Feeding habits of sperm whales and their impact on neon flying squid resources in the western North Pacific

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ABSTRACT

The stomach contents of forty five sperm whales (*Physeter macrocephalus*) sampled in the western North Pacific by JARPN II surveys from May to September each year 2000 to 2007 were analyzed. Thirty-eight prey species consisting of 33 squids, 1 octopus and 4 fishes, were identified. Sperm whales fed mainly on various deep-sea squids. The most important prey species were 4 squids (*Taningia danae, Histioteuthis dofleini*, *Belonella pacifica borealis* and *Gonatopsis borealis*). Sperm whales feed mainly on prey in the mesopelagic and/or bottom during daytime in the western North Pacific. The seasonal prey consumption (from May to September) by sperm whales in this region was calculated to be nearly 1.2 million tons. We also estimated that consumption of the commercially important neon flying squid *Ommastrephes bartrami* by sperm whales was 30,000 tons during May to September. This estimation was equivalent to roughly 2 times the recent total annual catch of neon flying squid fisheries in the western North Pacific. Estimated feeding contribution rates of the surface layer to predation by sperm whales in each sub-area were ranged from 4.7 to 11.4%. Since the population of sperm whale is large, the consumption in surface layer is also large. In 2000 to 2007 JARPN II, the large male sperm whales (B.L. > 13 m) could not be sample for technical reason. To understand more precisely the feeding habits of sperm whales, a larger number of samples, especially mature males are needed, though it was difficult to catch large animals due to the capacity of the research base ship. Our data will contribute for building ecosystem model in the western North Pacific.

KEYWORDS: SPERM WHALE; NORTH PACIFIC; FOOD/PREY; NEON FLYING SQUID, CONSUMPTION, ECOSYSTEM; SCIENTIFIC PERMITS

INTRODUCTION

The sperm whale (*Physeter macrocephalus*) is distributed in the world oceans from the equator to the edge of the polar pack ice area.

Some studies have been conducted on the stomach contents of sperm whales from Sanriku-Hokkaido coastal commercial whaling ground and the North Pacific pelagic commercial whaling ground. Berzin (1971) and Kawakami (1980) summarized these reports and pointed that the most dominant prey items were mesopelagic squids. However the ratios of fishes in the stomach contents of sperm whales caught varied largely by different in the regions they caught, occupation of fishes in the prey varied 1-68 %. In the northern part of the west of 180 degrees of longitude, fishes occupied 7-29 % in their stomach contents. Some of the important squid prey species in Sanriku-Hokkaido area during winter season were neon flying squid *Ommastrephes bartrami*, *Histioteuthis dolfleini*, *Octopoteuthis* sp. and robust clubhook squid *Onykia robusta*. Among the stomach contents data hitherto accumulated, the contents were usually classified to prey groups in most cases, such as krill, fish and squid. There were also records of empty stomachs and blank. The fullness of stomach contents was categorized into five classes (R = 3/4 - 4/4, rrr

= 2/4 – 3/4, rr = 1/4 – 2/4, r = < 1/4, 0 = empty). The freshness of stomach contents was categorized into four classes (F = fresh, fff = lightly digested, ff = moderately digested, f = heavily digested). However, the quantitative study of prey species of sperm whales was few in the western North Pacific. Sperm whales are considered to play an important role in the food web, especially, in the meso-pelagic and deep sea, because of their large abundance and biomass. To understand their role in the marine ecosystem in the western North Pacific, it is necessary to obtain more precise information on their feeding habits both qualitatively and quantitatively. However, since 1978, there have been few published reports of their feeding habits in this region.

Among prey species, the neon flying squid is very important target species for fisheries in the western North Pacific. They are widely distributed in both the coastal and offshore areas up to near east of 180 degrees of longitude (Fig. 1). Two groups (winter-spring spawner and fall spawner) are distributed in the western North Pacific. The winter-spring spawner move northern limit of the distribution for feeding in October, then the squid move and spawn southwards at 20-30 S for spawning from winter to spring. The resources were estimated 140,000-400,000 tons (average is 270,000 tons) in western North Pacific (western part of 170 degrees of longitude) and the average fisheries catch in recent 5 years was 15,000 tons from this region (Fisheries agency of Japan, 2008). Recently, catch by China is increasing, almost 5 times of the catch by Japan (Ichii, pers. comm.). The purpose of this study is to investigate the feeding habits of sperm whales precisely both qualitative and quantitative point of views and estimate their feeding impact on the neon flying squid resources in the western North Pacific. We also discuss that the feeding contribution rate for surface layer by predation of sperm whales. This result improves our knowledge of the feeding habits of sperm whales in this region and contributes to construct the ecosystem modelling.

MATERIALS AND METHODS

Research area and period

Forty five individuals of sperm whales were sampled in sub-areas 7, 8 and 9 excluding the EEZ of foreign countries. Fig. 2 shows the sighting positions of sperm whales sampled in each month from 2000 to 2007 seasons.

Sampling of animals and stomach contents

All sperm whales of primary and secondary sighting were targeted for sampling. Although, the sample size was small in each year (N<=10), we attempted to sample to cover the JARPN II's research ares as much as possible. The order of individuals to be sampled in a school were decided by a researcher on board using a series of tables of random sampling numbers (TRS), which were prepared according the size of the schools. When the sighting of the sperm whales was occurred, the SSV approached to the school of whales within 0.2n.miles. Observers on the top barrel counted a number of whales and estimated body length of each animal. If a sighting was solitary whale, it was sampled immediately after the body length estimation. For sampling of sperm whale, there was a restriction of body length (Body length: < 13 m) from the logistical reason (capacity of research base vessel). If the body length was within limitation, the whales were sampled. If a school was consisted of two or more animals, the researcher assigned a serial number to each individual, ranging from left to right. The first target whale was chosen using the TRS specific to the school size. When two whales should be sampled from a school, the second target was selected by the same manner after the first animal was sampled. In this case, the remaining individuals were renumbered according to the latest position in the school and TRS was used for the original school size minus one.

Therefore, the analyses of this report focused limitedly on small and medium size individuals.

Sampled whales were immediately transported to a research base vessel, where biological measurements were carried out.

As soon as the sperm whale was on the research base vessel upper deck, the stomachs were removed within a few hours after capture. Then, each stomach contents (both cases of including and excluding liquid) was weighed to the nearest 0.1 kg and kept frozen for later analyses. Table 1 shows the data of sex, body length, stomach contents weight and its ratio of body weight of each individual in each area.

Data analyses

In the laboratory prey species in the samples were identified to the lowest taxonomic level as possible. Undigested preys were identified using morphological characteristic (Kubodera and Furuhashi 1987, Nesis 1987, Okutani 1995, 2005). To identify the partly digested preys, fish otoliths and quid jaw plate (lower beaks) were applied (Kubodera and Furuhashi 1987, Kubotera *et al*. 2005).

The total number of all prey species in the sample was calculated by adding to the number of undigested prey, partly digested prey and buccal masses of squid and octopus and half the total number of free otoliths in stomach contents. The total weight of each prey species was obtained through apparent wet weight of each prey.

Feeding Indices (based on 2000 to 2007 results)

The relative frequency of occurrence of each prey species (*RF*) in each whale was calculated as follows:

$$RF = (Ni / N_{all}) \times 100 \quad (1)$$

Ni = the number of prey species i in each whales

N_{all} = the total number of prey species in each whales

Then, the relative prey importance by weight of each prey species (*RW*) was calculated as follows:

$$RW = (W_i / W_{all}) \times 100 \quad (2)$$

W_i = the apparent wet weight of contents containing prey species i

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

Sperm whale feed on prey from near surface to deep water, so we estimated the consumption by sperm whale in the surface and deeper waters. To estimate this value is important for constructing the ecosystem model such as Ecopath and Ecosim model (Mori *et al.*, 2009). The estimated feeding contribution rate for the surface layer (*CR*) to predation by each whale was calculated as follows:

$$CR = (CRW_i / W_{all}) \times 100 \quad (3)$$

CRW_i = the rate of stomach contents weight of organisms related the surface layer as prey in each whale I

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

Squids which related the surface layer were listed in Table. 2.

Daily and seasonal prey consumption

Tamura (2003) were calculated their dairy prey consumption (*I*) of sperm whale using following three equations.

(1) $I = 0.42M^{0.67}$

This method was proposed by Innes *et al*.(1986). I is daily prey consumption (kg per day) and M is average body weight (kg).

(2) $D = 206.25M^{0.783}$; $I = D/1{,}300$

This method was proposed by Sigurjónsson and Víkingsson (1997). D is daily caloric value of prey intake (kcal per day), M is average body weight (kg) and I is daily prey consumption (kg). We assumed that estimated caloric value of prey was 1,300 kcal/kg (Steimle and Terranova, 1985).

(3) $I = 0.035M$

This method was proposed by Klumov (1963). I is daily prey consumption (kg per day) and M is average body weight (kg).

The average dairy prey consumption of sperm whale (average body weight 18.5 tons) in North Pacific was estimated to be 433 kg ranged from 304 to 648 kg (from 1.6 to 3.5% of body weight). We used this estimation (433 kg per day) for calculation of seasonal consumption (From May to September). The number of sperm whales distributed in each season and sub-area were estimated by sighting data of JARPN II (Table 13; Hakamada *et al.*, 2008). The seasonal consumption of sperm whales were calculated as following,

(4) $SI = 433 \times SN \times D / 1{,}000$

SI is seasonal consumption of sperm whales (tons per day), *SN* is number of sperm whales distributed in early (May and June) and late season (from July to September). *SN* is described by Hakamada *et al*. (2009). *D* is days during early and late season (Early season: 61 days; late season: 92 days).

RESULTS

Diversity of prey species

Thirty-eight prey species consisting of 33 squids, 1 octopus and 4 fishes were identified in the stomach contents of whales caught in 2000-2007 JARPN II (Table 2).

Composition of prey species in each sperm whale

Among 2000 and 2007 in JARPN II, the occurrence (%) and apparent wet weight composition (%) of prey species consumed by sperm whales were shown on Tables 4-11. The apparent wet weight composition (%) of fish was ranged from 0.0 to 71.0 % in each animal. The estimated contribution rates for surface layer were ranged from 0.0 to 95.8 % in each animal (Tables 4-11).They fed mainly on 4 squids species (*Taningia danae, Histioteuthis dofleini, Belonella pacifica borealis* and the eight armed squid *Gonatopsis boreali*). The apparent wet weight composition (%) of fish was ranged from 0.4 to 14.2 % in each sub-area (Table 12).

Weight and freshness of stomach contents in each sperm whale

Between 2000 and 2007 JARPN II, the stomach contents weight ranged from 9.0 kg to 305.8 kg (Table 1). The maximum stomach contents rate of sperm whales was equivalent to 1.9% of their body weight. The freshness of stomach contents showed F (6 inds., 15.8%),), fff (11 inds., 28.9%), ff (8 ind., 21.1%) and f (7 inds., 18.4%).

The estimated feeding contribution rate for the surface layer to predation by each whale

The estimated feeding contribution rates for the surface layer to predation by each sperm whale were calculated to be among 0.0 % and 95.8 % (Tables 4 – 11). The estimated feeding contribution rates for the surface layer to predation by sperm whales in each sub-area were calculated to be a range of 4.7 % to 11.4 % (Table 12)

The daily and seasonal prey consumption

Estimated numbers of sperm whales distributed in the research area were 15,928 inds in early season and 20,297 inds in late season (Hakamada *et al.* 2009). The daily prey consumption during early season (May and June) and late season (from July to September) were calculated to be 6,897 tons and 8,787 tons, respectively in the research area. The seasonal prey consumption (from May to September) was estimated to be 1.2 million tons (Table 13).

The consumption of neon flying squid

Estimated numbers of sperm whales distributed in the sub-area 7 were 6,429 inds in early season and 7,550 inds in late season (Hakamada *et al.* 2009). The daily prey consumption during early season and late season were calculated to be 445 tons and 26 tons, respectively in the research area. The seasonal consumption (from May to September) was estimated 30 thousand tons (Table 14).

DISCUSSION

Diversity of prey species

Among 2000 and 2007 in JARPN II surveys, sperm whales fed mainly on various deep-sea squids. Thirty-three prey species consisting of 28 squid, 1 octopus and 4 fish were identified. The most important prey species in JARPNII surveys were 4 squids (*Taningia danae, Gonatopsis borealis, Histioteuthis dofleini* and *Belonella pacifica borealis*).

Dozens year ago, several papers have reported on the stomach contents of sperm whales from Sanriku-Hokkaido coastal whaling ground and the North Pacific pelagic whaling ground. Berzin (1971) and Kawakami (1980) summarized these reports. Squid was the most dominant prey category in the stomach contents of sperm whales. The most important prey species in Sanriku-Hokkaido area from winter to spring were *Histioteuthis dofleini*, *Octopoteuthis* sp., *Onykia robusta* and neon flying squid (*Ommastrephes bartrami*) (Okutani *et al*., 1976). However, in our results showed that the *Octopoteuthis* sp., *Onykia robusta* and neon flying squid were not important prey of sperm whales from spring to autumn.

It seems that there are geographical and seasonal changes of prey species in the research area.

Stomach contents and feeding activity

Based on JARPN II data, the stomach contents weight ranged from 9.0 kg to 305.8 kg. The maximum stomach contents rate was equivalent to 1.9% of their body weight. The weight of stomach contents of sperm whales may be different according to the size of whales, however it is considered to be less than 300 kg. In Kurile Island, they feed less than 200 kg (Betesheva and Akimushkin, 1955). The stomach contents weight of the sperm whale in the Cook Strait region of New Zealand was reported to have varied from 12.7 to 105 kg (Gaskin and Cawthorn, 1967). Clarke (1977) considered the amount of daily prey consumed by sperm whales would be from 2 to 4 % of their body weight and calculated as 300 kg and 200 kg for males and females, respectively. The average dairy prey consumption of sperm whale (average body weight 18.5 tons) in North Pacific was estimated to be 433 kg ranged from 304 to 648 kg (from 1.6 to 3.5% of body weight) (Tamura, 2003).

They generally feed on prey near the surface during night time in the Antarctic (Matsushita, 1955). However, the some prey species in the almost stomach contents in JARPN II were very fresh (no digestion), and therefore sperm whales feed on prey in the meso-pelagic and/or bottom during daytime in the western North Pacific.

According to these results, the sperm whale might feed on prey for several times in a day in this region.

The feeding impact for neon flying squid resources

In sub-area 7, three sperm whales fed on some neon flying squids. The average rates of neon flying squids consumed by sperm whales sampled during early season (May and June) and late season (July to September) were estimated 16.0% and 0.8% in the western North Pacific, respectively.

In this study, the consumption of neon flying squid fed by the sperm whales from May to September was estimated to be 29,000 tons, equivalent to roughly 2 times the total estimated recent neon flying squid fisheries catch in the western North Pacific. In previous report, the sperm whales fed mainly on neon flying squids (20%: occurrence of squids in the stomach contents of sperm whales caught) around Joban area (sub-area 7) in winter (Okutani *et al*., 1976). The information of feeding habits of sperm whales, especially mature male of sperm whales from spring to fall and winter in recent years is needed for accurate impact on neon flying squid resources by sperm whales.

The application of results collected JARPN II for ecosystem model

The sperm whales are considered to be the mesopelagic / deep-sea squid feeder. In other area such as Iceland, Bering Sea, West of Canada and New Zealand, it was reported that they fed mainly on mesopelagic and/or bottom fishes (Pike, 1950; Okutani and Nemoto, 1964; Gaskin and Cawthorn, 1967;

Roe, 1969). However, in the present research area, it was confirmed that they fed mainly on mesopelagic / deep-sea squids. Furthermore, it was confirmed that sperm whale in this region also fed on some squids related to surface layer such as *Onychoteuthis borealijaponica*, *O. banksi*, *Onykia loennbergi*, eight armed squid (*Gonatopsis borealis*) and neon flying squid. Estimated contribution rates (%) of the surface layer in each sub area were ranged from 4.7 to 11.4, suggesting the consumption in surface layer by biomass of sperm whale is large.

And, the neon-flying squid, which was found in the some stomach contents, is one of the important commercial squids, and therefore there is a possibility of direct competition with fishery and sperm whales. The data collected by JARPN II is useful for management of neon flying squid in the western North Pacific in the future.

These data such as food habit, consumption by sperm whale were used for Ecopath & Ecosym type model to understand the role of sperm whale in the marine ecosystem (Mori *et al.*, 2009).

In this present study, stomach contents of 45 sperm whales sampled in the western North Pacific from May to September in 2000-2007 JARPN II, were analyzed. However, these samples were biased in immature males and females due to the restriction of body length. To understand the feeding habits of sperm whales more precisely, a larger number of sample, especially mature male animals are needed in future study, though such program is difficult logistically in the capacity of the present research base ship.

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Table 1. The biological and stomach contents data of sperm whales sampled by JARPN II surveys from 2000 to 2007.

Sub area	N		Body length (m)			Stomach contents (kg)			Ratio of body weight (%)			Frequency of freshness of stomach contents					
	Male	Female	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	F	fff	ff	f	Empty	Broken
7	7	16	10.0	12.8	8.2	102.0	242.2	9.0	0.7	1.4	0.1	6	5	3	5	1	3
8	3	4	9.9	12.7	7.9	87.3	160.2	18.9	0.8	1.8	0.2	0	2	2	0	2	1
9	3	12	10.4	11.7	8.4	163.2	305.8	23.6	1.0	1.9	0.1	0	4	3	2	3	3

Table 2. The prey species of sperm whales in western North Pacific from 2000 to 2007.

(○ is shown in previous report as prey species of sperm whales around of Japan)

	Scientific name	English name	Occurences in previous report	Ref.	Remarks
Cephalopoda					
	Enoploteuthis chuni			3	Day time: 300-900 m; Nigh ttime: Upper 200m
	Ancistrocheirus lesueuri		○	1	Night time: Upper 100m (DML is u<0.01er 35mm)
	Taningia danae		○	1	Night time: Upper 180m (Sub-adult); Upper 1,200m (Adult)
	Octopoteuthis sicula		○	1	Day time: Lower 200m, especially 300-400m, Night time: Lower 500m (DML is u<0.01er 15mm)
	O deletron			1	Day time: Lower 200m, especially 300-400m, Night time: Lower 500m (DML is u<0.01er 15mm)
	O. megaptera			2	Day time: Mid-bottom water; Night time: Surface layer
	O. sp. (Type M)				
	O. sp. (Type L)				
**	*Onychoteuthis borealijaponica*			2	Surface layer
**	*O. banksi*			1	Upper 150 m
*	*Onykia loennbergi*		○	2	From surface layer to bottom layer
	O. robusta	Giant squid	○	1	U<0.01er 100m of bottom layer
	Gonatus berryi			1	Day time: 500-800 m; Nigh ttime: 400-800m (Sub-adult)
	G. onyx				
	G. pyros			1	Day time: 400-700m, Night time: 100-500m especially 300-400m (DML is u<0.01er 20mm)
	G. madokai				
	G. middendorffi			1	Day time: 400-800m, Night time: Upper 500m (DML is u<0.01er 21mm)
	Eogonatus tinro			2	From surface layer to bottom layer
	G. spp.				
*	*Gonatopsis borealis*	Eight-armed squid	○	1	Day time: 400-800m (DML is 16-47mm), Night time: 0-400m
	G. makko				
	Berryteuthis magister				
	Histioteuthis dofleini		○	1	Day time: 500m, Night time: 50m (DML is 12-14mm)
	H. corona inermis			1	Day time: 600m (DML is 25-27mm)
	H. sp.				
	H. meleagroteuthis			1	Day time: 700m, Night time: 400m (DML is 16-32mm)
	Architeuthis cf. japonica			1	From 200-1200 m
*	*Ommastrephes bartrami*	Neon flying squid	○	4	Day time: 300-400m, Night time: Surface layer
	Pholidoteuthis sp.			1,2	Day time: Bottom layer (400-2,000m), Night time: Mid layer
	Discoteuthis discus			1	Day time: upper 750m, Night time: upper 400m (DML is u<0.01er 53mm)
	Cycloteuthis akimushkini			1	Day time: Upper 650m, Night time: Upper 200m
	Chiroteuthis picteti			2	From mid layer to bottom layer
	C. calyx		○	1	Day time: 500-800m, Night time: 0-500m (Sub-adult)
	Asperoteuthis acanthoderma			2	From mid layer to bottom layer
	Galiteuthis phyllura			1	Day time: lower 900m, Night time: 0-1200m (Sub-adult)
	Galiteuthis sp.				
	Belonella pacifica borealis		○	1	Day time: 600-800m (DML is u<0.01er 60mm)
	Megalocranchia maxima			2	Mid layer
	Megalocranchia sp.				
	Cranchidae sp.				
	Haliphron atlanticus			1	0-3,200 m, especially 0-200m, 450-1,000m
Pisces					
	Trachipterus trachypterus				
	Laemonema longipes	Threadfin hakeling	○		
	Coryphaenoides pectoralis				
	Theragra chalcogramma	Walleye pollock	○		

*: Surface migration during night; **: Surface distribution in a day

1: Roper, C. F. E. and R. E. Young (1975) , 2: Nesis, K. N. (1987), 3: Okutani, T. (1980), 4: Tanaka (in Japanese: 2000)

Table 3. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in each sub-area. *: Surface migration during night; **: Surface distribution in a day

	Prey species	S001		S002		S003	
		Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda							
	Enoploteuthis chuni						
	Ancistrocheirus lesueuri	20.5	18.6	7.4	0.3	29.0	12.7
	Taningia danae			50.0	92.1	34.2	60.1
	Octopoteuthis sicula						
	Octopoteuthis deletron	2.6	0.1			7.9	0.6
	O. megaptera						
	O. sp. (Type M)	2.6	2.3	13.0	0.6	7.9	1.1
	O. sp. (Type L)						
**	*Onychoteuthis borealijaponica*						
**	*O. banksi*						
*	*Onykia loennbergi*						
	O. robusta			3.7	5.7	7.9	7.3
	Gonatus berryi						
	G. onyx	2.6	0.1				
	G. pyros						
	G. middendorffi						
	Eogonatus tinro						
	G. spp.						
*	*Gonatopsis borealis*						
	Histioteuthis dofleini	53.9	76.3	3.7	0.2	7.9	3.5
	H. corona inermis						
	H. sp.	15.4	2.6	22.2	1.2	2.6	0.01
	H. meleagroteuthis						
	Architeuthis cf. japonica					2.6	14.6
*	*Ommastrephes bartrami*						
	Pholidoteuthis sp.						
	Discoteuthis discus	2.6	0.03				
	Cycloteuthis akimushkini						
	Chiroteuthis picteti						
	C. calyx						
	Asperoteuthis acanthoderma						
	Galiteuthis phyllura						
	Galiteuthis sp.						
	Belonella pacifica borealis						
	Megalocranchia maxima						
	Megalocranchia sp.						
	Cranchidae sp.						
	Unidentified squids						
	Haliphron atlanticus						
Pisces							
	Trachipterus trachypterus						
	Laemonema longipes						
	Theragra chalcogramma						
	Unidentified fish						
Estimated contribution rate of surface *		0.0	0.0	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *+**		0.0	0.0	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *						0.0	0.0
Estimated contribution rate of surface *+**						0.0	0.0

Table 4. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2000.

***: Surface migration during night; **: Surface distribution in a day**

	Prey species	S001		S002		S003		S004		S005	
		Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda											
	Enoploteuthis chuni										
	Ancistrocheirus lesueuri	1.6	<0.01			1.6	3.1				
	Taningia danae					1.6	2.4				
	Octopoteuthis sicula			0.8	0.2					1.2	0.1
	Octopoteuthis deletron										
	O. megaptera										
	O. sp. (Type M)										
	O. sp. (Type L)										
**	*Onychoteuthis borealijaponica*			0.8	2.8					1.2	<0.01
**	*O. banksi*										
*	*Onykia loennbergi*							3.3	2.0		
	O. robusta	2.1	40.2			3.2	16.1				
	Gonatus berryi					1.6	0.2				
	G. pyros										
	G. middendorffi	0.5	0.2					1.7	0.1	2.3	0.3
	Eogonatus tinro									1.2	0.1
	G. spp.	0.5	0.2							8.1	0.1
*	*Gonatopsis borealis*			0.8	2.9			15.0	30.2	36.0	48.4
	Histioteuthis dofleini	34.7	29.2	11.9	25.5	79.0	77.3	28.3	44.5	4.7	19.0
	H. corona inermis										
	H. sp.										
	H. meleagroteuthis										
	Architeuthis cf. japonica	0.5	8.5								
*	*Ommastrephes bartrami*										
	Pholidoteuthis sp.										
	Discoteuthis discus							3.3	1.8		
	Cycloteuthis akimushkini										
	Chiroteuthis picteti									1.2	0.1
	C. calyx			1.6	1.6						
	Asperoteuthis acanthoderma										
	Galiteuthis phyllura	4.7	0.5	1.6	0.5			18.3	6.6	7.0	2.3
	Galiteuthis sp.	1.1	0.2			1.6	0.0				
	Belonella pacifica borealis	48.9	13.0	82.5	66.6	6.5	0.2	13.3	5.2	34.9	29.2
	Megalocranchia maxima							15.0	6.3		
	Megalocranchia sp.										
	Cranchidae sp.					4.8	0.7				
	Unidentified squids	2.1	<0.01							2.3	0.4
	Haliphron atlanticus							1.7	3.4		
Pisces											
	Trachipterus trachypterus	0.5	3.6								
	Laemonema longipes	0.5	<0.01								
	Theragra chalcogramma	0.5	<0.01								
	Unidentified fish	1.6	4.4								
Estimated contribution rate of surface *		0.0	0.0	0.8	2.9	0.0	0.0	18.3	32.1	36.0	48.4
Estimated contribution rate of surface *+**		0.0	0.0	1.6	5.7	0.0	0.0	18.3	32.1	37.2	48.4
Estimated contribution rate of surface *										11.0	16.7
Estimated contribution rate of surface *+**										11.4	17.3

Table 5. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2001.

***: Surface migration during night; **: Surface distribution in a day**

	Prey species	S001		S002		S003		S004		S005		S008	
		Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda													
	Enoploteuthis chuni												
	Ancistrocheirus lesueuri	34.5	55.6			25.0	14.3	7.6	2.2	21.3	25.9		
	Taningia danae							9.1	1.7				
	Octopoteuthis sicula												
	Octopoteuthis deletron					12.5	0.7			7.9	5.7		
	O. megaptera							3.0	2.2				
	O. sp. (Type M)	3.4	3.4			18.8	9.1	18.2	16.1				
	O. sp. (Type L)					3.1	55.5	7.6	13.1				
**	*Onychoteuthis borealijaponica*												
**	*O. banksi*												
*	*Onykia loennbergi*	24.1	5.6							1.1	1.4		
	O. robusta												
	Gonatus berryi												
	G. pyros	3.4	<0.01	16.7	<0.01			10.6	<0.01				
	G. middendorffi												
	Eogonatus tinro												
	G. spp.			16.7	1.9			9.1	3.3	1.1	<0.01	25.0	ND
*	*Gonatopsis borealis*												
	Histioteuthis dofleini	34.5	35.5			18.8	5.4	4.5	9.5	38.2	27.6		
	H. corona inermis									2.2	0.4		
	H. sp.												
	H. meleagroteuthis												
	Architeuthis cf. japonica												
*	*Ommastrephes bartrami*			33.3	95.8								
	Pholidoteuthis sp.					6.3	14.6						
	Discoteuthis discus							1.5	<0.01				
	Cycloteuthis akimushkini							1.5	4.4				
	Chiroteuthis picteti									1.1	<0.01		
	C. calyx							1.5	1.7	1.1	1.1		
	Asperoteuthis acanthoderma							1.5	3.2				
	Galiteuthis phyllura							7.6	2.1	20.2	3.2	75.0	ND
	Galiteuthis sp.												
	Belonella pacifica borealis			16.7	2.3	12.5	0.5	7.6	1.0	4.5	0.5		
	Megalocranchia maxima												
	Megalocranchia sp.							1.5	0.5				
	Cranchidae sp.												
	Unidentified squids			16.7	<0.01	3.1	<0.01	4.5					
	Haliphron atlanticus												
Pisces													
	Trachipterus trachypterus							3.0	39.0	1.1	34.2		
	Laemonema longipes												
	Theragra chalcogramma												
	Unidentified fish												
Estimated contribution rate of surface *		24.1	5.6	33.3	95.8	0.0	0.0	0.0	0.0	1.1	1.4	0.0	0.0
Estimated contribution rate of surface *+**		24.1	5.6	33.3	95.8	0.0	0.0	0.0	0.0	1.1	1.4	0.0	0.0
Estimated contribution rate of surface *												9.8	17.1
Estimated contribution rate of surface *+**												9.8	17.1

Table 6. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2002.

***: Surface migration during night; **: Surface distribution in a day**

	Prey species	S001		S003		S004		S005	
		Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda									
	Enoploteuthis chuni								
	Ancistrocheirus lesueuri			1.6	5.2	1.6	<0.01	15.4	10.2
	Taningia danae			6.3	21.5	14.1	52.8	10.3	27.2
	Octopoteuthis sicula								
	Octopoteuthis deletron	1.5	0.5	7.9	1.5				
	O. megaptera								
	O. sp. (Type M)			1.6	0.7				
	O. sp. (Type L)								
**	*Onychoteuthis borealijaponica*	2.3	8.7						
**	*O. banksi*								
*	*Onykia loennbergi*								
	O. robusta								
	Gonatus berryi	3.1	1.3						
	G. pyros								
	G. middendorffi								
	Eogonatus tinro								
	G. spp.	0.8	0.04	3.2	0.1			2.6	<0.01
*	*Gonatopsis borealis*	2.3	0.3	6.3	0.3	1.6	0.2	5.1	<0.01
	Histioteuthis dofleini	8.4	20.3	41.3	45.3	70.3	45.4	64.1	62.6
	H. corona inermis								
	H. sp.	6.1	9.2	27.0	6.7	7.8	1.4	2.6	<0.01
	H. meleagroteuthis								
	Architeuthis cf. japonica								
*	*Ommastrephes bartrami*			1.6	18.5				
	Pholidoteuthis sp.								
	Discoteuthis discus								
	Cycloteuthis akimushkini			1.6	0.2				
	Chiroteuthis picteti	0.8	<0.01						
	C. calyx	6.1	8.4						
	Asperoteuthis acanthoderma								
	Galiteuthis phyllura	7.6	2.9	1.6	<0.01	1.6	0.3		
	Galiteuthis sp.								
	Belonella pacifica borealis	61.1	48.3			3.1	<0.01		
	Megalocranchia maxima								
	Megalocranchia sp.								
	Cranchidae sp.								
	Unidentified squids								
	Haliphron atlanticus								
Pisces									
	Trachipterus trachypterus								
	Laemonema longipes								
	Theragra chalcogramma								
	Unidentified fish								
Estimated contribution rate of surface *		2.3	0.3	7.9	18.8	1.6	0.2	5.1	0.0
Estimated contribution rate of surface *+**		4.6	9.0	7.9	18.8	1.6	0.2	5.1	0.0
Estimated contribution rate of surface *								4.2	4.8
Estimated contribution rate of surface *+**								4.8	7.0

Table 7. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2003.

*: Surface migration during night; **: Surface distribution in a day

Prey species	S001		S004		S005		S006		S007		S008		S009		S010	
	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda																
Enoploteuthis chuni																
Ancistrocheirus lesueuri			7.8	2.0	3.8	<0.01										
Taningia danae	23.8	83.4	33.3	80.9	34.6	49.8	93.8	100.0	86.7	98.0	38.9	98.5	83.3	93.9	100.0	100.0
Octopoteuthis sicula			2.0	0.2												
Octopoteuthis deletron																
O. megaptera					3.8	<0.01										
O. sp. (Type M)																
O. sp. (Type L)																
** *Onychoteuthis borealijaponica*																
** *O. banksi*																
* *Onykia loennbergi*																
O. robusta					3.8	37.8										
Gonatus berryi					11.5	1.4	3.1	<0.01	3.3	<0.01	2.8	<0.01				
G. pyros	4.8	0.1														
G. middendorffi																
Eogonatus tinro																
G. spp.			5.9	1.7	3.8	<0.01	3.1	<0.01			2.8	<0.01				
* *Gonatopsis borealis*			3.9	0.2												
Histioteuthis dofleini	61.9	16.6	29.4	11.3	23.1	9.5			6.7	1.9	55.6	1.50	16.7	6.1		
H. corona inermis			2.0	0.3												
H. sp.	9.5	<0.01			15.4	1.3										
H. meleagroteuthis																
Architeuthis cf. japonica																
* *Ommastrephes bartrami*																
Pholidoteuthis sp.																
Discoteuthis discus																
Cycloteuthis akimushkini																
Chiroteuthis picteti																
C. calyx																
Asperoteuthis acanthoderma																
Galiteuthis phyllura			15.7	3.4					3.3	0.1						
Galiteuthis sp.																
Belonella pacifica borealis																
Megalocranchia maxima																
Megalocranchia sp.																
Cranchidae sp.																
Unidentified squids																
Haliphron atlanticus																
Pisces																
Trachipterus trachypterus																
Laemonema longipes																
Theragra chalcogramma																
Unidentified fish																
Estimated contribution rate of surface *	0.0	0.0	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *+**	0.0	0.0	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *															0.5	0.03
Estimated contribution rate of surface *+**															0.5	0.03

Table 8. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2004.

***: Surface migration during night; **: Surface distribution in a day**

	Prey species	S001		S002		S003	
		Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda							
	Enoploteuthis chuni						
	Ancistrocheirus lesueuri						
	Taningia danae					37.1	79.7
	Octopoteuthis sicula						
	Octopoteuthis deletron						
	O. megaptera						
	O. sp. (Type M)						
	O. sp. (Type L)	4.3	12.0				
**	*Onychoteuthis borealijaponica*						
**	*O. banksi*						
*	*Onykia loennbergi*						
	O. robusta	4.3	*	100.0	100.0		
	Gonatus berryi						
	G. pyros						
	G. middendorffi						
	Eogonatus tinro						
	G. spp.					2.9	*
*	*Gonatopsis borealis*	43.5	67.6				
	Histioteuthis dofleini	34.8	20.4			54.3	20.3
	H. corona inermis						
	H. sp.						
	H. meleagroteuthis						
	Architeuthis cf. japonica					2.9	*
*	*Ommastrephes bartrami*						
	Pholidoteuthis sp.						
	Discoteuthis discus						
	Cycloteuthis akimushkini						
	Chiroteuthis picteti						
	C. calyx	4.3	*				
	Asperoteuthis acanthoderma						
	Galiteuthis phyllura						
	Galiteuthis sp.						
	Belonella pacifica borealis	4.3	*				
	Megalocranchia maxima	4.3	*			2.9	*
	Megalocranchia sp.						
	Cranchidae sp.						
	Unidentified squids						
	Haliphron atlanticus						
Pisces							
	Trachipterus trachypterus						
	Laemonema longipes						
	Theragra chalcogramma						
	Unidentified fish						
Estimated contribution rate of surface *		43.5	67.6	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *+**		43.5	67.6	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *						14.5	22.5
Estimated contribution rate of surface *+**						14.5	22.5

Table 9. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2005.

***: Surface migration during night; **: Surface distribution in a day**

	Prey species	S001		S002		S003		S004		S005	
		Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda											
	Enoploteuthis chuni	0.8	0.1								
	Ancistrocheirus lesueuri	7.8	6.4	10.3	5.7						
	Taningia danae	3.1	10.4	1.1	3.0						
	Octopoteuthis sicula										
	Octopoteuthis deletron					1.0	0.7				
	O. megaptera										
	O. sp. (Type M)	3.9	0.5	1.1	1.4	5.1	2.4				
	O. sp. (Type L)										
**	*Onychoteuthis borealijaponica*										
**	*O. banksi*										
*	*Onykia loennbergi*										
	O. robusta	1.6	0.4	1.1	0.5	1.0	0.1				
	Gonatus berryi	1.6	0.3	2.3	0.1						
	G. pyros										
	G. middendorffi										
	Eogonatus tinro										
	G. spp.					1.0	0.03	16.7	54.7		
*	*Gonatopsis borealis*			1.1	1.9			66.7	38.2		
	Histioteuthis dofleini	70.3	78.9	55.2	31.6	56.1	83.5				
	H. corona inermis										
	H. sp.										
	H. meleagroteuthis										
	Architeuthis cf. japonica			2.3	31.8						
*	*Ommastrephes bartrami*										
	Pholidoteuthis sp.										
	Discoteuthis discus	0.8	0.0								
	Cycloteuthis akimushkini	2.3	0.4	8.0	15.9						
	Chiroteuthis picteti	0.8	0.0			2.0	0.7				
	C. calyx										
	Asperoteuthis acanthoderma										
	Galiteuthis phyllura										
	Galiteuthis sp.	2.3	1.0	2.3	0.9	16.3	5.1				
	Belonella pacifica borealis	2.3	0.1			16.3	7.4				
	Megalocranchia maxima	1.6	1.4	11.5	4.9	1.0	0.03	16.7	7.1		
	Megalocranchia sp.	0.8	0.1	2.3	2.2						
	Cranchidae sp.			1.1	0.001						
	Unidentified squids										
	Haliphron atlanticus										
Pisces											
	Trachipterus trachypterus										
	Laemonema longipes										
	Theragra chalcogramma										
	Unidentified fish										
Estimated contribution rate of surface *		0.0	0.0	1.1	1.9	0.0	0.0	66.7	38.2	0.0	0.0
Estimated contribution rate of surface *+**		0.0	0.0	1.1	1.9	0.0	0.0	66.7	38.2	0.0	0.0
Estimated contribution rate of surface *										17.0	10.0
Estimated contribution rate of surface *+**										17.0	10.0

Table 10. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2006.

*: Surface migration during night; **: Surface distribution in a day

	Prey species	S001		S002		S003		S004		S005		S006	
		Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda													
	Enoploteuthis chuni												
	Ancistrocheirus lesueuri											0.42	0.01
	Taningia danae									1.5	1.6		
	Octopoteuthis sicula												
	Octopoteuthis deletron							2.1	0.1	3.0	0.6		
	O. megaptera												
	O. sp. (Type M)	100.0	100.0	14.3	6.7			2.1	1.3	1.5	0.04		
	O. sp. (Type L)												
**	*Onychoteuthis borealijaponica*												
**	*O. banksi*												
*	*Onykia loennbergi*												
	O. robusta											1.7	10.3
	Gonatus onyx							18.8	4.4				
	G. berryi			14.3	79.9			1.0	0.1	13.4	1.4	6.8	5.6
	G. pyros												
	G. madokai											0.4	0.1
	G. middendorffi											0.4	0.01
	Eogonatus tinro												
	G. spp.			28.6	1.3	33.3	17.0	3.1	1.4	1.5	0.4	2.1	1.3
*	*Gonatopsis borealis*			14.3	0.7					3.0	0.1		
	G. makko											7.6	14.4
	Berryteuthis magister											2.1	3.2
	Histioteuthis dofleini							12.5	50.5	49.3	19.6	43.5	52.9
	H. corona inermis												
	H. sp.							20.8	20.2	3.0	0.1	1.7	0.1
	H. meleagroteuthis												
	Architeuthis cf. japonica												
*	*Ommastrephes bartrami*												
	Pholidoteuthis sp.												
	Discoteuthis discus												
	Cycloteuthis akimushkini												
	Chiroteuthis picteti							27.1	10.8				
	C. calyx							1.0	0.1	6.0	2.0		
	Asperoteuthis acanthoderma												
	Galiteuthis phyllura			14.3	6.4			8.3	5.8	7.5	0.2	6.8	1.6
	Galiteuthis sp.					33.3	72.3	2.1	5.3	6.0	2.2		
	Belonella pacifica borealis			14.3	5.0	33.3	10.8	1.0	0.1	3.0	1.0	24.9	6.1
	Megalocranchia maxima												
	Megalocranchia sp.												
	Cranchidae sp.											0.8	0.01
	Unidentified squids												
	Haliphron atlanticus												
Pisces													
	Trachipterus trachypterus												
	Laemonema longipes												
	Theragra chalcogramma												
	Coryphaenoides pectoralis											0.4	3.8
	Unidentified fish									1.5	71.0	0.4	0.8
Estimated contribution rate of surface *		0.0	0.0	14.3	0.7	0.0	0.0	0.0	0.0	3.0	0.1	0.0	0.0
Estimated contribution rate of surface *+**		0.0	0.0	14.3	0.7	0.0	0.0	0.0	0.0	3.0	0.1	0.0	0.0
Estimated contribution rate of surface *												2.9	0.1
Estimated contribution rate of surface *+**												2.9	0.1

Table 11. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in 2007.

***: Surface migration during night; **: Surface distribution in a day**

	Prey species	S001		S002		S003	
		Number %	Weight %	Number %	Weight %	Number %	Weight %
Cephalopoda							
	Enoploteuthis chuni						
	Ancistrocheirus lesueuri	20.5	18.6	7.4	0.3	29.0	12.7
	Taningia danae			50.0	92.1	34.2	60.1
	Octopoteuthis sicula						
	Octopoteuthis deletron	2.6	0.1			7.9	0.6
	O. megaptera						
	O. sp. (Type M)	2.6	2.3	13.0	0.6	7.9	1.1
	O. sp. (Type L)						
**	*Onychoteuthis borealijaponica*						
**	*O. banksi*						
*	*Onykia loennbergi*						
	O. robusta			3.7	5.7	7.9	7.3
	Gonatus berryi						
	G. onyx	2.6	0.1				
	G. pyros						
	G. middendorffi						
	Eogonatus tinro						
	G. spp.						
*	*Gonatopsis borealis*						
	Histioteuthis dofleini	53.9	76.3	3.7	0.2	7.9	3.5
	H. corona inermis						
	H. sp.	15.4	2.6	22.2	1.2	2.6	0.01
	H. meleagroteuthis						
	Architeuthis cf. japonica					2.6	14.6
*	*Ommastrephes bartrami*						
	Pholidoteuthis sp.						
	Discoteuthis discus	2.6	0.03				
	Cycloteuthis akimushkini						
	Chiroteuthis picteti						
	C. calyx						
	Asperoteuthis acanthoderma						
	Galiteuthis phyllura						
	Galiteuthis sp.						
	Belonella pacifica borealis						
	Megalocranchia maxima						
	Megalocranchia sp.						
	Cranchidae sp.						
	Unidentified squids						
	Haliphron atlanticus						
Pisces							
	Trachipterus trachypterus						
	Laemonema longipes						
	Theragra chalcogramma						
	Unidentified fish						
Estimated contribution rate of surface *		0.0	0.0	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *+**		0.0	0.0	0.0	0.0	0.0	0.0
Estimated contribution rate of surface *						0.0	0.0
Estimated contribution rate of surface *+**						0.0	0.0

Table 12. Occurrence (%) and wet weight composition (%) of prey species consumed by sperm whales in each area from 2000 to 2007.

Prey species	7 N=23 (N=1: Empty, N=3: Broken) Occurrence %	Number of squids %	Weight of squids %	8 N=7 (N=2: Empty, N=1: Broken) Occurrence %	Number of squids %	Weight of squids %	9 N=15 (N=3: Empty, N=3: Broken) Occurrence %	Number of squids %	Weight of squids %
Cephalopoda									
Taningia danae		15.3	24.1		5.1	17.0		23.2	35.9
Histioteuthis dofleini		26.2	26.1		36.0	34.0		26.4	19.4
Belonella pacifica borealis		15.3	9.3		4.1	1.7		5.3	1.5
* *Gonatopsis borealis*		3.7	4.6		13.9	7.6		3.9	4.7
* *Ommastrephes bartrami*		1.8	6.4		0.0	0.0		0.0	0.0
Enoploteuthis chuni		0.0	0.0		0.0	0.0		0.1	0.0
Ancistrocheirus lesueuri		6.4	6.6		0.0	0.0		5.0	2.9
Octopoteuthis sicula		0.2	0.0		0.0	0.0		0.0	0.0
Octopoteuthis deletron		1.6	0.5		1.2	0.3		0.7	0.0
O. megaptera		0.4	0.1		0.0	0.0		0.0	0.0
O. sp. (Type M)		2.2	1.6		1.7	0.7		9.5	7.5
O. sp. (Type L)		0.6	3.8		0.0	0.0		0.3	0.8
** *Onychoteuthis borealijaponica*		0.2	0.6		0.0	0.0		0.0	0.0
** *O. banksi*		0.0	0.0		0.0	0.0		0.0	0.0
* *Onykia loennbergi*		1.5	0.5		0.0	0.0		0.0	0.0
O. robusta		0.5	5.2		0.2	0.0		8.0	8.3
Gonatus berryi		1.2	0.2		3.8	0.9		0.4	0.0
G. onyx		0.0	0.0		2.9	0.3		1.6	5.7
G. pyros		1.6	0.0		1.0	0.0		0.0	0.0
G. madokai		0.0	0.0		0.0	0.0		0.0	0.0
G. middendorffi		0.2	0.0		0.0	0.0		0.0	0.0
G. makko		0.0	0.0		0.0	0.0		0.5	1.0
G. spp.		4.2	0.4		4.5	11.3		4.6	1.3
Eogonatus tinro		0.1	0.0		0.0	0.0		0.0	0.0
Berryteuthis magister		0.0	0.0		0.0	0.0		0.1	0.2
Histioteuthis corona inermis		0.2	0.0		0.0	0.0		0.0	0.0
H. meleagroteuthis		0.0	0.0		0.0	0.0		0.0	0.0
H. sp.		3.1	1.0		6.7	4.0		2.8	0.3
Architeuthis cf. japonica		0.0	0.5		0.0	0.0		0.5	3.1
Pholidoteuthis sp.		0.3	0.8		0.0	0.0		0.0	0.0
Discoteuthis discus		0.3	0.1		0.0	0.0		0.2	0.0
Cycloteuthis akimushkini		0.2	0.3		0.0	0.0		0.7	1.1
Chiroteuthis picteti		0.2	0.0		5.8	2.3		0.1	0.0
C. calyx		0.5	0.7		1.4	0.4		0.3	0.0
Asperoteuthis acanthoderma		0.1	0.2		0.0	0.0		0.0	0.0
Galiteuthis phyllura		8.6	1.2		3.2	1.2		1.4	0.5
Galiteuthis sp.		0.1	0.0		4.9	2.5		2.5	4.9
Megalocranchia maxima		0.8	0.3		3.5	1.4		1.4	0.4
Megalocranchia sp.		0.1	0.0		0.0	0.0		0.2	0.2
Cranchidae sp.		0.3	0.0		0.0	0.0		0.1	0.0
Unidentified squids		1.5	0.0		0.0	0.0		0.0	0.0
Haliphron atlanticus		0.1	0.2		0.0	0.0		0.0	0.0
Pisces		0.0	0.0		0.0	0.0		0.0	0.0
Trachipterus trachypterus		0.2	4.3		0.0	0.0		0.0	0.0
Laemonema longipes		0.0	0.0		0.0	0.0		0.0	0.0
Theragra chalcogramma		0.0	0.0		0.0	0.0		0.0	0.0
Coryphaenoides pectoralis		0.0	0.0		0.0	0.0		0.0	0.3
Unidentified fish		0.1	0.2		0.3	14.2		0.0	0.1
Estimated contribution rate of surface *		7.1	10.8		13.9	7.6		3.9	4.7
Estimated contribution rate of surface *+**		7.3	11.4		13.9	7.6		3.9	4.7

Table 13. The daily and total prey consumption in research season of sperm whales in research area.

Sub-area	Season	Abundance inds.	Daily consumption (Per capita: kg)	Daily consumption (tons)	Total consumption (thousand tons)
7	Early	6,429	433	2,784	170
	Late	7,550	433	3,269	301
8	Early	1,117	433	484	30
	Late	3,678	433	1,593	147
9	Early	8,382	433	3,629	221
	Late	9,064	433	3,925	361
Total	Early	15,928		6,897	421
	Late	20,292		8,786	808
	Total				1,229

Table 14. The daily and total prey consumption in research season of neon flying squids by sperm whales in research area.

Season	Abundance inds.	Daily consumption (kg)	Neon flying squid (%)	Daily consumption (tons)	Total consumption (thousand tons)
Early	6,429	433	16.0	445	27
Late	7,550	433	0.8	26	2
Total					30

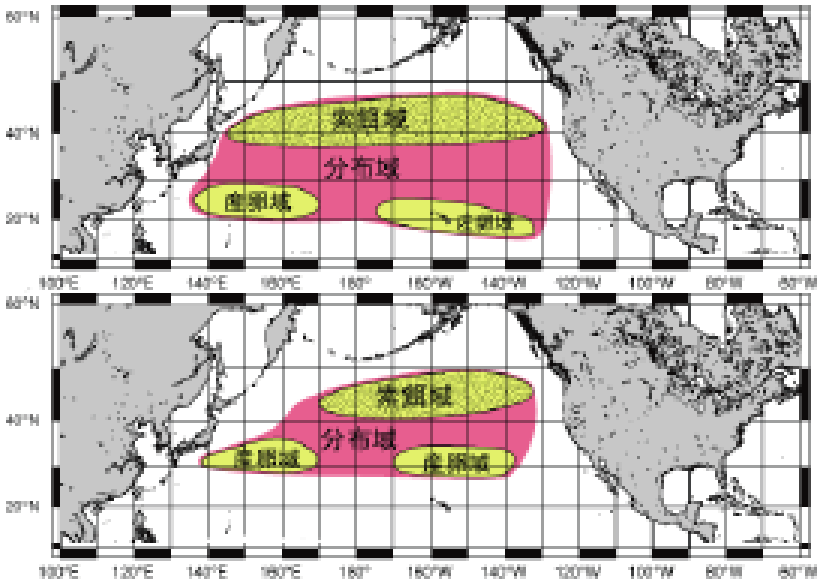
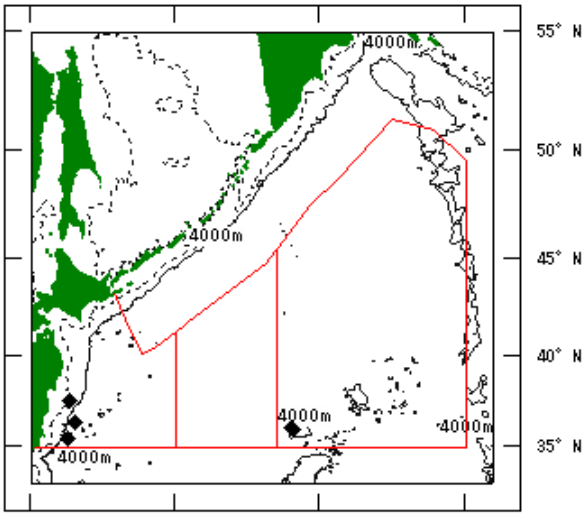
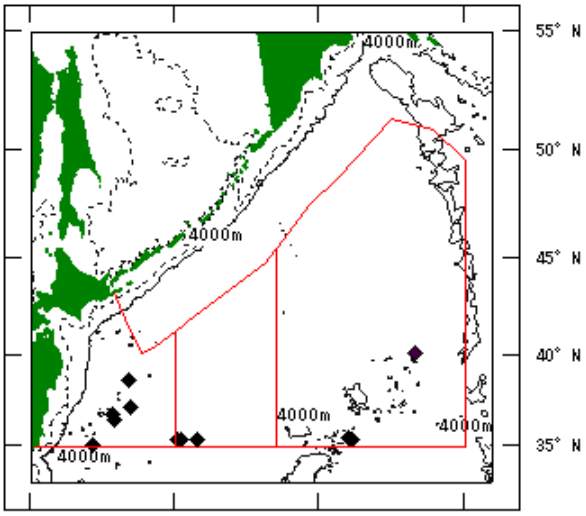


Fig. 1. The distribution of neon flying squid (Enclosure of red frame; Upper winter-spring spawner; Lower fall spawner) (Fisheries agency of Japan, 2008)

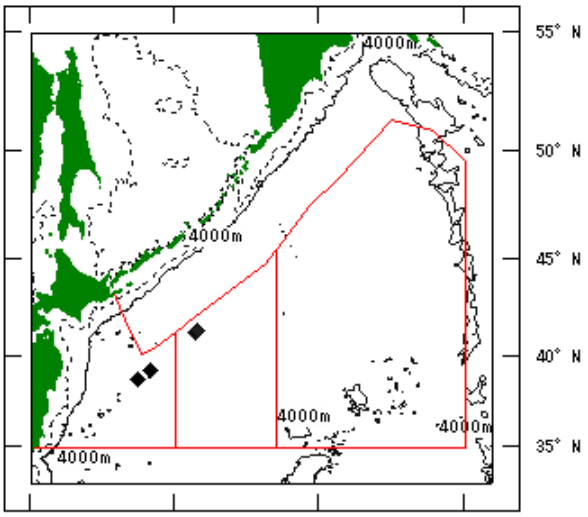
May



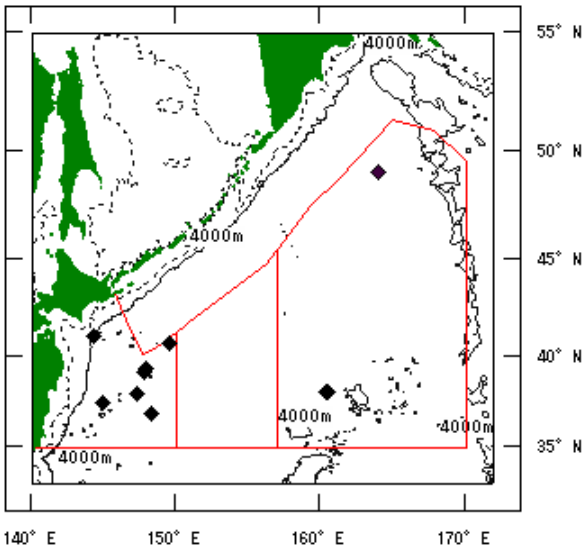
June



July



August



September

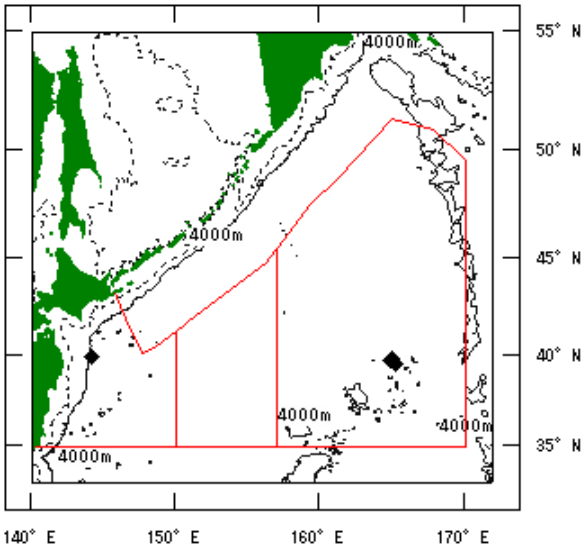


Fig. 2. The sighting positions of sperm whale sampled from 2000 to 2007.