SC/F16/JR/24

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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

The relationship between maturity and feeding habit of common minke whales in the coastal region off Kushiro was examined based on biological parameter and stomach contents of common minke whales sampled by JARPNII in 2002 to 2013. A total of 589 stomach contents of common minke whales sampled off Kushiro from September to October were analyzed. The dominant preys consisted of one species of krill (*E. pacifica*), five of fishes (Japanese anchovy, Japanese sardine, chub mackerel, Pacific saury and walleye pollock) and one of squid (Japanese common squid). Differences in feeding habits between immature and mature whales in the coastal waters off Kushiro in autumn suggested previously could be confirmed. These results suggested that migration and prey preference of common minke whales in the coastal waters off Kushiro in autumn possibly differed with their maturity stage. Feeding strategy of common minke whales might change to adapt the local environments. Differences can be explained by the trade-offs of cost of foraging activity for prey and/or energy demands between immature and mature whales.

KEYWORDS: COMMON MINKE WHALE; KUSHIRO; NORTH PACIFIC; SCIENTIFIC PERMIT

INTRODUCTION

The common minke whale *Balaenoptera acutorostrata* is widely distributed in the world. In the western North Pacific, common minke whales are opportunistic feeders consuming a broad of prey with flexible feeding habits. According to previous reports, they consume several prey species such as pelagic schooling fish and zooplankton (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992).

The results of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) and JARPNII feasibility study (2000 and 2001) 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 on Pacific saury in July/August (Tamura and Fujise, 2000a, 2002a, 2002b). The estimated prey consumption by common minke whales was comparable to that of the commercial fisheries, indicating the some extent interaction between common minke whales and fisheries may occur in the coastal area (Tamura and Fujise, 2000b, 2002a, 2002c).

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). Off Kushiro region, the coastal component of JARPNII was started in 2002 and carried out since 2004 under the full JARPNII research plan (Government of Japan, 2002; 2004).

The coastal waters off Kushiro, south eastern part of the Pacific coast of Hokkaido, northern Japan, is one of the major migrating area of common minke whales in autumn (Hatanaka and Miyashita, 1997), and also important fishing grounds for species such as Japanese sardine, Pacific saury, mackerels, walleye pollock and Japanese common squid. Background and details of the surveys were summarized in Kishiro *et al*. 2009a.

Kishiro *et al.* (2009b) examined the relationship between body size, maturity, and feeding habit of common minke whales off Kushiro in autumn season, based on the 2002 to 2007 whale sampling surveys under the JARPNII coastal component off Kushiro. The dominant prey species were Japanese anchovy, Pacific saury, walleye pollock and Japanese common squid. Smaller and immature whales tend to feed on walleye pollock and krill whilst larger and mature whales tend to feed on Pacific saury. Japanese common squid was consumed only by mature whales. Japanese anchovy was evenly consumed by both immature and mature whales. The results suggested that migration and prey preference of common minke whales differed with maturity stage and that immature whales preferred to feed walleye pollock and krill than mature whales on the continental shelf and slope regions. Kishiro *et al.* (2009b) noted that these results were relevant for the estimations of local prey consumptions and for constructing the ecosystem models for restricted coastal small area, especially in the coastal waters off Kushiro.

The purpose of the present study was to update the analyses started by Kishiro *et al.* (2009b) on the relationship between feeding habits and biological parameters such as sex and maturity stages in the common minke whales off Kushiro.

MATERIALS AND METHODS

Research area, year, season and sample size

The study area was comprised north of 41°N and between longitudes 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 from 2002 to 2007. The sample size for the minke whale in the Kushiro component started with 50 animals in 2003. 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). A total of 589 common minke whales were sampled during the period from 2002 to 2013 (Table 1). Methodology and details of these surveys were described in Kishiro *et al.*, 2009a.

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 the forestomach and fundus.

The stomach contents were removed from each compartment and weighed to the nearest 0.1kg at the land station. 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).

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. Information on sexual maturity of each whales 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 of copepods (Brodskii, 1950), euphausiacea (Baker *et al*., 1990), squids (Kubodera and Furuhashi, 1987) and fish (Masuda *et al*., 1988; Chihara and Murano, 1997). The otoliths and jaw plate were used to identify the fish and squid 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 season and period

In order to simplify the comparison of feeding indices, prey species were divided into the following prey groups: krill (*Euphausia pacifica*), Japanese anchovy, Japanese sardine, Pacific saury, walleye pollock, 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 sexual maturity and year 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.

Oceanographic featured off Kushiro region

The oceanographic features off Kushiro were shown in Figure 2. SST (°C) data were obtained from the MODIS-Aqua Level 3, 4km product from 'Ocean Colour Web' (http://oceancolor.gsfc.nasa.gov/). The satellite information were averaged with 0.5 by 0.5 degree mesh by ArcGIS 10.2.1 (Esri Inc.), and all plotted for each year.

RESULTS

Sex ratio and maturity stage of common minke whales

A total of 589 whales consisting of 394 males and 195 females (sex ratio of males was 66.9%), was examined. The sexual maturity composition (%) of whales sampled is shown in Table 1. In males, ratio of sexually mature animals was 36.8%. In females, only 28 individuals or 14.4% of total 195 females were sexually mature animals.

Diversity of prey species

The dominant preys consisted of one species of krill (*Euphausia pacifica*), five of fishes (Japanese anchovy, Japanese sardine, Pacific saury, chub mackerel and walleye pollock) and one of squid (Japanese common squid). Main and minor prey species are shown in Table 2.

Feeding habit and prey switch of common minke whales

The prey composition (% of weight) of prey species between immature and mature whales was summarized in Table 3. Between 2002 and 2011, the dominant prey species were the Japanese anchovy and walleye pollock. Japanese anchovy was the dominant prey in regardless of the maturity and sex. On the other hand, the composition of walleye pollock in immature whales was higher than in mature whales during 2002 to 2013. The composition of Pacific saury in immature whales was lower than in mature whales before 2007. Since 2008, Pacific saury did not appear in the stomach contents of common minke whales caught off Kushiro region. The dominant prey species were replaced from Japanese anchovy to Japanese sardine and mackerels since 2012.

Relationship between whales' maturity stage and prey species

Comparison of the composition of prey species based on the restored wet weight of their stomach contents among sexual maturity stage was made in Figure 3. The occurrence of walleye pollock and krill in immature whales was higher than that of mature whales while the occurrence of Pacific saury in immature whales was lower than that of mature whales. Japanese common squid was only found in mature whales.

Geographic distribution of feeding

Geographical distribution of the whales, including information on their prey species found in the stomach, are shown in Figure 4. Although the positions of the whales were somewhat dispersed, the whales feeding on walleye pollock and Japanese common squids were relatively concentrated in the continental shelf and slope regions with water depth shallower than 1,000m. On the other hand, distribution of the whales feeding on Japanese anchovy, Japanese sardine and Pacific saury were more spread, and widely distributed in the offshore area. Walleye pollock and Japanese common squids are known to be demersal or mesopelagic species while Japanese anchovy, Japanese sardine and Pacific saury are pelagic fishes.

The average, maximum and minimum depth (m) of sampling position in each main prey species were shown in Table 4. Three geographic groups were considered based on the sampling positions of the whales as follows: i) Continental shelf area with water depth shallower than 200m; ii) Continental slope area with water depth from 200m to 1,000m; and iii) Offshore area with water depth of 1,000m or more. All prey species occurred in the continental slope area. However, the average depth of the whale catch position feeding on walleye pollock and Japanese common squid were shallower than the average depth of position of whales feeding on Pacific saury and mackerels.

DISCUSSION

The differences of feeding habits between immature and mature whales in the coastal waters off Kushiro in autumn reported previously, could be confirmed by the present study. In the continental shelf and slope regions with water depths of less than 1,000m, immature whales tend to feed on walleye pollock and krill while mature whales tend to feed on Pacific saury, mackerels and Japanese common squid. Japanese common squid is consumed only by mature whales. Japanese anchovy and/or Japanese sardine are evenly consumed by both immature and mature whales. These results emphasized the previous view that migration and prey preference of common minke whales in the coastal waters off Kushiro in autumn possibly differed with their maturity stage.

Differences might be explained by the availability of prey species for the whales. Availability seems to depend on factors such as distribution, migration, and shoaling behaviour of prey species. Walleye pollock is stably and restrictively distributed in the continental shelf and slope regions, and it could be easily detected by the whales. On the other hand, Pacific saury and Japanese common squid are large migratory species and their distribution are not stable. In this case, the whales have to search in wider areas to find and feed on these species. It is expected that mature whale has higher capability of swimming and experience to seek these prey, but required more energy cost than immature whales. Japanese anchovy and/or Japanese sardine are distributed widely throughout the coastal area and shoaling in shallow waters, both immature and mature whales possibly can feed on these species easily.

Watanabe *et al* (2009) examined prey preference of common minke whale based on the data from midwater trawl, IKMT, and acoustic surveys in their habitat as well as the stomach content data of the whales off Kushiro from 2002 to 2007. The result of whale sighting surveys indicated that the common minke whale was generally distributed in the slope water region of less than 16˚C SST and that its distributions expanded to the offshore region in 2002 when SST of both inshore and offshore region was less than 15˚C due to the strong influence of the Oyashio. They noted that the common minke whale might prefer rich prey environment affected by the Oyashio not only in the continental shelf region where walleye pollock, Pacific saury, and euphausiids could be distributed but also in the offshore region where Pacific saury and euphausiids could be distributed.

Kishiro *et al*. (2009b) and Watanabe *et al* (2009) stated that these differences in prey preference of common minke whales off Kushiro region might be explained by the trade-offs of cost of foraging activity for prey and/or energy demands between immature and mature whales.

In the coastal waters off the Sanriku district, northeastern part of the Japanese main island, three species (krill, Japanese anchovy, and sand lance, *Ammodytes personatus*) were found as major prey species of common minke whales in spring, but changes of prey species by maturity stage were not detected (Yoshida *et al*., 2009, Tamura *et al*., 2016: SC/F16/JR17). However, this may be due to the difference of the locality and season of the surveys. Sampling positions of the whales off Sanriku were concentrated in the Sendai Bay on the continental shelf region less than 200m water depth. In this area, topography of sea bottom is monotonous compared with those off Kushiro, and sand lance is dominantly distributed and abundant. Thus, sand lance is thought to be fed easily by both immature and mature whales as well as Japanese anchovy and Japanese sardine. The whale off Sanriku in spring is thought to be on the way to the northward migration after the breeding season, and the whale off Kushiro in autumn is thought to be on the way to the southward migration from the northern feeding areas. Seasonal migration route of common minke whales is also known to be different between sex and maturity status (Hatanaka and Miyahita, 1997). These appeared that the feeding strategy of common minke whales might be changed to adapt the local environments. . Satellite tracking data showed that tagged minke whale stayed in the coastal waters off Kushiro, for at least four weeks in autumn (Kishiro and Miyashita, 2011). The animal moved along the continental shelf off Hokkaido. Further information from tagging experiments could assist further the interpretation of the feeding habit of common minke whales in coastal waters.

From the viewpoint of the ecosystem modelling and multi stock management, the difference in prey preference by maturity stage may be affect the local inshore ecosystem and coastal fisheries. Thus, this information should be considered for the estimation of local prey consumptions in the coastal waters off Kushiro.

ACKNOWLEDGMENTS

We would like to thank all captains, crews and researchers, who were involved in coastal component of JARPNII surveys. We thank OB.DAAC for providing SST products. Our sincere thanks to Dr. Luis A. Pastene of the Institute of Cetacean Research (ICR) for their valuable suggestions and useful comments on this paper.

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 (JARPNII). 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.

Government of Japan, 2002. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPNII). Paper SC/54/O2 presented to the IWC Scientific Committee, May 2002 (unpublished). 115pp.

Government of Japan, 2004. Revised research plan for cetacean studies in the western North Pacific under special permit (JARPNII). Paper SC/56/O1 presented to the IWC Scientific Committee, June 2004 (unpublished). 14pp.

Hatanaka, H. and Miyashita, T. 1997. On the feeding migration of the Okhotsk Sea-West Pacific Stock of minke whales, estimates based on length composition data. *Rep.int. Whal. Commn* 47: 557-64.

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.

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.

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.

Kishiro, T., Yoshida, H., Goto, M., Bando, T. and Kato, H. 2009a. Methodology and survey procedure under the JARPNII – coastal component of Sanriku and Kushiro-, with special emphasis on whale sampling procedures. Paper SC/J09/JR3 presented to the JARPNII Review Workshop, Tokyo, January 2009 (unpublished). 27pp.

Kishiro, T., Yoshida, H., Tamura, T., Konishi, K., Kanda, N., Okamoto, R. and Kato, H. 2009b. Relationship between body size, maturity, and feeding habit of common minke whales off Kushiro in autumn season, from 2002-2007 whale sampling surveys under the JARPNII coastal components off Kushiro. Paper SC/J09/JR13 presented to the JARPNII Review Workshop, Tokyo, January 2009 (unpublished). 25pp.

Kishiro, T. and Miyashita, T. 2011. Satellite tracking of a common minke whale in the coastal waters off Hokkaido, northern Japan in 2010. Paper SC/63/RMP10 submitted to the 63nd IWC Scientific Committee Meeting (unpublished). 10pp.

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].

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.

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.

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.

Tamura, T. and Fujise, Y. 2000a. Geographical and seasonal changes of prey species in the western North pacific minke whale. Paper SC/F2K/J22 presented to the JARPN review meeting, February 2000 (unpublished). 26pp.

Tamura, T. and Fujise, Y. 2000b. Daily and seasonal food consumption by the western North Pacific minke whale Paper SC/F2KJ24 presented to the JARPN review meeting, February 2000 (unpublished). 18pp.

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

Tamura, T. and Fujise, Y. 2002b. Food habit of common minke whales based on JARPNII. Apendix 4, pp 47-63. *In*: Government of Japan (Fujise, Y., Kawahara, S., Pastene, L.A. and Hatanaka, H. Eds.) Report of 2000 and 2001 feasibility study of the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPNII). Paper SC/54/O17 submitted to the 54th IWC Scientific Committee Meeting (Available from the IWC Secretariat).

Tamura, T and Fujise, Y. 2002c. Daily and seasonal prey consumption by common minke whale and Bryde's whale in the western North Pacific. Appendix 4. pp 85-96. *In*: Government of Japan (Fujise, Y., Kawahara, S., Pastene, L.A. and Hatanaka, H. eds.), Report of 2000 and 2001 feasibility study of the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPNII). Paper SC/54/O17 submitted to the 54th IWC Scientific Committee Meeting (Available from the IWC Secretariat).

Tamura, T., Kishiro, T., Yoshida, H., Konishi, K., Yasunaga, G., Bando, T., Saeki, M., Onodera, K., Mitsuhashi, M., Yamashita, Y., Funamoto, T. and Kato, H. 2016. Updated prey consumption by common minke whales and interaction with fisheries in coastal areas. Paper SC/F16/JR17 presented to the 2016 JARPNII final review, February, 2016 (unpublished). **pp.

Yoshida, H., Kishiro, T., Goto, M., Bando, T., Tamura, T., Konishi, K., Okamoto, R. and Kato, H. 2009. Relationship between body size, maturity, and feeding habit of common minke whales off Sanriku in spring season, from 2003-2007 whale sampling surveys under the JARPNII coastal component off Sanriku. Paper SC/J09/JR12 presented to the JARPNII Review Workshop, Tokyo, January 2009 (unpublished) 20pp.

Watanabe, H., Yonezaki, S., Kiwada, H., Kumagai, S., Kishiro, T., Yoshida, H. and Kawahara, S. 2009. Distribution and abundance of prey species and prey preference of common minke whale Balaenoptera acutorostrata in the coastal component of JARPNII off Kushiro from 2002 to 2007. Paper SC/J09/JR11 presented to the JARPNII Review Workshop, Tokyo, January 2009 (unpublished) 37pp.

Table 1. Sample size and sexual maturity composition (%) of whales sampled.

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 2. Prey species of common minke whales sampled off Kushiro in JARPNII.

	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
Squid	*Todarodes pacificus*	Japanese common squid
Miner prey		
Pisces	*Brama japonica*	Japanese pomfret
	Paralepis atlantica	Duckbill barracudina

Table 3. Prey composition and average energy contents intake (KJ/kg) of prey species in each maturity of common minke whales sampled off the Pacific coast of Kushiro.

Year	Numeber (N)	Average depth (m)	Prey composition (%) Krill	Anchovy	Sardine	Saury	Mackerel	Pollock	Squid	Energy contents (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. Average, maximum and minimum depth (m) of sampling position of whales in each main prey species

Main prey species	Numbers	Depth (m) of sampling position		
		Average	Maximum	Minimum
Krill (*Euphausia pacifica*)	56	525	1,515	68
Japanese anchovy	225	350	1,532	28
Japanese sardine	51	448	1,096	38
Pacific saury	34	827	1,342	157
Mackerels	8	682	1,025	312
Walleye pollock	184	321	1,304	69
Japanese common squid	16	291	731	82

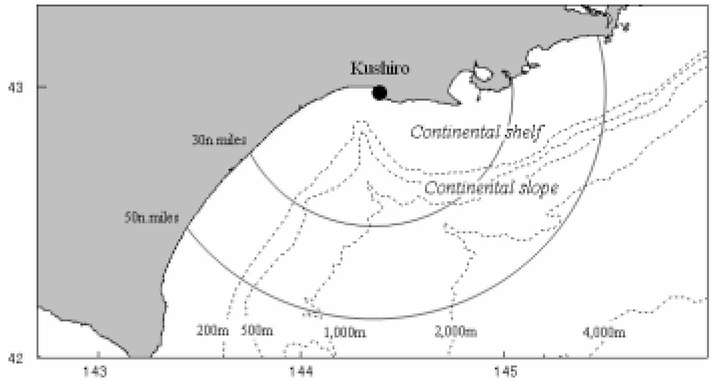


Figure 1. Research area off the Pacific coast of Kushiro

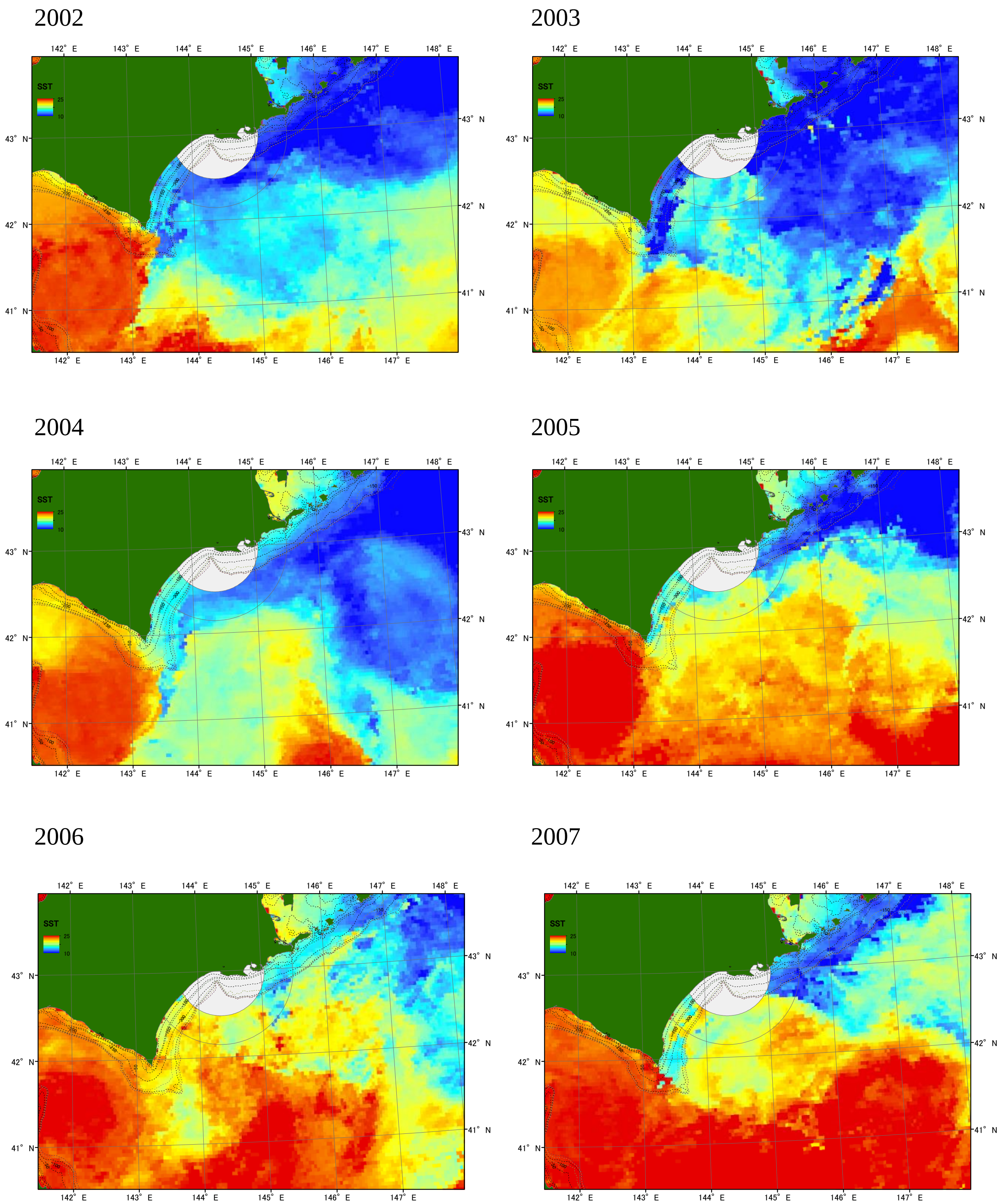
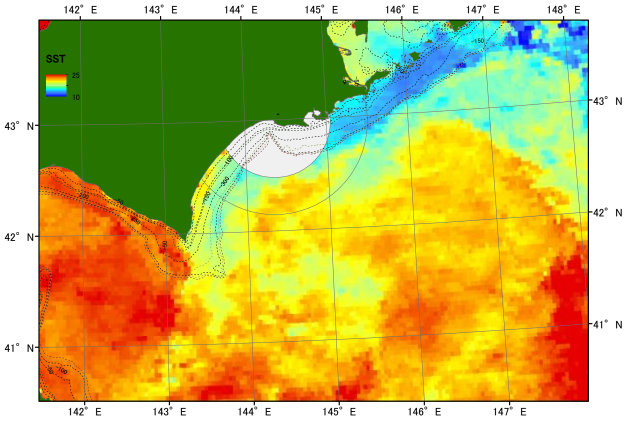
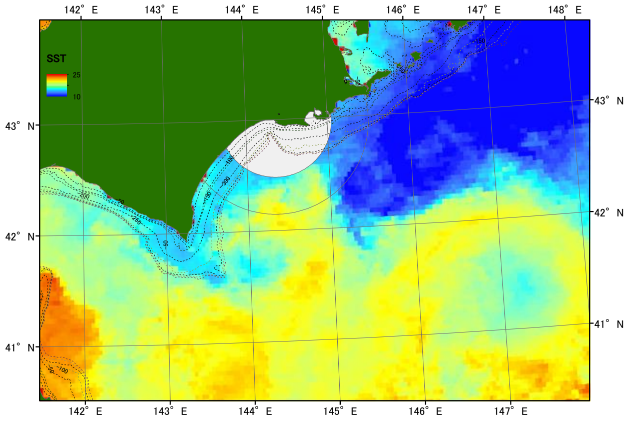


Figure 2. Oceanographic distribution off Kushiro region in September during 2002-2013.

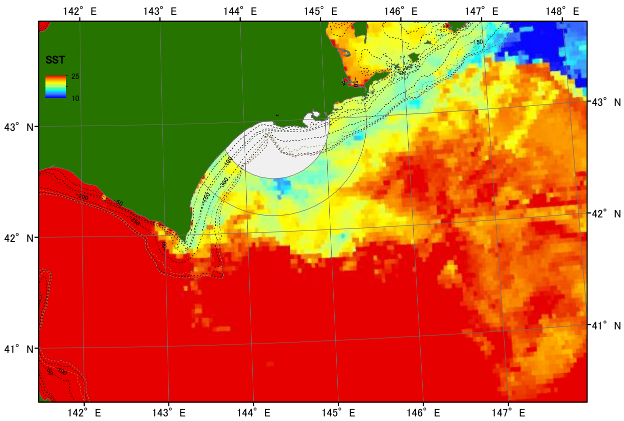
2008



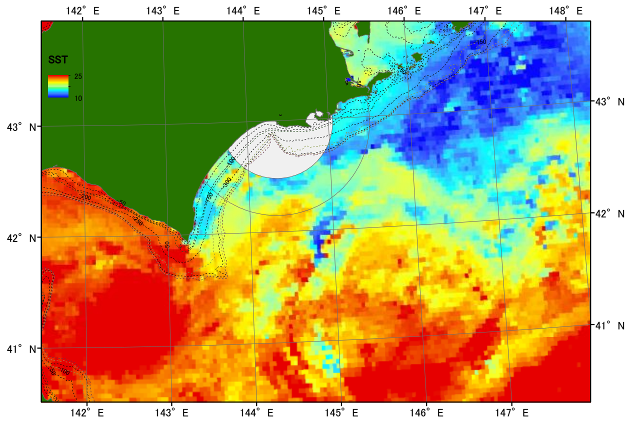
2009



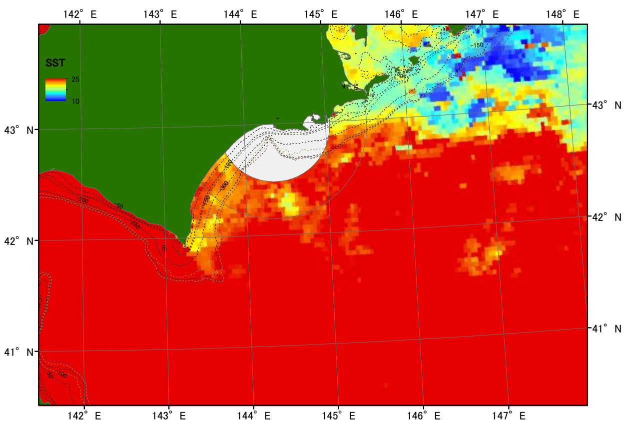
2010



2011



2012



2013

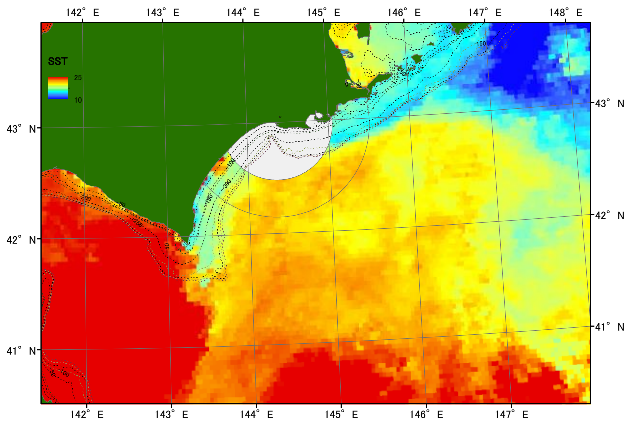


Figure 2. Continued.

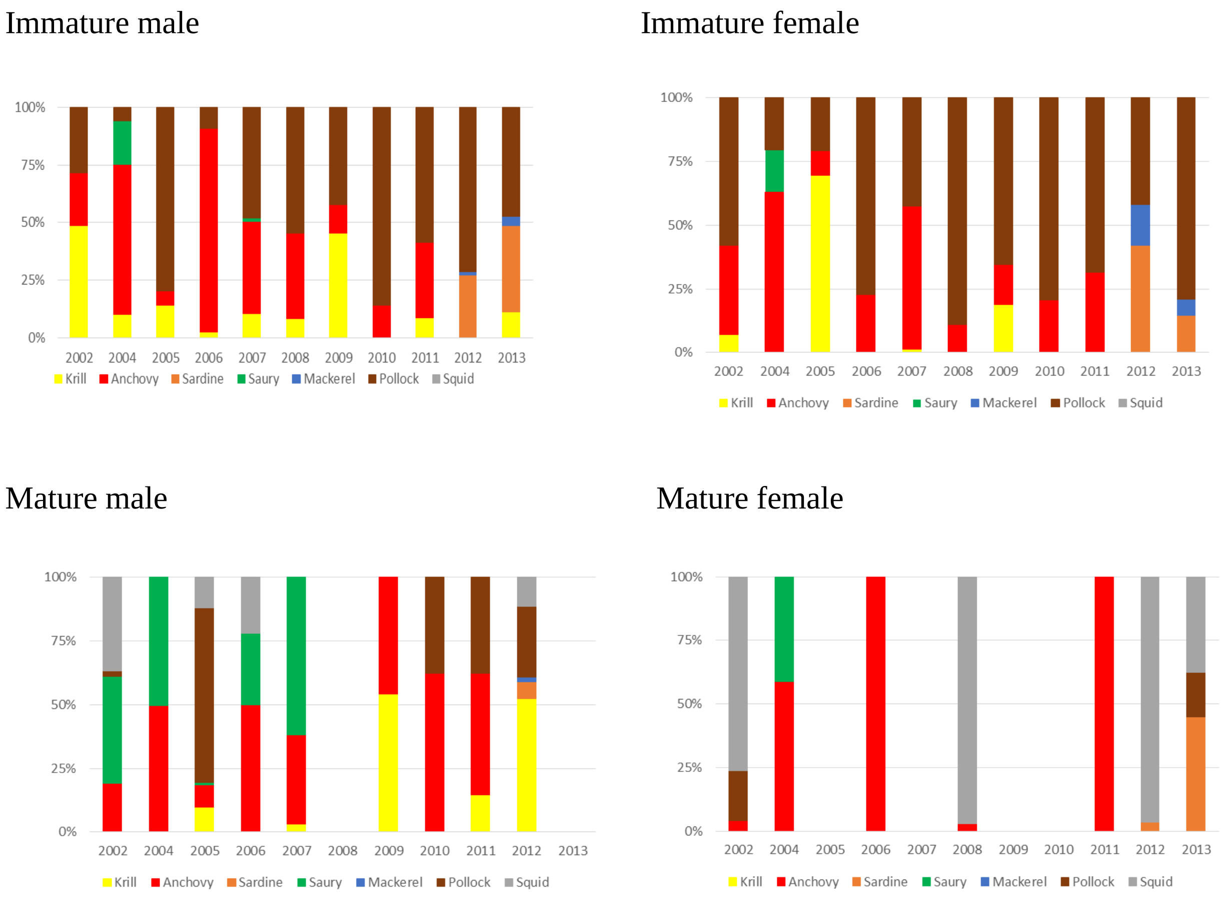


Figure 3. The yearly change of composition of prey species based on the restored wet weight of their stomach contents among sexual maturity stage.

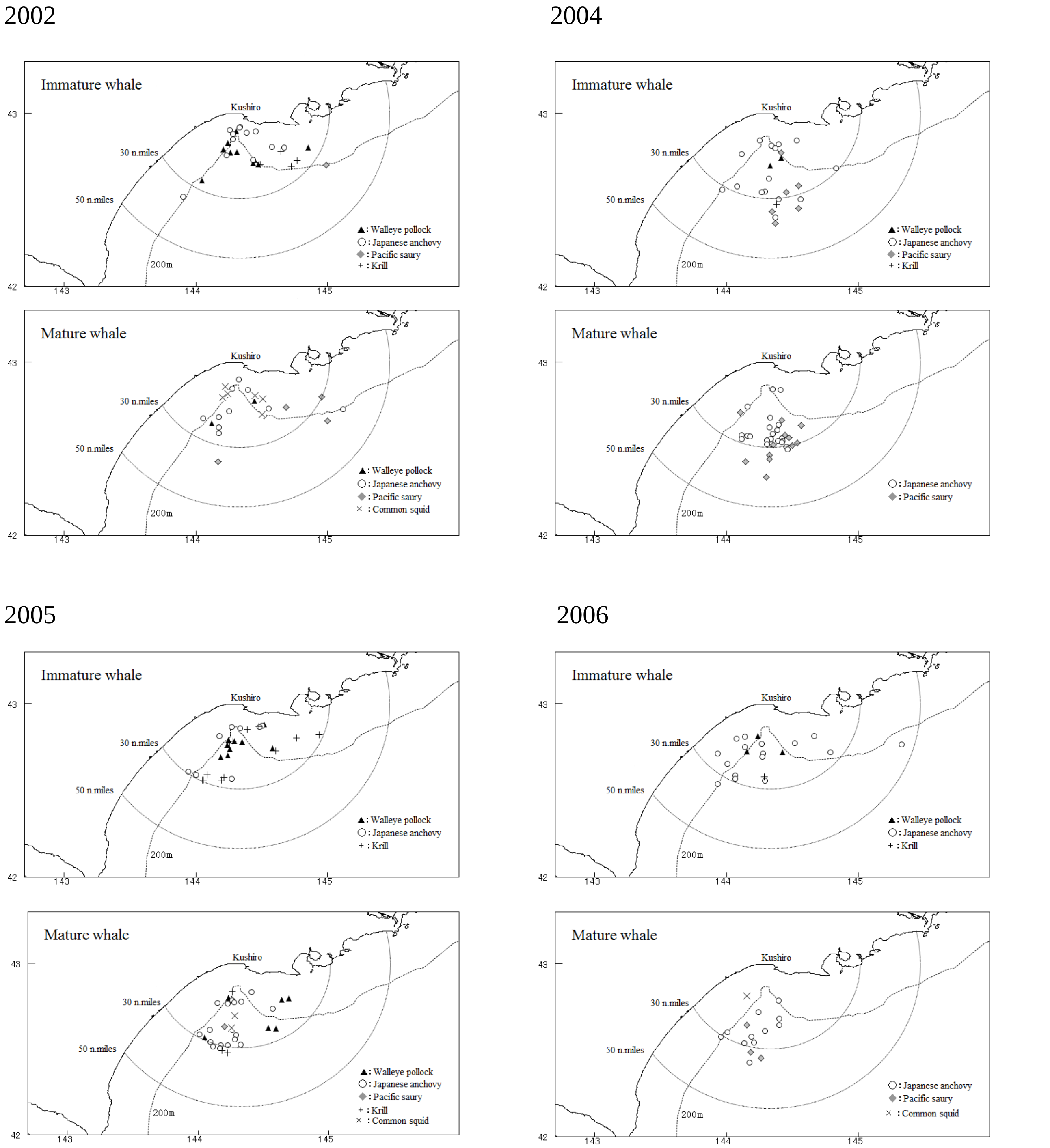


Figure 4. The sighting positions of common minke whales caught by sexual maturity and major prey species found in the stomach contents in the coastal survey off Kushiro.

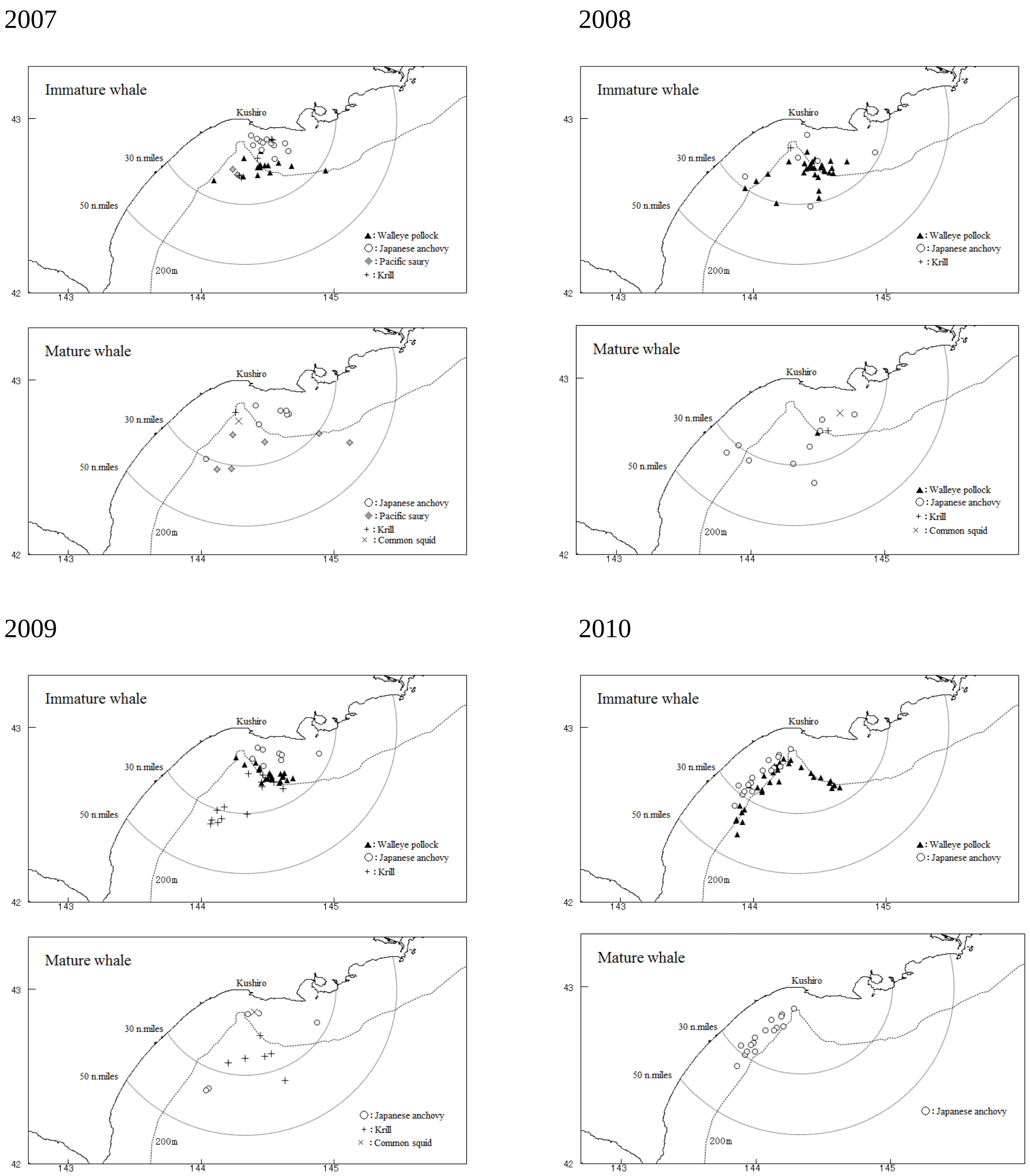
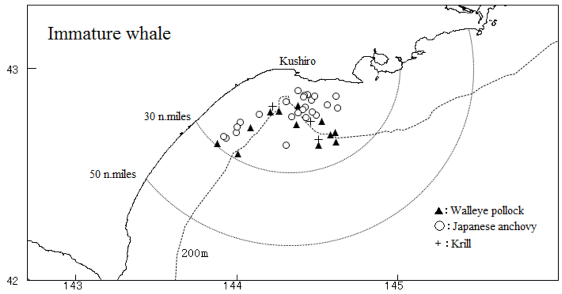
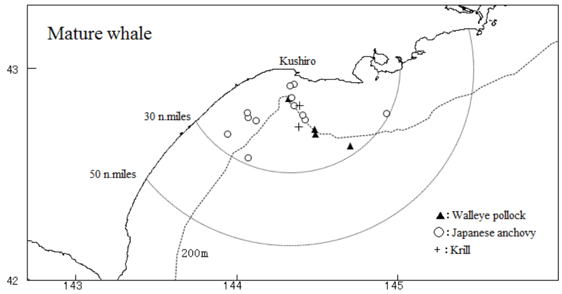


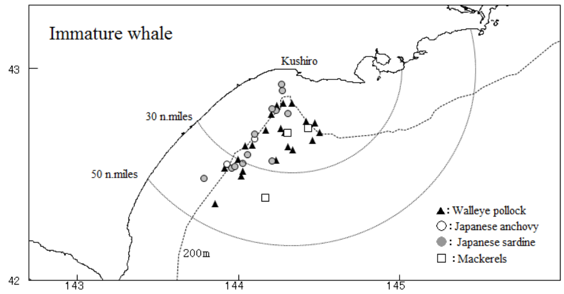
Figure 4. Continued.

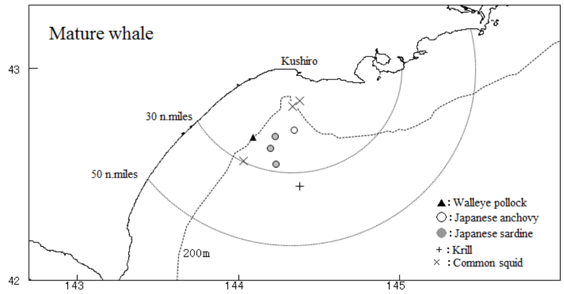
2011



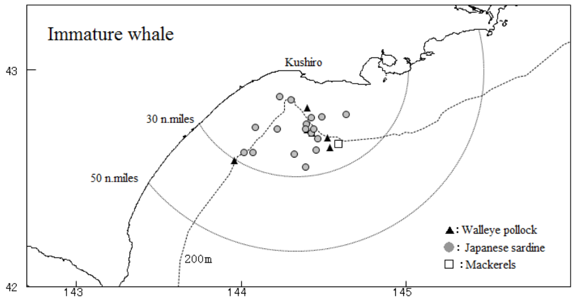


2012





2013



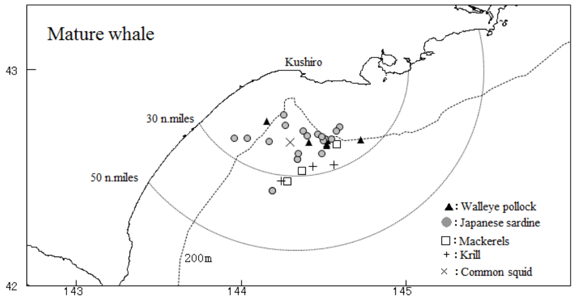


Figure 4. Continued.