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Total	142	234	125	291	96	157	84	196	69	113	60	141	65	107	57	133	65	107	57	133

Table 9-1. Continued.

Sub-area 9

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Copepods	36	60	32	74	5	9	5	11	-	-	-	-	-	-	-	-	-	-	-	-
Krill	9	15	8	19	2	3	2	4	7	12	6	15	0.6	1.0	0.5	1.3	-	-	-	-
Anchovy																				
B.L < 80 mm									0.02	0.03	0.01	0.03	1	2	1	2	0.3	0.5	0.3	0.6
B.L > 80 mm					25	41	22	51	0.3	0.5	0.2	0.6	19	31	17	39	5	9	5	11
Saury	23	23	23	23	48	79	42	99	59	97	52	121	46	75	40	94	60	98	53	123
Mackerels	46	76	40	94	-	-	-	-	-	-	-	-	0.2	0.3	0.1	0.3	-	-	-	-
Walleye pollock	-	-	-	-	-	-	-	-	0.05	0.08	0.04	0.10	0.008	0.01	0.01	0.02	-	-	-	-
Japanese flying squid	-	-	-	-	-	-	-	-	-	-	-	-	0.002	0.003	0.001	0.003	-	-	-	-
Sardine	-	-	-	-	-	-	-	-	-	-	-	-	0.000	0.001	0.000	0.001	-	-	-	-
Pacific pomfret	-	-	-	-	-	-	-	-	3	4	2	5	0.3	0.5	0.3	0.6	-	-	-	-
Salmonids	7	11	6	14	-	-	-	-	-	-	-	-	0.4	0.6	0.3	0.8	-	-	-	-
Min. armed squid	-	-	-	-	-	-	-	-	-	-	-	-	13	21	11	26	-	-	-	-
Attka mackerel	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-
Other fish	2	3	1	3	-	-	-	-	0.1	0.2	0.1	0.3	0.07	0.1	0.06	0.1	-	-	-	-
Total	123	202	108	252	81	133	71	165	70	114	61	142	80	132	71	165	65	108	57	134

Table 9-2. Daily prey consumption (kg)+ of sei whales sampled in each month, sexual maturity stage and sub-area.

Sub-area 7

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Copepods									54	72	59	86	54	72	59	86	54	72	59	86
Anchovy																				
B.L < 80 mm	541	725	593	861	541	725	593	861	498.8	668.2	546.7	793.8	499	668	547	794	499	668	547	794
B.L > 80 mm	5	7	6	9	5	7	6	9												
Sardine	0.05	0.07	0.06	0.09	0.05	0.07	0.06	0.09												
Saury									5	6	5	7	5	6	5	7	5	6	5	7
Mackerels	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03												
Total	546	732	599	870	546	732	599	870	557	746	611	887	557	746	611	887	557	746	611	887

Sub-area 8

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Copepods	0.5	0.6	0.5	0.7	12	16	13	19	17	23	19	28	9	12	10	14				
Krill	244	327	268	389	137	183	150	218	331	444	363	527	166	222	182	264				
Anchovy																				
B.L < 80 mm	7	9	7	11	90	120	98	143					9	12	10	14	9	13	10	15
B.L > 80 mm	22	29	24	34	293	392	321	466	269	360	294	427	436	584	478	694	226	302	247	359
Saury	0.3	0.4	0.3	0.5	4	6	5	7	4	6	5	7	2	3	2	3				
Mackerels	309	413	338	491	10	14	11	16												
Japanese flying squid									0.06	0.08	0.07	0.10	0.031	0.04	0.03	0.05				
Total	582	779	638	926	545	731	598	868	622	833	681	990	622	833	681	990	475	636	520	756

Sub-area 9

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Copepods	397	532	436	633	167	224	183	266	95	128	104	152	51	69	56	82	456	611	500	726
Krill	250	335	274	398	37	49	40	58	172	231	189	274	53	71	58	85				
Anchovy																				
B.L < 80 mm	3	5	4	5	30	40	32	47	24	32	26	38	0.3	0.4	0.3	0.4	0.01	0.01	0.01	0.01
B.L > 80 mm	33	44	36	53	288	386	316	459	231	309	253	367	280	375	306	445	8	11	9	13
Sardine													5	7	6	8				
Saury	0.6	0.8	0.6	0.9	16	21	17	25	17	22	18	26	62	83	68	98				
Mackerels	57	76	62	90	3	4	4	5	31	41	34	49					190	254	208	302
Japanese flying squid					0.4	0.6	0.5	0.7	0.4	0.6	0.5	0.7								
Total	741	993	812	1,180	542	726	594	863	572	766	627	910	451	605	495	719	654	876	716	1,040

Table 9-3. Daily prey consumption (kg) of Bryde's whales sampled in each month, sexual maturity stage and sub-area.

Sub-area 7

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Krill	536	779	522	869	418	609	408	678	157	229	153	255	25	37	25	41	23	34	23	38
Anchovy	67	98	65	109	122	178	119	198	276	402	269	448	366	533	357	594	393	572	383	637
B.L < 80 mm	52	75	51	84	94	137	92	153	154	223	150	249	165	240	161	268	357	519	348	578
B.L > 80 mm	15	22	15	25	28	40	27	45	123	178	120	199	201	292	196	326	36	53	35	59
Mackerels					15	22	15	25	15	22	15	25								
Total	603	877	588	977	556	809	542	901	448	653	437	727	391	570	382	635	416	606	406	675

Sub-area 8

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Krill	166	242	162	270	166	242	162	270	157	228	153	254								
Anchovy	135	197	132	219	135	197	132	219	296	431	289	480	385	561	376	625	385	561	376	625
B.L < 80 mm	129	188	126	210	129	188	126	210	212	309	207	345	204	297	199	331	204	297	199	331
B.L > 80 mm	6	9	6	10	6	9	6	10	83	121	81	135	181	264	177	294	181	264	177	294
Mackerels	148	215	144	239	148	215	144	239	0.4	0.5	0.4	0.6								
Japanese flying squid	0.01	0.02	0.010	0.02	0.01	0.02	0.010	0.02												
Total	449	653	438	728	449	653	438	728	453	659	442	735	385	561	376	625	385	561	376	625

Sub-area 9

Month	May				June				July				August				September			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Krill	72	105	70	117	72	105	70	117	19	28	19	31	25	37	25	41				
Anchovy	299	435	292	485	299	435	292	485	376	548	367	610	238	346	232	385	332	483	324	538
B.L < 80 mm	137	200	134	223	137	200	134	223	219	319	214	356	2	3	2	4	3	5	3	5
B.L > 80 mm	161	235	157	262	161	235	157	262	157	229	153	255	235	342	229	382	329	478	321	533
Mackerels	37	54	36	60	37	54	36	60												
Oceanic lightfish	0	0	0	0	0	0	0	0					106	154	103	171				
Total	408	594	398	662	408	594	398	662	396	576	386	642	369	536	359	598	358	521	349	580

Table 10. Seasonal prey consumption (tons) of whales sampled in each sexual maturity stage and sub-area.

Sub-area 7

Prey species	Common minke whale					Sei whale					Bryde's whale					Total
	IM	MM	IF	MF	Total	IM	MM	IF	MF	Total	IM	MM	IF	MF	Total	(t)
Copepods	0.04	0.2	0.02	0.04	0.3	169	681	93	404	1,347	0	0	0	0	0	1,348
Krill	2,182	9,661	639	921	13,403						9,828	10,617	10,893	31,591	62,929	76,332
Anchovy																
B.L < 80 mm	1	4	0.4	1	6	7,414	14,132	13,674	3,743	38,963	14,314	21,646	11,072	28,926	75,958	114,927
B.L > 80 mm	8,812	38,546	2,469	3,396	53,223	59	79	129	0	268	7,550	11,564	5,727	14,855	39,696	93,187
Saury	338	1,732	154	305	2,529	14	58	8	34	114	0	0	0	0	0	2,643
Mackerels	82	420	37	74	613	0.2	0.2	0.4	0	1	370	528	311	836	2,045	2,658
Walleye pollock	2,581	11,245	713	965	15,504	0	0	0	0	0	0	0	0	0	0	15,504
Japanese flying squid	15	76	7	13	111	0	0	0	0	0	0	0	0	0	0	111
Sardine	1	4	0.3	0.4	6	1	1	1	0	3	0	0	0	0	0	8
Other fish	3	17	2	3	26	0	0	0	0	0	0	0	0	0	0	26

Sub-area 8

Prey species	Common minke whale					Sei whale					Bryde's whale					Total
	IM	MM	IF	MF	Total	IM	MM	IF	MF	Total	IM	MM	IF	MF	Total	(t)
Copepods	1	8	0.4	0.5	9	250	821	251	1,471	2,794	0	0	0	0	0	2,803
Krill	223	2,099	106	126	2,553	8,942	25,812	7,273	49,751	91,778	5,534	7,516	2,957	13,853	29,860	124,191
Anchovy																
B.L < 80 mm	0	0	0	0	0	1,174	3,005	771	6,229	11,179	13,992	18,601	6,800	30,973	70,366	81,545
B.L > 80 mm	789	7,440	374	448	9,051	7,703	26,246	8,183	46,016	88,148	8,729	11,500	4,068	18,282	42,579	139,778
Saury	242	2,640	52	280	3,213	82	254	75	471	883	0	0	0	0	0	4,096
Mackerels	48	448	23	27	545	6,749	16,437	4,034	35,152	62,372	1,488	2,164	1,035	5,158	9,844	72,760
Japanese flying squid	8	99	0	13	120	0.4	2	1	3	6	0.1	0.2	0.07	0.4	0.7	126
Sardine	0.01	0.1	0.01	0.01	0.2	0	0	0	0	0	0	0	0	0	0	0
Salmonids	16	155	8	9	188	0	0	0	0	0	0	0	0	0	0	188
Other fish	0.1	1	0	0.2	1	0	0	0	0	0	0	0	0	0	0	1
Other squid	0.4	4	0.2	0.2	4	0	0	0	0	0	0	0	0	0	0	4

Sub-area 9

Prey species	Common minke whale					Sei whale					Bryde's whale					Total
	IM	MM	IF	MF	Total	IM	MM	IF	MF	Total	IM	MM	IF	MF	Total	(t)
Copepods	500	4,598	175	615	5,887	31,343	88,815	32,672	112,271	265,100	0	0	0	0	0	270,988
Krill	207	1,532	108	525	2,372	15,751	45,434	16,381	58,979	136,545	1,116	2,045	1,134	6,134	10,429	149,347
Anchovy																
B.L < 80 mm	13	55	11	63	142	1,206	2,686	1,285	3,149	8,325	4,867	7,885	4,241	26,013	43,007	51,474
B.L > 80 mm	387	2,414	244	1,301	4,346	16,625	42,792	17,513	48,934	125,865	14,938	22,680	11,977	78,739	128,334	258,545
Saury	2,138	10,895	1,488	7,978	22,498	1,706	5,101	1,774	5,663	14,244	0	0	0	0	0	36,743
Mackerels	592	5,439	209	734	6,974	6,254	19,683	6,457	23,666	56,059	124	398	243	807	1,573	64,605
Walleye pollock	0.5	2	0.4	3	6	0	0	0	0	0	0	0	0	0	0	6
Japanese flying squid	0.02	0.06	0.01	0.07	0.2	17	39	18	44	118	0	0	0	0	0	118
Sardine	0.004	0.02	0.003	0.02	0.04	87	297	89	326	800	0	0	0	0	0	800
Pacific pomfret	27	114	22	132	296	0	0	0	0	0	0	0	0	0	0	296
Salmonids	3	15	3	17	38	0	0	0	0	0	0	0	0	0	0	38
Min. armed squid	118	495	97	571	1,281	0	0	0	0	0	0	0	0	0	0	1,281
Attka mackerel	6	26	5	30	67	0	0	0	0	0	0	0	0	0	0	67
Oceanic lightfish	2	8	2	10	22	0	0	0	0	0	2,068	3,009	1,569	10,804	17,450	17,471
Other fish	2	8	1	9	19	0	0	0	0	0	0	0	0	0	0	19

Table 11. Seasonal prey consumption (tons) of whales sampled.

All

Prey species	Common minke whale				Sei whale				Bryde's whale				Total
	Sub-area 7	Sub-area 8	Sub-area 9	**Total**	Sub-area 7	Sub-area 8	Sub-area 9	**Total**	Sub-area 7	Sub-area 8	Sub-area 9	**Total**	**(t)**
Copepods	0.3	9	5,887	5,897	1,347	2,794	265,100	269,241	0	0	0	0	275,138
Krill	13,403	2,553	2,372	18,328		91,778	136,545	228,323	62,929	29,860	10,429	103,218	349,870
Anchovy													
B.L < 80 mm	6	0	142	148	38,963	11,179	8,325	58,468	75,958	70,366	43,007	189,330	247,946
B.L > 80 mm	53,223	9,051	4,346	66,620	268	88,148	125,865	214,280	39,696	42,579	128,334	210,610	491,510
Saury	2,529	3,213	22,498	28,240	114	883	14,244	15,241	0	0	0	0	43,481
Mackerels	613	545	6,974	8,131	1	62,372	56,059	118,432	2,045	9,844	1,573	13,461	140,023
Walleye pollock	15,504	0	6	15,510	0	0	0	0	0	0	0	0	15,510
Japanese flying squid	111	120	0.2	231	0	6	118	123	0	1	0	1	355
Sardine	6	0.2	0.04	6	3	0	800	803	0	0	0	0	809
Pacific pomfret	0	0	296	296	0	0	0	0	0	0	0	0	296
Salmonids	0	188	38	226	0	0	0	0	0	0	0	0	226
Min. armed squid	0	0	1,281	1,281	0	0	0	0	0	0	0	0	1,281
Attka mackerel	0	0	67	67	0	0	0	0	0	0	0	0	67
Oceanic lightfish	0	0	0	0	0	0	0	0	0	0	17,450	17,450	17,450
Other fish	26	1	22	48	0	0	0	0	0	0	0	0	48
Other Squid	0	4	0	4	0	0	0	0	0	0	0	0	4
Total				145,033				904,911				534,069	
								Total consumption				**1,584,013**	**t**

Table 12. The comparison among the prey consumption of three baleen whale species, the catch of fisheries and the resources of fishes.

Prey species	Prey consumption (tons)				Fisheries		Resources	
	Minke	**Sei**	**Bryde's**	**Total**	**catch (tons)**	**%**	**(tons)**	**%**
Japanese anchovy	66,768	272,748	399,940	739,456	330,000	224.1	4,800,000	15.4
Mackerels	8,131	118,432	13,461	140,023	420,000	33.3	1,010,000	13.9
Pacific saury	28,240	15,241	0	43,481	410,000	10.6	4,500,000	1.0

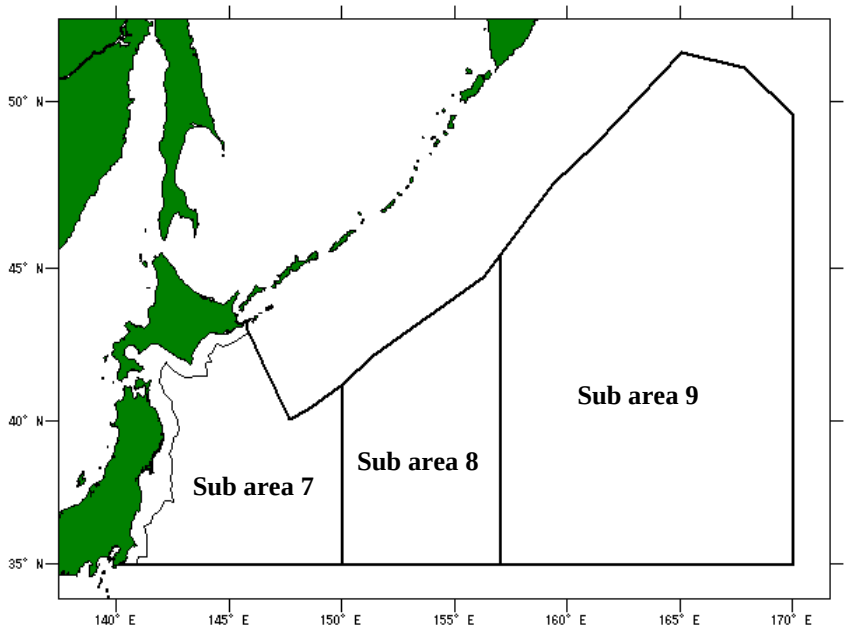
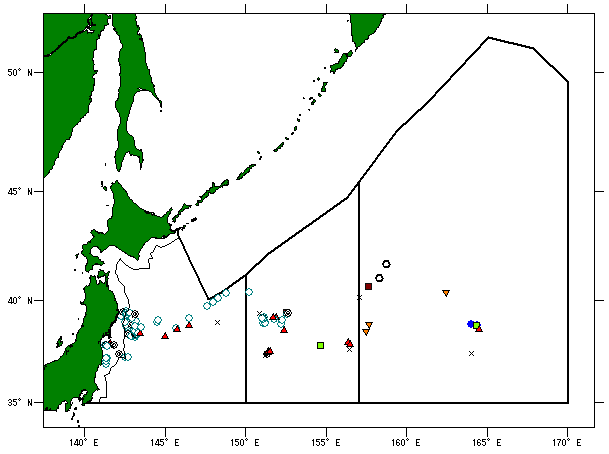
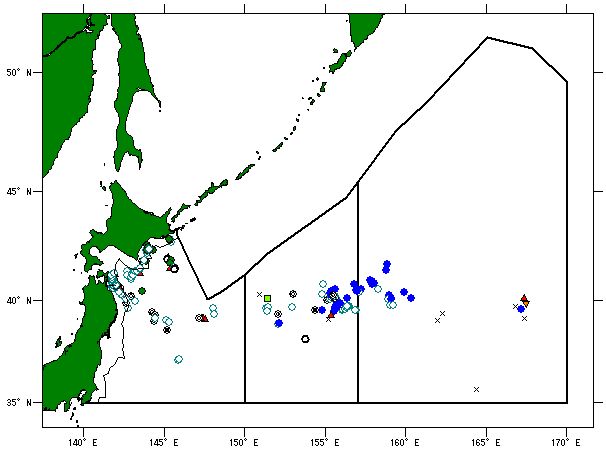


Fig.1 Research area

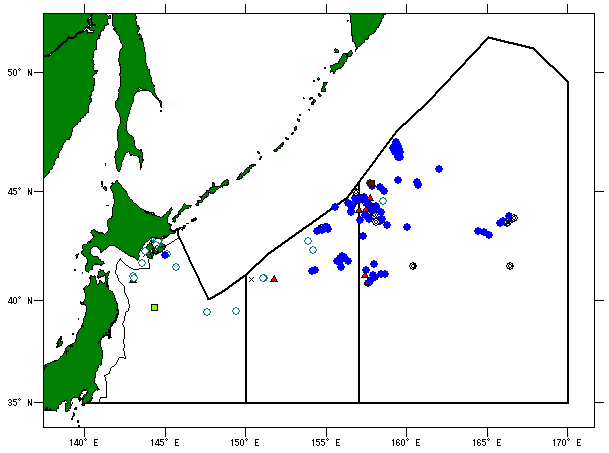
May



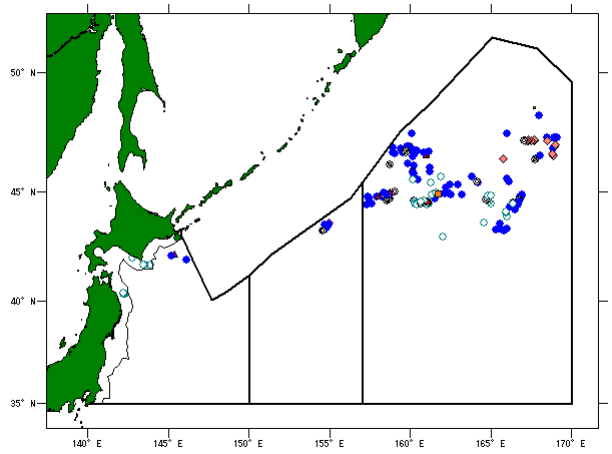
June



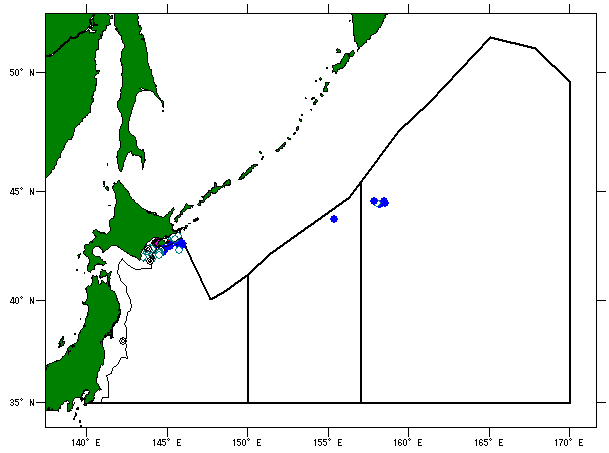
July



August



September



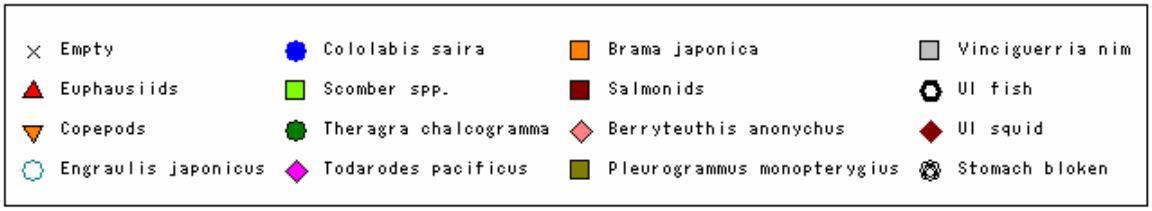
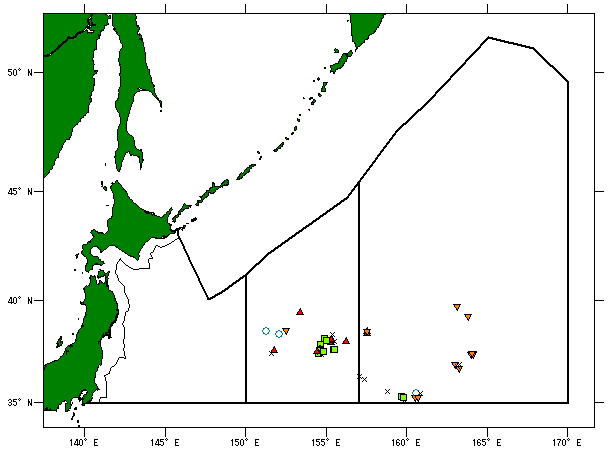
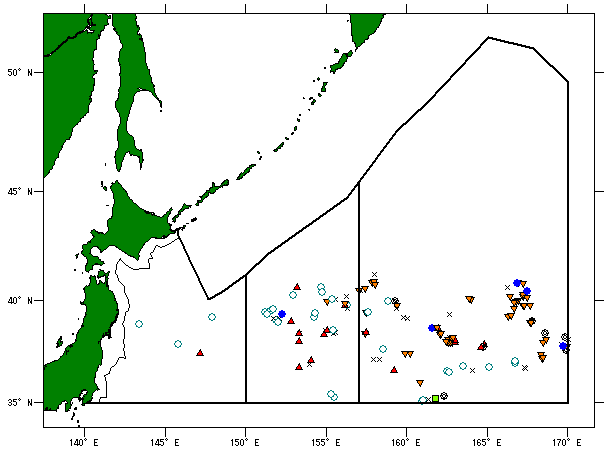


Fig. 2-1. Sighting position of common minke whales sampled and their dominant prey species (2000-2007JARPN II)

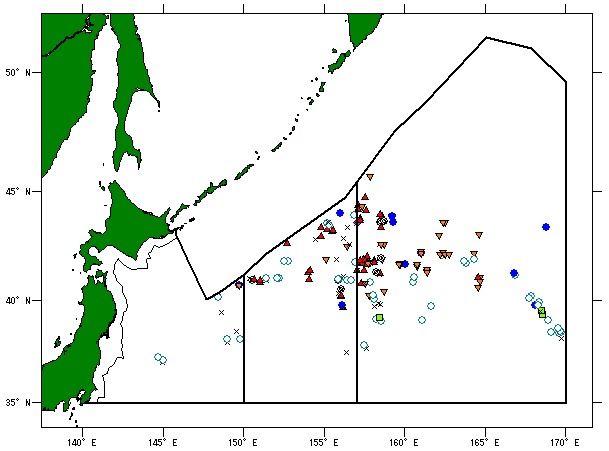
May



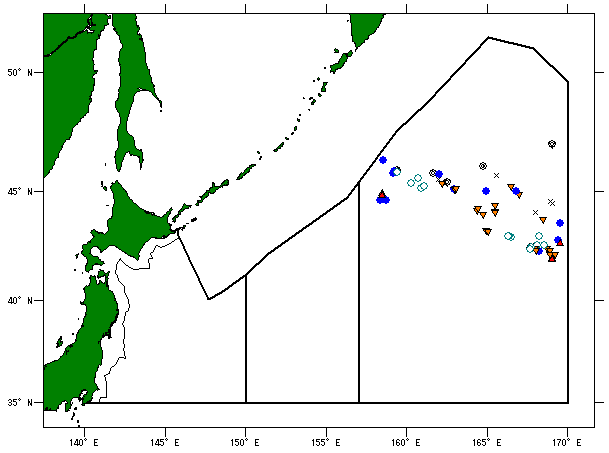
June



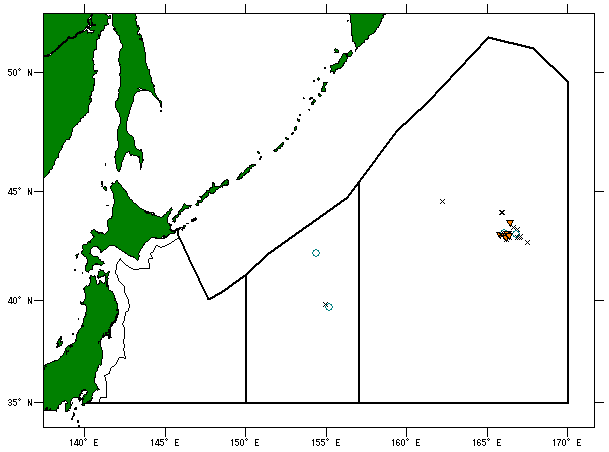
July



August



September



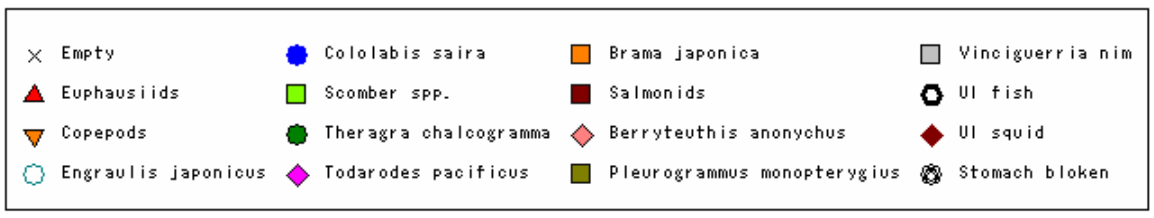
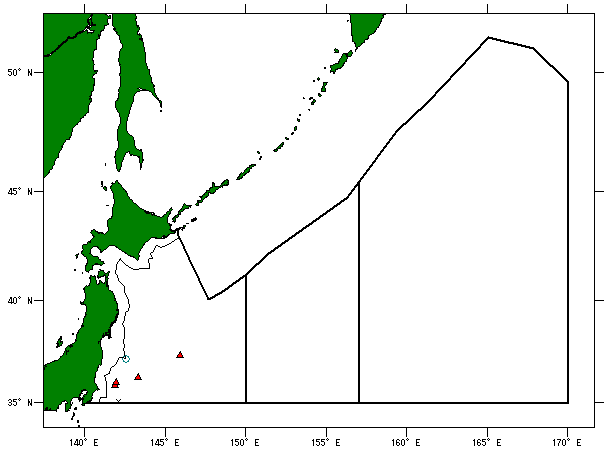
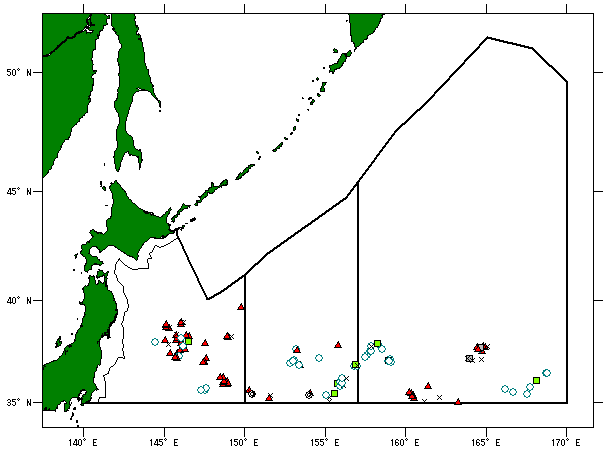


Fig. 2-2. Sighting position of sei whales sampled and their dominant prey species (2002-2007JARPN II)

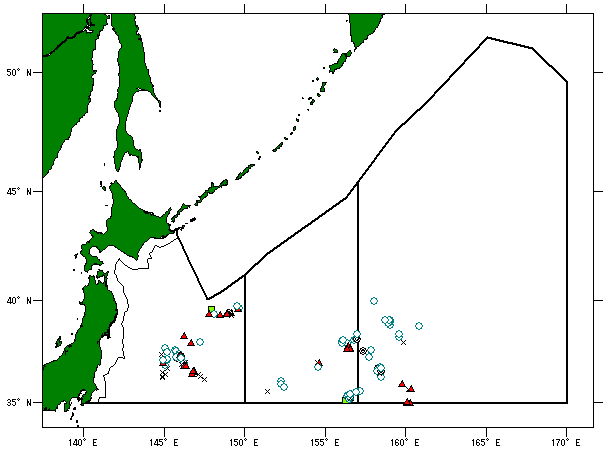
May



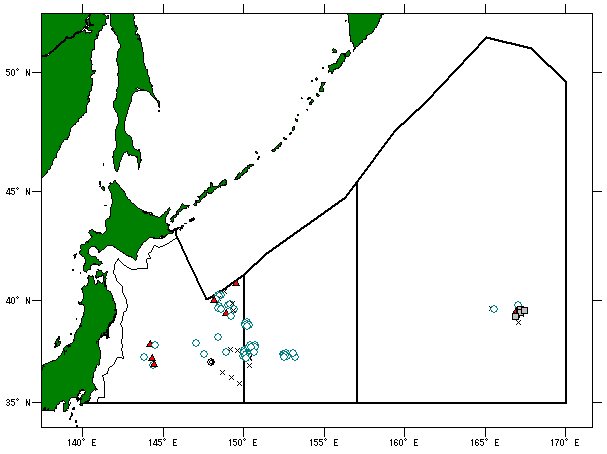
June



July



August



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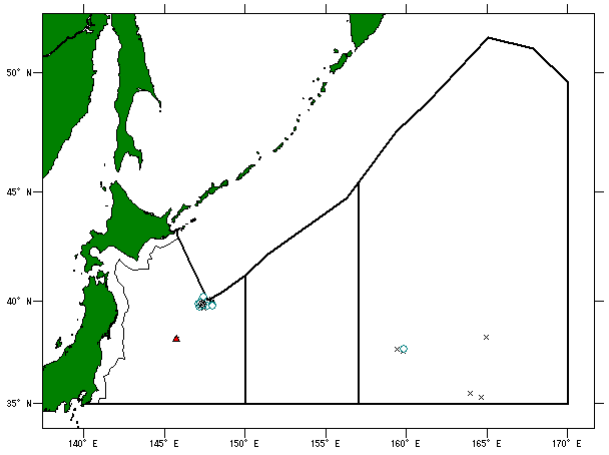


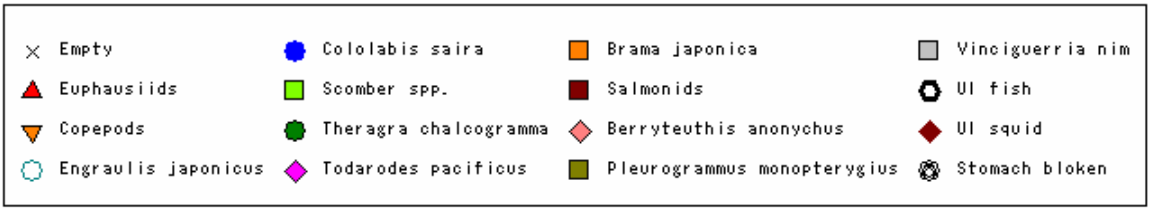
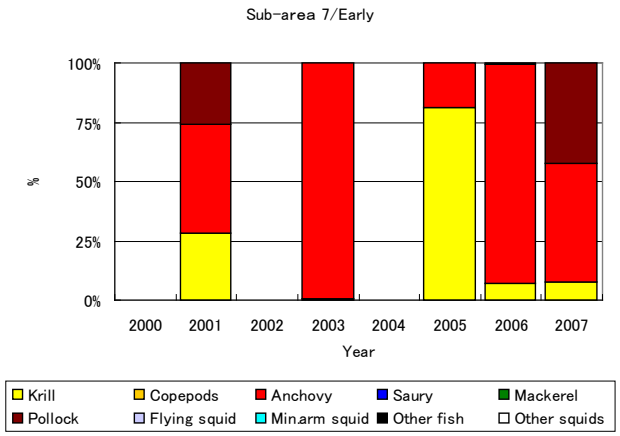


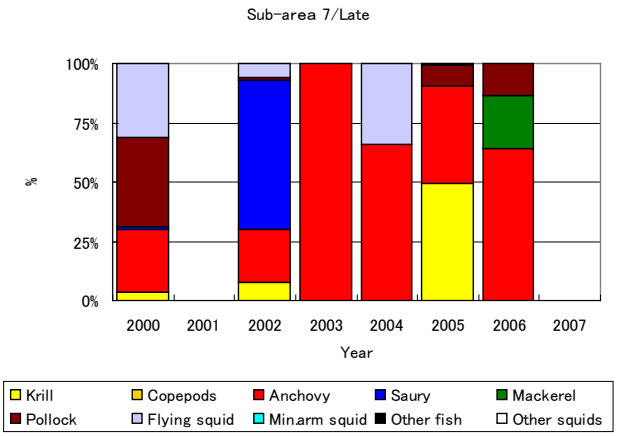
Fig. 2-3. Sighting position of Bryde's whales sampled and their dominant prey species (2000-2007JARPN II)

Sub-area 7

Early season

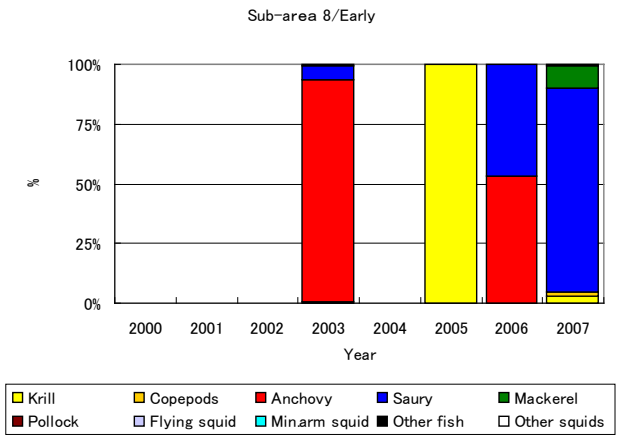


Late season

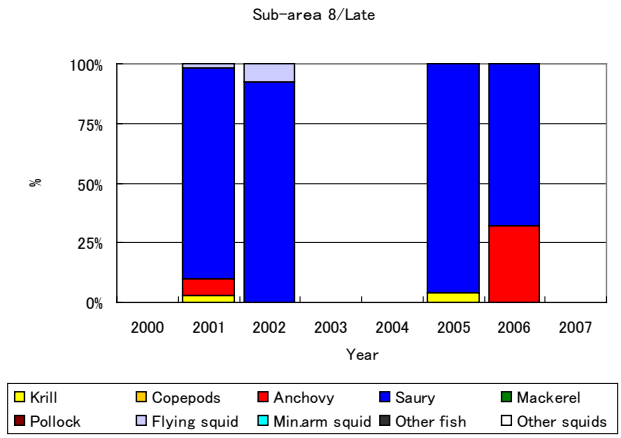


Sub-area 8

Early season

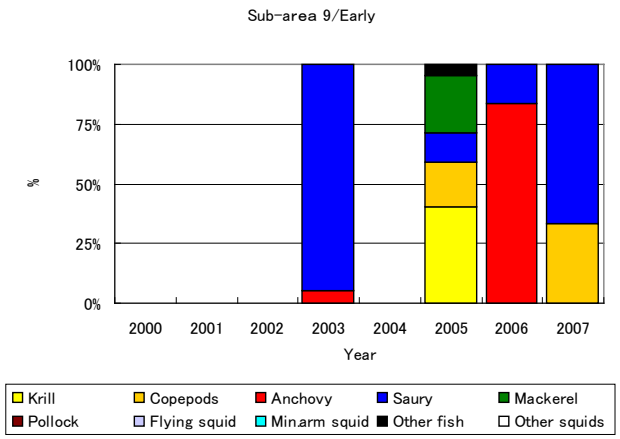


Late season



Sub-area 9

Early season



Late season

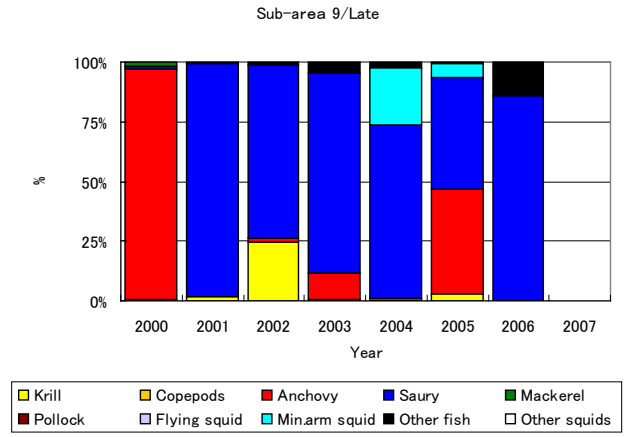
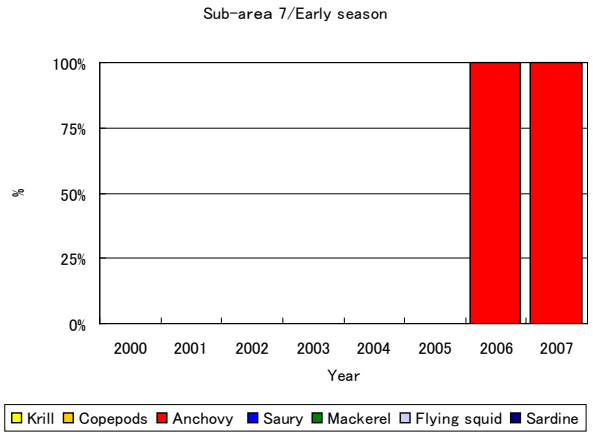


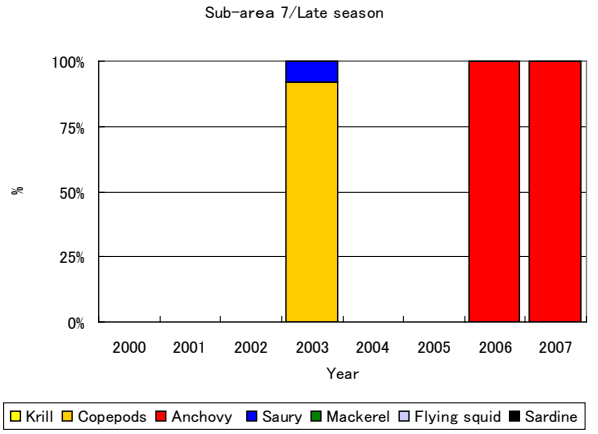
Fig. 3-1. The yearly change of prey species composition of common minke whales sampled in each sub-area

Sub-area 7

Early season

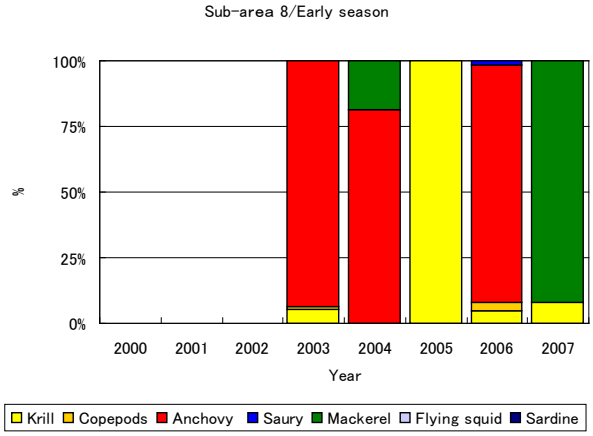


Late season

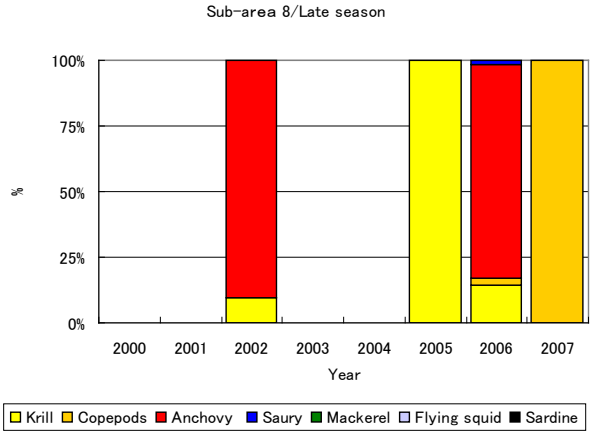


Sub-area 8

Early season

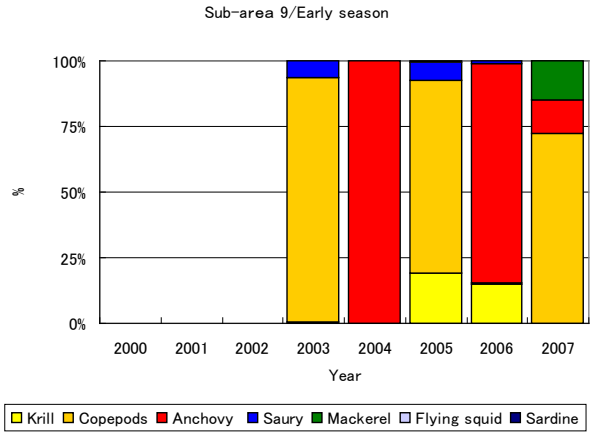


Late season



Sub-area 9

Early season



Late season

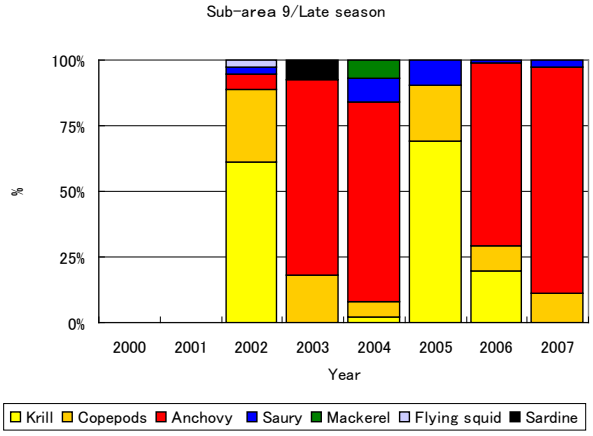
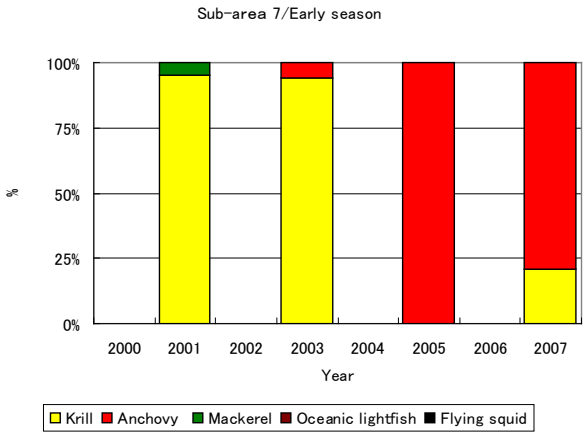


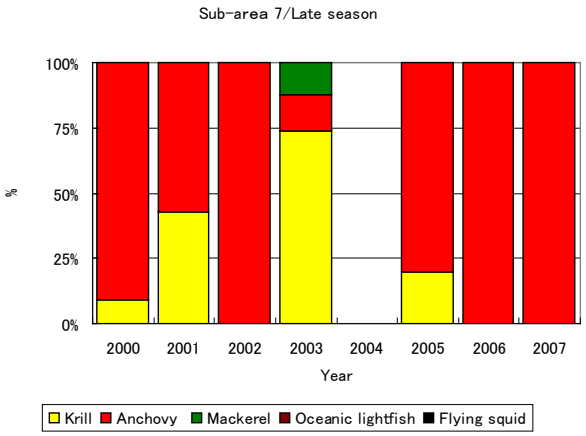
Fig. 3-2. The yearly change of prey species composition of sei whales sampled in each sub-area

Sub-area 7

Early season

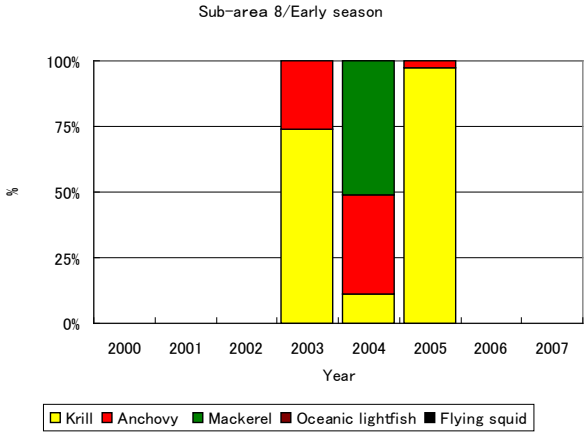


Late season

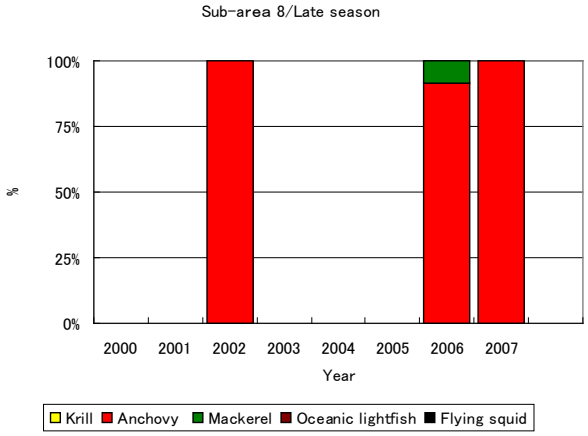


Sub-area 8

Early season

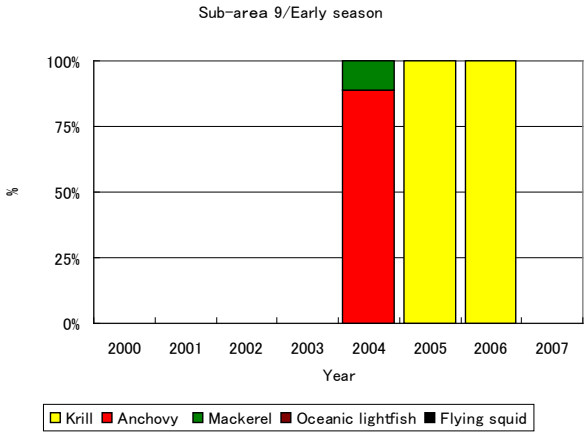


Late season



Sub-area 9

Early season



Late season

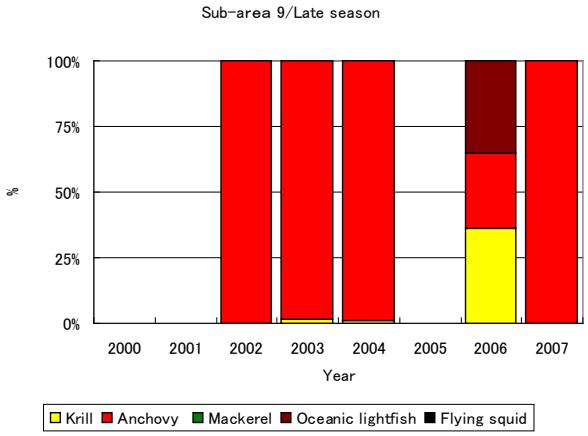


Fig. 3-3. The yearly change of prey species composition of Bryde's whales sampled in each sub-area

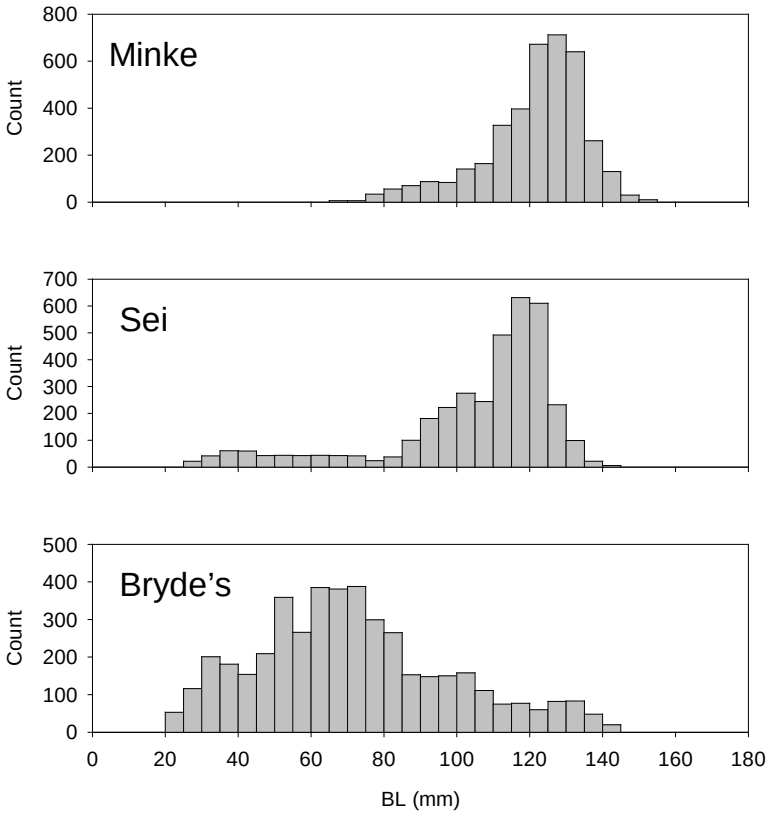


Fig. 4-1. The distribution of Japanese anchovy size in the stomach contents of three baleen whales

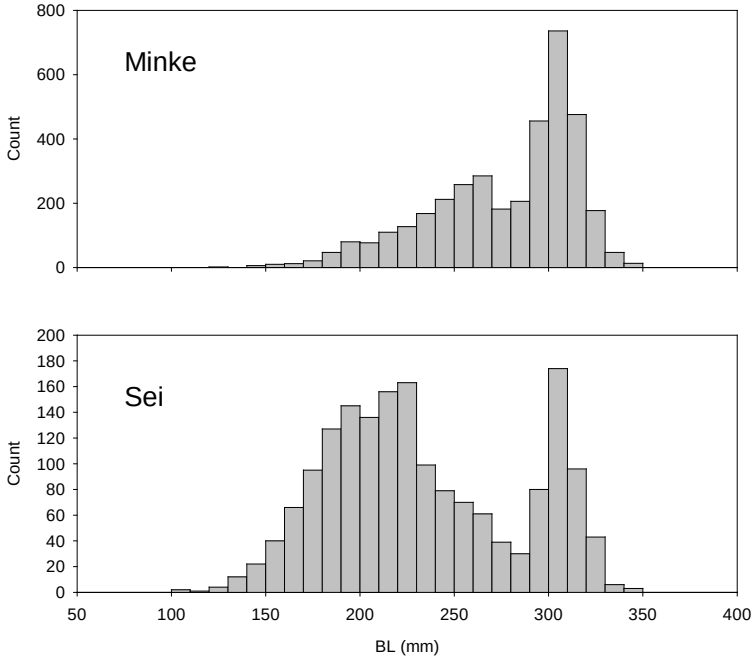


Fig. 4-2. The distribution of Pacific saury size in the stomach contents of three baleen whales

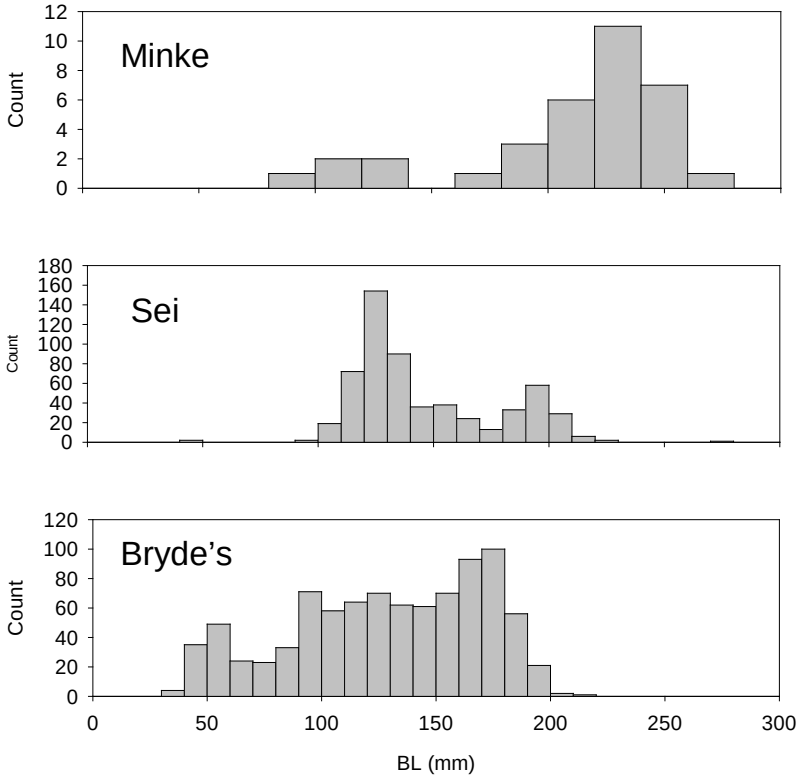


Fig. 4-3. The distribution of mackerels size in the stomach contents of three baleen whales