Diurnal change in feeding activity in the western North Pacific minke whale

Tsutomu Tamura and Yoshihiro Fujise

The Institute of Cetacean Research, 4-18 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

To study the pattern of diurnal change in feeding activity in the western North Pacific minke whale, The changes in freshness and weight of stomach contents of minke whales were analyzed. We examined 498 samples obtained by JARPN surveys from 1994 to 1999, using the dominant prey species: the Japanese anchovy, Pacific saury, walleye pollock and krill in the Pacific side of Japan and krill in the southern Okhotsk Sea. In the Pacific side of Japan, there were no significant changes in freshness and mean weight of forestomach and fundus contents for Japanese anchovy and Pacific saury, with time periods ($p > 0.05$). The mean weight of forestomach and fundus contents of walleye pollock showed high values in the evening. On the other hand, in the southern Okhotsk Sea, there was no difference in freshness and mean weight of forestomach and fundus contents of krill with time periods ($p > 0.05$) These results suggested little diurnal change of feeding activity of western North Pacific minke whale.

INTRODUCTION

Some authors reported that baleen whales have diurnal change in feeding activity. For example, the feeding activity of baleen whales in the Antarctic has a feeding peak in the early morning (04:00 – 08:00 time period) with relatively little feeding occurring during the rest of the day (Ohsumi, 1979; Bushuev, 1986). Tamura (1998) based on the JARPA surveys data reported that feeding activity in the Antarctic minke whales *Balaenoptera acutorostrata* decreased after 04:00 hrs. It depended on the fluctuation of daylight, which affected dispersion and availability of krill and/or diurnal vertical migration of this prey species. In the eastern North Atlantic minke whales, feeding activity was not observed at night at least for 3 hours (Folkow and Blix, 1993). In the western North Pacific, Tamura *et al.* (1998), based on data from JARPN surveys for the period 1994 and 1995 in sub area 9, reported that minke whales have not diurnal change in feeding activity. However, during the 1996 JARPN survey in sub-areas 7, 8 and 11, the proportion of the undigested stomach contents was higher in the evening (Lindstrøm *et al.*, 1998). It seems that diurnal changes in feeding activities vary according to prey species. Tamura and Fujise (2000) reported that krill (*Euphausia pacifica*, *Thysanoessa longipes*, *T. inermis*, *T. inspinata*), Japanese anchovy *Engraulis japonicus*, Pacific saury *Cololabis saira* and walleye pollock *Theragra chalcogramma* were the dominant prey species in the Pacific side (sub-areas 7W, 7E, 8 and 9) and that krill (*E. pacifica*, *T. longipes*) was the dominant prey species in the southern Okhotsk Sea (sub-area 11).

In this study we examined further aspects of the diurnal change in feeding activity in the western North Pacific minke whales, based on the weight and freshness of forestomach and fundus contents collected by the JARPN surveys from 1994 to 1999 for each dominant prey species.

MATERIALS AND METHODS

Research area, year and sample size

The research area of the JARPN was a part of sub-areas 7, 8, 9 and 11 which were established by the IWC/SC (IWC, 1994), excluding the EEZ of Russia. Furthermore, sub-area 7 was divided into east (7E) and west (7W) (Fig. 1). The survey months, years and sample size in each sub-area are shown in Table 1.

Sampling of stomach contents of minke whales

Minke whales have four chambered stomach system (Hosokawa and Kamiya, 1971; Olsen *et al.*, 1994). The forestomach contents have proved sufficient for determination of the minke whale diet in the Northeast Atlantic (Lindstrøm *et al.*, 1997). However, mixing of contents have occurred through the relatively large hole between the forestomach and the fundic chumber (Olsen *et al.*, 1994). The prey species composition of forestomach and fundus were very similar (Lindstrøm *et al.*, 1997; Tamura and Fujise, 2000A). Therefore, the analyses of this study were based on contents from forestomach and fundus contents.

The forestomach and fundus contents were removed on the ship's flensing deck within eight hours after capture. Then, forestomach and fundus contents were weighed to the nearest 0.1 kg. We decided the predominant prey species by using the total weight of each prey species in each whale. Most minke whales (90.4 %) had fed upon one single prey species (Tamura and Fujise, 2000). We estimated the total weight of each predominant prey species by using the results from the sub-sample (3-4 kg).

Data analyses

The data was taken from 409 stomach contents containing predominant prey species: Japanese anchovy, Pacific saury, walleye pollock and krill in the Pacific side of Japan and krill in the southern

Okhotsk Sea.

Freshness category

The freshness of forestomach contents was categorized into four classes (F=fresh, fff=lightly digested, ff=moderately digested, f=heavily digested: Table 2).

Time period

Based on sighting time we defined four time periods (04:00 – 08:00, 08:00 – 12:00, 12:00 – 16:00, 16:00 – 20:00). The JARPN survey used ship time, which was transferred local time.

Statistical analysis

Analysis of differences in freshness categories for predominant prey species was firstly conducted considering the towing time (time spent between capture and the start of processing at the vessel). For that purpose we defined four categories of towing time: within 60 minutes after the catch, between 61 and 120 minutes, between 121 and 180 minutes and over 180 minutes. Differences in freshness categories among towing time were tested using the chi-square test. If not significant differences were found, then we combined data regardless towing time.

Next we examined changes in freshness categories with the time periods defined above. We combined the data for each prey species and examined the relationship between freshness categories and time periods for the entire research area. Changes were tested using the chi-square test.

Change in feeding activities was also investigated examining the relationship between the weight of undigested contents (freshness category F and fff) and total contents (all freshness categories), expressed as a percentage of body weight of minke whale, and the time periods. We combined data for each prey species and examined the relationship between the mean weight of undigested contents (and total contents) and the time periods for the entire research area. Changes were tested using the Kruskal-Wallis test.

RESULTS

Freshness categories and towing time

Japanese anchovy (Pacific side of Japan)

The change of freshness categories by towing time for this prey species is shown in Fig. 2. There were no significant changes in freshness categories with towing time (chi-square test : $9.04 < \chi^2(9;0.05) = 16.92$).

Pacific saury (Pacific side of Japan)

The change of freshness categories by towing time for this prey species is shown in Fig. 3. There were no significant changes in freshness categories with towing time (chi-square test : $8.21 < \chi^2(9;0.05) = 16.92$).

Krill (southern Okhotsk Sea)

The change of freshness categories by towing time for this prey species is shown in Fig. 4. There were no significant changes in freshness categories with towing time (chi-square test : $12.25 < \chi^2(6;0.05) = 12.59$).

Freshness categories and time periods

Japanese anchovy (Pacific side of Japan)

The relationship between freshness categories and the time periods was examined for all data combined (Fig. 5). There were no significant changes in freshness categories with time periods (chi-square test : $9.90 < \chi^2(9;0.05) = 16.92$).

Pacific saury (Pacific side of Japan)

The relationship between freshness categories and the time periods was examined for all data combined (Fig. 6). Although this figure shows a higher proportion of freshness categories F and fff in the 4:00 – 8:00 and 16:00 – 20:00 time periods, no significant changes in freshness categories with time periods were found (chi-square test : $10.74 < \chi^2(9;0.05) = 16.92$).

Walleye pollock (Pacific side of Japan)

The relationship between freshness categories and the time periods was examined for all data combined (Fig. 7). This figure showed a high proportion of freshness categories F and fff in the 16:00 – 20:00 time period. However, sample sizes examined were small and no statistical analysis was conducted.

Krill (Pacific side of Japan)

The relationship between freshness categories and the time periods was examined for all data combined (Fig. 8). This figure showed a high proportion of freshness categories F and fff in the 12:00 – 16:00 time period. However, sample sizes examined were low and no statistical analysis was conducted.

Krill (southern Okhotsk Sea)

The relationship between freshness categories and the time periods was examined for all data combined (Fig. 9). This figure showed a high proportion of freshness categories F and fff in the 16:00 – 20:00 time period. However, sample sizes in this time period were low and no statistical analysis was conducted.

Weight of forestomach and fundus contents

Japanese anchovy (Pacific side of Japan)

The relationship between the weight and time periods was examined for all data combined (Fig. 10). There were no significant changes in the weight with time periods (Kruskal-Wallis test: undigested contents p=0.93, total contents p=0.25).

Pacific saury (Pacific side of Japan)

The relationship between the weight and time periods was examined for all data combined (Fig. 11). There were no significant changes in the weight with time periods (Kruskal-Wallis test: undigested contents p=0.09, total contents p=0.25).

Walleye pollock (Pacific side of Japan)

The relationship between the weight and time periods was examined for all data combined (Fig. 12). This figure showed high values of the weight in the 16:00 – 20:00 time period. However, sample sizes examined were low and no statistical analysis was conducted.

Krill (Pacific side of Japan)

The relationship between the weight and time periods was examined for all data combined (Fig. 13). There were no changes in the weight with time periods. However, sample sizes examined were low and no statistical analysis was conducted.

Krill (southern Okhotsk Sea)

The relationship between the weight and time periods was examined for all data combined (Fig. 14). There was no difference in weight of total contents with time periods except the 16:00 – 20:00 time period (Kruskal-Wallis test: total contents p=0.47).

DISCUSSION

Feeding activity of western North Pacific minke whales in the Pacific side of Japan

Our results suggested that little diurnal change of feeding activity of western North Pacific minke whales in the Pacific side of Japan.

During daytime in summer, Pacific saury is mainly distributed at 10 to 15 m depths, where it feeds on copepods and krill (Hotta and Odate, 1956; Wada and Kitakata, 1982). Japanese anchovy is also distributed shallower than 30 m depth, where it feeds on copepods in the same period of the year

(Kondo, 1969). These two fish species are distributed widely in temperate waters of the western North Pacific. Pacific saury and Japanese anchovy migrate to this area to feed on copepods and krill during June through September (Kondo, 1969; Odate, 1977). By considering the results of our study and distribution information of dominant fish species, it seems that minke whales feed throughout the day at the surface.

An apparent high proportion of freshness categories F and fff and the apparent high values of the mean weight of stomach contents of walleye pollock were observed in the evening. Walleye pollock distributes vertically with water temperature (Yabuki *et al.*, 1993), depth and distribution of prey (Maeda *et al.*, 1988). These reports indicated that older and/or larger walleye pollock are more likely to occure near the bottom. Ohshimo and Hamatsu (1996) found their distribution were related to the thermocline, smaller pollocks shoaled near the thermocline and larger pollocks occurred under the thermocline. Walleye pollock is separated into surface groups (coastal waters, over continental shelf) and deeper water groups (100 – 300 m) after spawning (Maeda *et al.*, 1988). The fork length of walleye pollock ingested by minke whales ranged from 310 to 530 mm, they were adult fish. Minke whales probably feed on at the surface groups. They are important prey species for minke whale in coastal waters, over the continental shelf (Tamura and Fujise, 2000).

During the 1996 JARPN survey in sub-areas 7, 8 and 11, the proportion of the undigested stomach contents was increasing in the evening. The values of the undigested stomach contents increasing in the evening might to respond the high values of the walleye pollock. However it should be emphasized that sample size was too small to conclude this matter.

Feeding activity of western North Pacific minke whales in the southern Okhotsk Sea

Our results suggested that an apparent high proportion of krill in freshness categories fff was observed in the evening, however it should be emphasized that small sample size was not sufficient and that more sample should be investigated in the future. By considering the results of our study, it seems that the little diurnal change of feeding activity of western North Pacific minke whales in the southern Okhotsk Sea.

Possibility of feeding during night

The minke whales do not feed at night in the eastern North Atlantic (Folkow and Blix, 1993; Haug *et al.* 1997), and minke whale do not feed at night in Yellow Sea (Zhongxue *et al.*, 1983). Data were insufficient to make clear whether minke whale do not feed at night in western North Pacific, because the JARPN surveys were conducted from 6:00 to 19:00 only. The behavior observation using echo-sounder at night and sampling of minke whale at night might be necessary in the future.

ACKNOWLEDGEMENTS

We are indebted to R. Zenitani, H. Isikawa, M. Goto, T. Bando and S. Otani of the Institute of Cetacean Research (ICR) who collected and weighed the stomach contents in JARPN surveys.
We would like to thank all captains, crews and researchers, who were involved in JARPN surveys from 1994 to 1999. Our sincere thank to Prof. T. Haug of the Norwegian Institute of Fisheries and Aquaculture, Dr. H. Hatanaka of the National Research Institute of fisheries Science and Dr. Luis A. Pastene of the Institute of Cetacean Research (ICR) for their valuable suggestions and useful comments on this paper.

REFERENCES

Bushuev, S. G. 1986. Feeding of minke whales, *Balaenoptera acutorostrata*, in the Antarctic. *Rep. int. Whal. Commn*, 36:241-5.

Folkow, L. P. and Blix, A. S. 1993. Daily changes in surfacing rates of minke whales (*Balaenoptera acutorostrata*) in Norwegian waters. *Rep. int. Whal. Commn*, 43:311-14.

Haug, T. Nillsen, T. Lindstrøm, U., Skaug, H. J. 1997. On the variation in size and composition of minke whale (*Balaenoptera acutorostrata*) forestomach contents. *J.Northw. Atl. Fish. Sci.* 22: 105-14.

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

Hotta, H. and Odate, K. 1956. The food and feeding habits of the Saury, *Cololabis saira*. *Bull. Tohoku Reg. Fish. Res. Lab.*, 7:60-9.

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

Kondo, K. 1969. Ecological studies of life pattern of the Japanese anchovy, *Engraulis japonica* (HOUTTUYN). *Bull. Tokai Reg. Fish. Res. Lab.*, 60:29-81.

Lindstrøm, U., Haug, T. and Nilssen, K. T. 1997. Diet studies based on contents from two separate stomach content compartments of northeast Atlantic minke whales *Balaenoptera acutorostrata*. *Sarsia*. 82:63-8.

Lindstrøm, U., Fujise, Y., Haug, T. and Tamura, T. 1998. Feeding habits of western North Pacific minke whales, *Balaenoptera acutorostrata*, as observed in July–September 1996. *Rep. int. Whal. Commn*, 48:463-9.

Maeda, T., Nakatani, T., Takahashi, T. and Takagi, T. 1988. Distribution and migration of adult walleye pollock off Hiyama, southwestern Hokkaido. *Proc. Int. Symp. Biol. Mgmt. Walleye Pollock*,325-47.

Odate, S. 1977. On the distribution of Pacific saury in the North Pacific Ocean. *Res. Inst. North Pacific Fish., Fac. Fish. Hokkaido Univ*. Special vol:353-81.

Ohshimo, S. and Hamatsu, T. 1996. Vertical distribution and acoustic estimation of biomass of walleye pollock *Theragra chalcogramma*, and anchovy *Engraulis japonicus* in the Pacific coast of eastern Hokkaido. *Bull. Hokkaido Natl. Fish. Res. Inst.*, 60:225-37.

Ohsumi, S. 1979. Feeding habits of the minke whale in the Antarctic. *Rep. int. Whal. Commn*, 29:473-6.

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*). *J. Zool., Lond* 234:55-74.

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., Fujise, Y. and Shimazaki, K. 1998. Diet of minke whales *Balaenoptera acutorostrata* in the Northwestern part of the North Pacific in summer, 1994 and 1995. *Bull. Japan. Soc. Sci. Fish.*, 24:311-16.

Tamura, T. and Fujise, Y. 2000. Geographical and seasonal changes of prey species in the western North Pacific minke whale. In this meeting:26pp.

Wada, T. and Kitakata, M. 1982. Sampling research with mid-water drift gillnet and behavior of saury in the daytime. *Bull. Hokkaido Reg. Fish. Res. Lab.*, 47:11-22.

Yabuki, K., Hamatsu, T. and Watanabe, K. 1993. Distribution of walleye pollock, *Theragra chalcogramma* (Pallas), off the Pacific coast of the southern Kuril Island. *Bull. Hokkaido Natl. Fish. Res. Inst.*, 57:63-74. [In Japanese with English abstract].

Zhongxue, L., Hanguang, X., Shulin, J. and Wenxiang, H. 1983. Studies on the minke whale from the northern Yellow Sea. *Acta. Zoologica. sinca.* 29:86-92. [In Chinese with English abstract].

Table 1. Sub-areas, months and years of surveys and sample size used in this study.

Sub-area	Survey month	Year	Sample size
7W	June	1999	50
	August	1996	15
	September	1996	15
7E	May	1998	56
	June	1997	2
	July	1996	1
8	May	1998	8
	June	1998	36
	July	1996, 1997	42
	August	1996	5
9	May	1997	27
	June	1995, 1997	54
	July	1994, 1995	69
	August	1994, 1995	34
	September	1994	4
11	July	1999	50
	August	1996	30
Total			498

Table 2. Category of freshness in the forestomach contents of minke whale.

Code	Class	Description
F	Fresh	Prey not affected by digestion
fff	Lightly digested	Prey slightly affected by digestion
ff	Moderately digested	Prey moderately to highly fragmented
f	Heavily digested	Unidentifiable remains or indigestible parts only

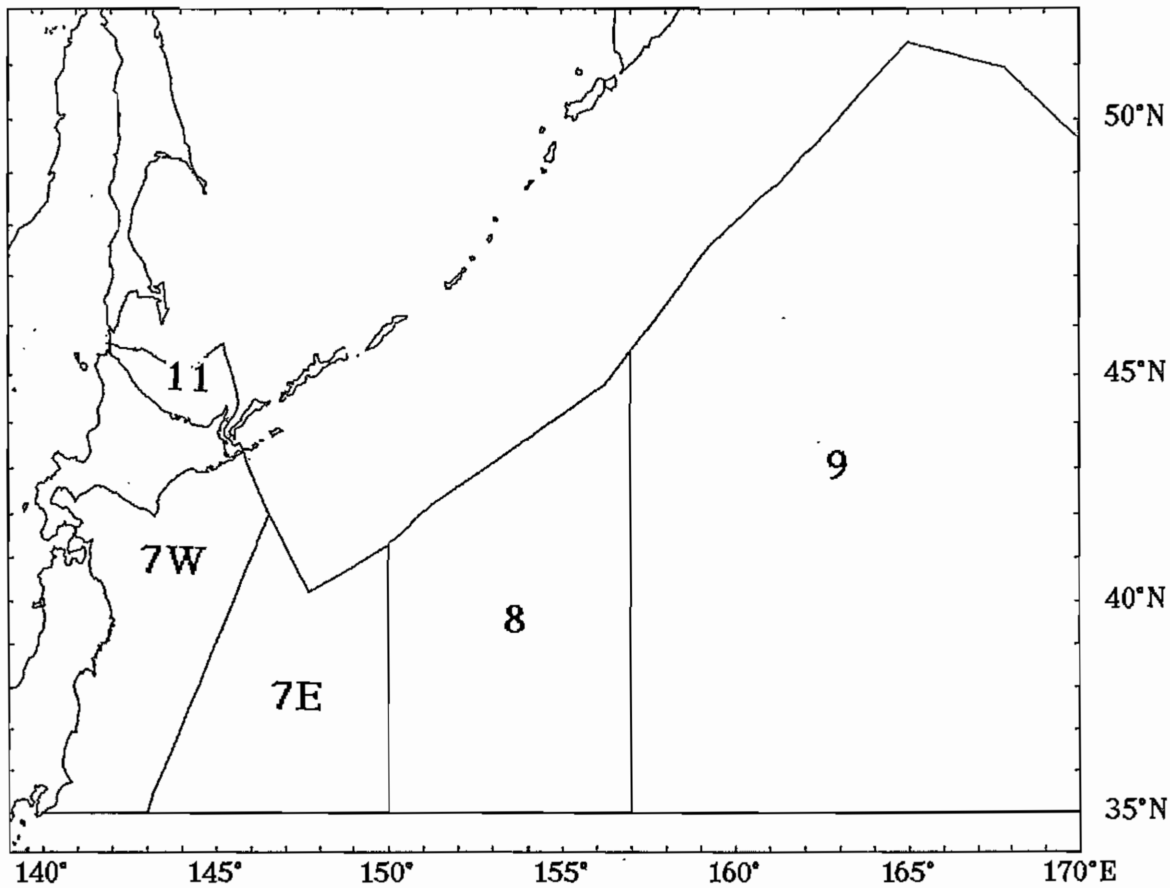

Fig.1. Sub-areas surveyed by the JARPN from 1994 to 1999. Sub-areas were based on IWC (1994), excluding the EEZ of Russia. Furthermore, sub-area 7 was divided into east (7E) and west (7W).

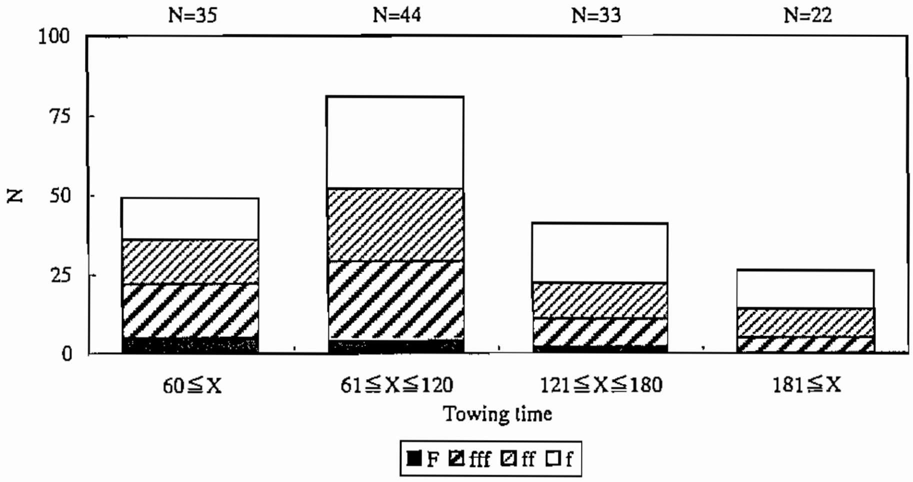

Fig.2. Change in freshness category of Japanese anchovy with towing time.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

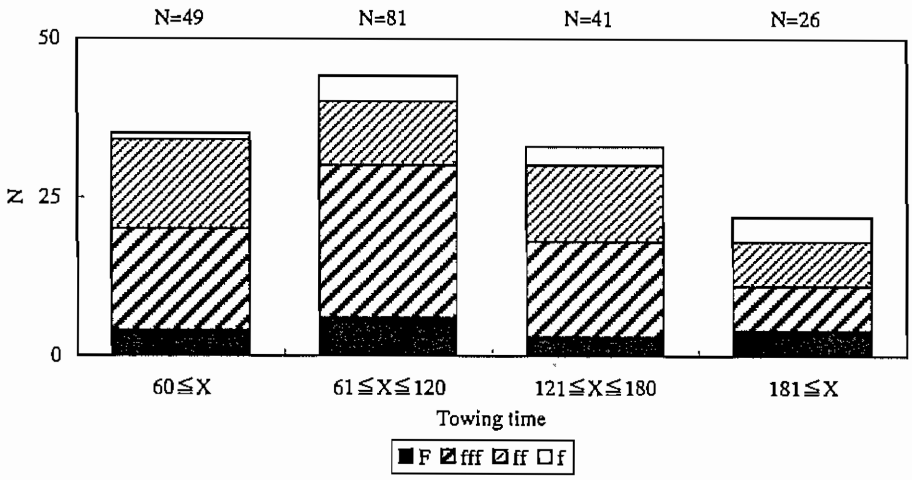

Fig.3. Change in freshness category of Pacific saury with towing time.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

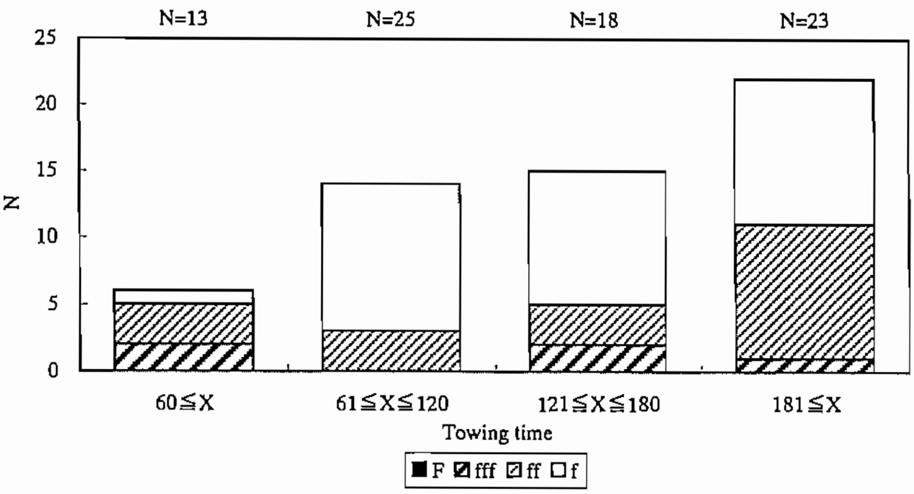

Fig.4. Change in freshness category of krill with towing time.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

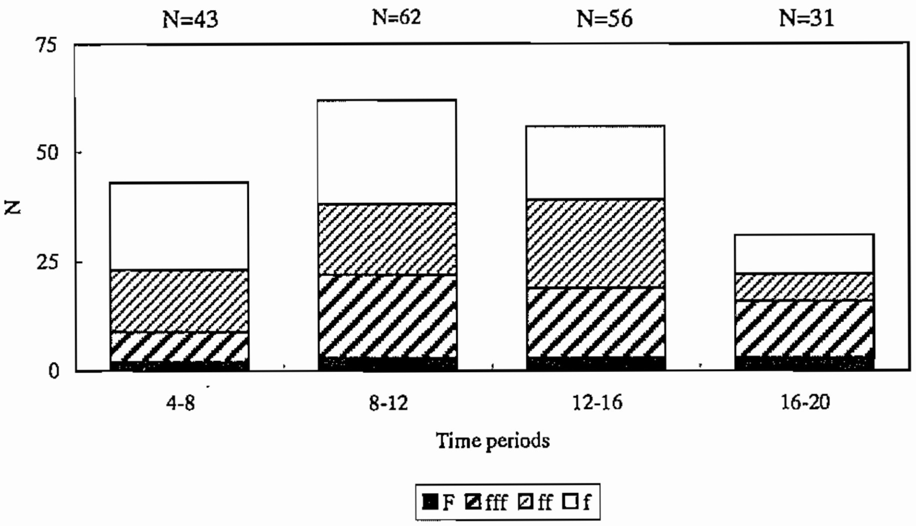

Fig.5. Relationships between freshness categories for Japanese anchovy and time periods.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

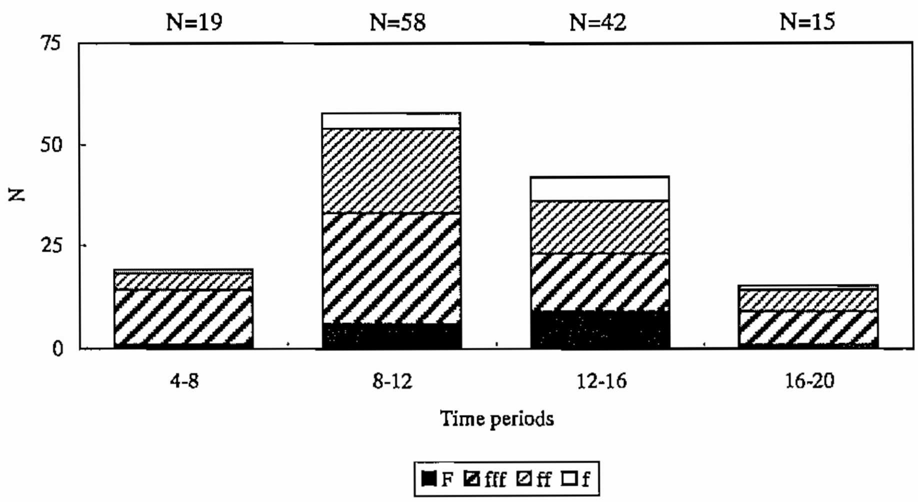

Fig.6. Relationships between freshness categories for Pacific saury and time periods.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

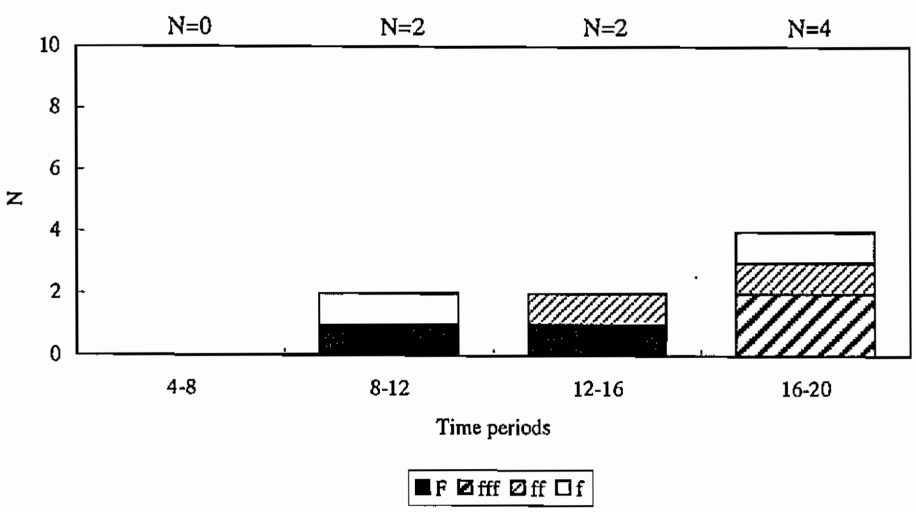

Fig.7. Relationships between freshness categories for walleye pollock and time periods.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

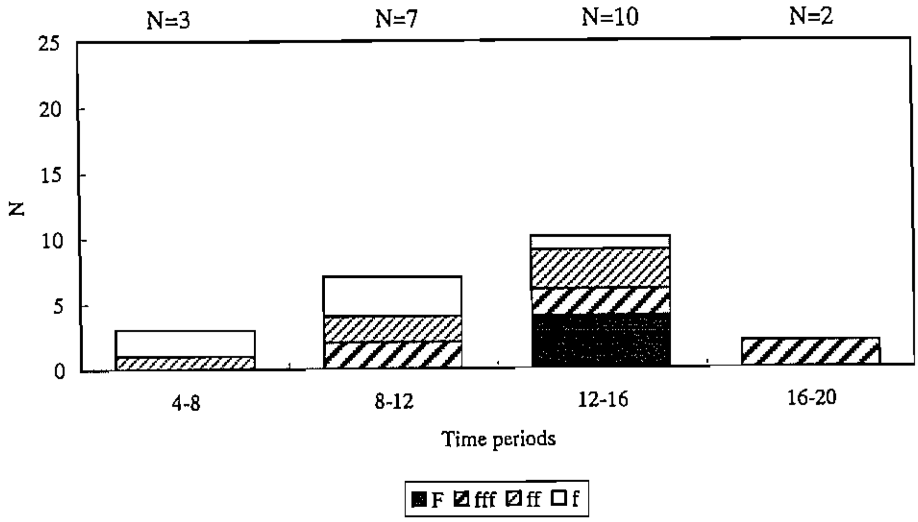

Fig.8. Relationships between freshness categories for krill and time periods in the Pacific side.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

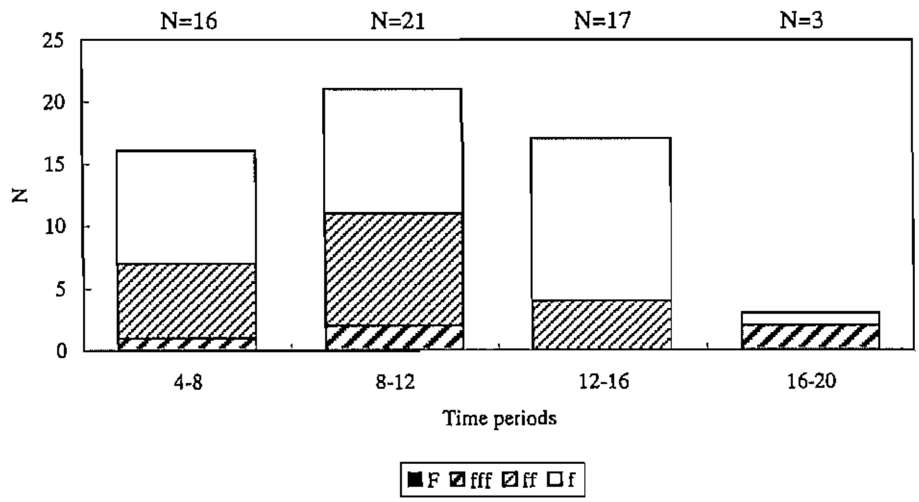

Fig.9. Relationships between freshness categories for krill and time periods in the Okhotsk Sea.
F: fresh, fff: lightly digested, ff: moderately digested, f: heavily digested

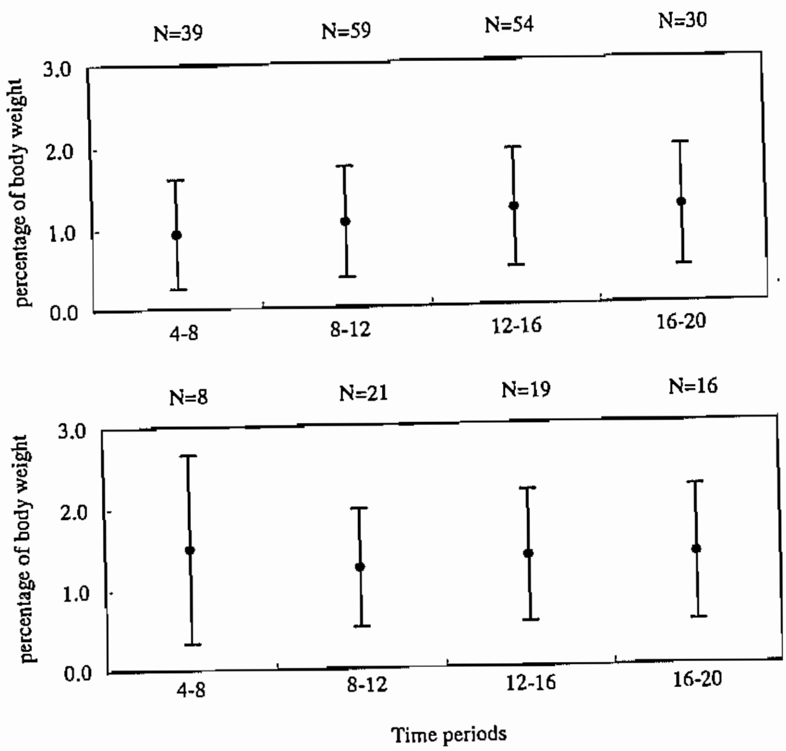

Fig.10. Change in the mean and *S.D.* weight of stomach content (Japanese anchovy) with time periods. Weight expressed as percentage of minke whale body weight. (Upper: all freshness categories,Bottom: F and fff categories)

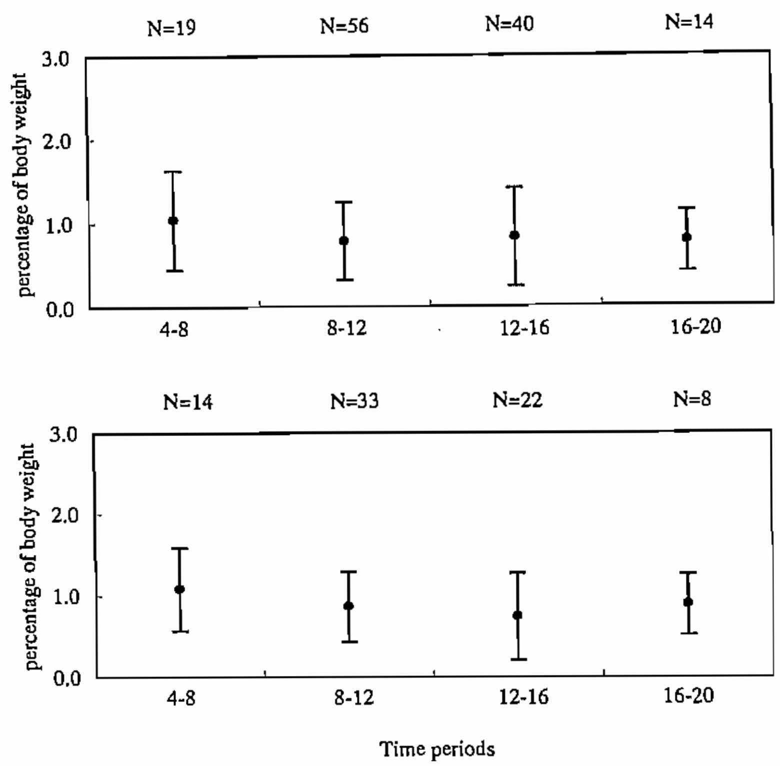

Fig.11. Change in the mean and *S.D.* weight of stomach content (Pacific saury) with time periods. Weight expressed as percentage of minke whale body weight. (Upper: all freshness categories, Bottom: F and fff categories)

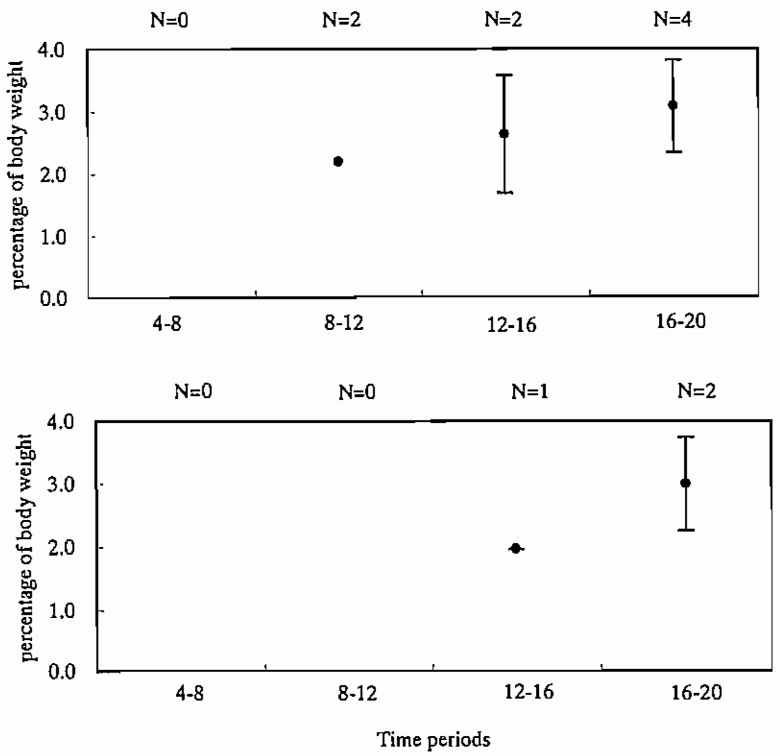

Fig.12. Change in the mean and *S.D.* weight of stomach content (walleye pollock) with time periods. Weight expressed as percentage of minke whale body weight. (Upper: all freshness categories, Bottom: F and fff categories)

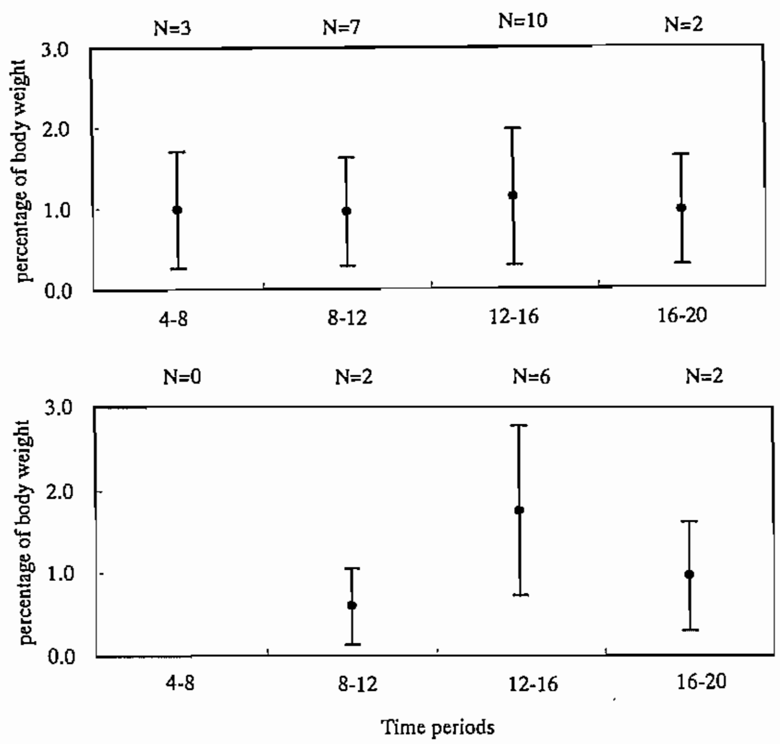

Fig.13. Change in the mean and *S.D.* weight of stomach content (krill in the Pacific side) with time periods. Weight expressed as percentage of minke whale body weight. (Upper: all freshness categories, Bottom: F and fff categories)

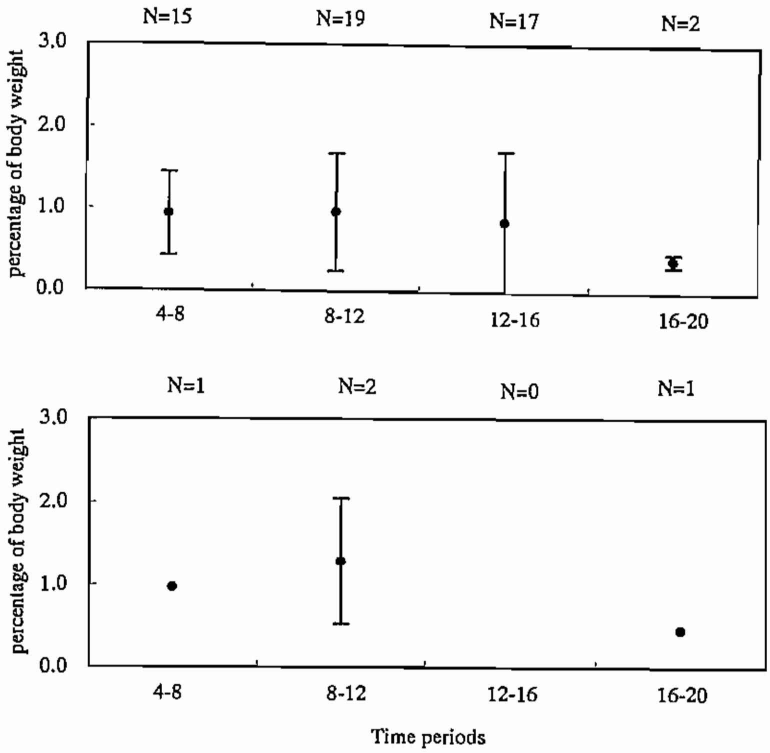

Fig.14. Change in the mean and *S.D.* weight of stomach content (krill in the Okhotsk Sea) with time periods. Weight expressed as percentage of minke whale body weight. (Upper: all freshness categories, Bottom: F and fff categories)