Report of 2000 and 2001 feasibility study of the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPN II)

Government of Japan

(Edited by Yoshihiro Fujise*1, Shigeyuki Kawahara*2, Luis A. Pastene*1 and Hiroshi Hatanaka*3)

ABSTRACT

As a continuation of the Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN), Japan initiated a new research program titled 'Cetacean Studies in the western North Pacific under Special Permit (JARPN II)' in the year 2000. The top research priority moved from stock structure of minke whale in JARPN to feeding ecology and ecosystem studies in JARPN II. In addition to minke whale the new research program incorporated the Bryde's and sperm whales as target species as they are abundant and play an important role in the western North Pacific ecosystem. Also some dolphin and porpoise species taken by the Japanese commercial fishery were considered for the ecosystem study. Feeding ecology and ecosystem studies involve three elements: i) food consumption of cetaceans, ii) prey preference of cetacean and iii) ecosystem model. The other objectives of the JARPN II defined in year 2000 were stock structure and environmental effects on cetacean and marine ecosystem, in that order of priority. JARPN II started with two feasibility surveys in 2000 and 2001 and several studies have been conducted using samples and data obtained in these surveys. While most of these studies are within the 'feasibility' category some others are a continuation of the studies initiated under JARPN. In general the feasibility study was necessary, among other reasons, to evaluate the performance of the concurrent prey and whale surveys (which is essential to investigate prey preference of cetacean) and to investigate whether or not information on feeding ecology (particularly food consumption) can be obtained for Bryde's and sperm whales in the same way as it had been obtained for minke whales under JARPN. In this report the results of the JARPN II feasibility study in 2000 and 2001 are presented in the context of the objectives established in 2000 and discussed in the context of the implementation of the full-scale JARPN II. It is concluded that the concurrent prey and whale surveys are feasible and should be continued in the full JARPN II. Results of preliminary analyses of data derived from this concurrent survey were useful to determine the prey preference of cetaceans. Also it was confirmed that information on feeding ecology of Bryde's and sperm whales could be obtained in the same way as it has been obtained for minke whales.

---

*1 : The Institute of Cetacean Research , 4-5, Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan,

*2 : National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu, Shizuoka 424-8633 Japan

*3 : Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan

---

Individual appendices in this report should be cited in the form:

'Author name'. 2002. 'Appendix title'. Appendix XX, pp XX-XX. *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 (JARPN II). Paper SC/54/O17 submitted to the 54th IWC Scientific Committee Meeting (Available from the IWC Secretariat).

CONTENTS

APPENDICES

INTRODUCTION

The Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN) was conducted during 1994-1999 to address the issues of stock structure and mixing rates of minke whales, as requested for the Implementation Simulation Trials (Government of Japan, 1994). The objectives were to clarify whether or not W Stock exists in offshore areas of the North Pacific, estimate the mixing rate of the hypothesized W Stock with O Stock (the Okhotsk Sea-West Pacific Stock) and the validity of O sub-stock scenario. In 1996, an IWC/SC working group reviewed the new information mainly from the JARPN surveys and dropped the O sub-stock scenario. In that same year, feeding ecology of minke whales was added as a new objective of the JARPN, firstly as a feasibility study (Government of Japan, 1996). During the JARPN a total of 498 minke whales were sampled from sub-areas 7, 8, 9 and 11 during May to September (Fujise, 2000).

In 2000 an IWC/SC Workshop was held in Tokyo to review the JARPN. Regarding to the objective of stock structure most of the approaches used revealed no evidence for the existence of additional stock structure in the western North Pacific (e.g. W stock). However, the workshop agreed that, based on the results of the mtDNA analysis, the possibility of the existence of some group of minke whales to the east of Japan that differ from the O Stock could not be ruled out. The Workshop recommended the attainment of further genetic samples from sub-areas 12, 9 and possibly sub-area 8 (IWC, 2001). Regarding to the feasibility studies on feeding ecology, the workshop considered them as successful. The results showed that the main prey species of minke whale changed seasonally and geographically. As most of these prey species are also the target species of Japanese commercial fisheries, a possible competition between minke whales and fisheries was postulated. The Workshop agreed that, if ecological studies are to be conducted in the area, the sampling regime must be designed to allow for a more quantitative estimation of temporal and geographical variation in diet. It was also recommended that acoustic and trawl surveys should be conducted concurrently with future whale surveys, if possible (IWC, 2001).

A new research plan titled 'Cetacean Studies in the western North Pacific under Special Permit (JARPN II)' was started by Japan in the year 2000. Given consideration to the success of the feasibility studies on feeding ecology under JARPN and the importance that deserve the interactions between cetacean and commercial fisheries, the priority in JARPN II moved to feeding ecology and ecosystem studies. In addition to minke whales, Bryde's and sperm whales were added as target species as they are abundant and play an important role in the western North Pacific ecosystem. Also, some dolphin and porpoise species taken by the commercial fishery were considered for the ecosystem study. Under JARPN II, studies on feeding ecology and ecosystem involve three elements: prey consumption by cetaceans, prey preference of cetaceans and ecosystem model. To deal with the second element JARPN II introduced a prey species survey, which is conducted concurrently with the whale survey. The other objectives of the JARPN II defined in 2000 were stock structure and environmental effects on cetaceans and marine ecosystem (Government of Japan, 2000).

JARPN II started with two feasibility surveys, one conducted in 2000 and the other in 2001 (Fujise *et al.*, 2001; 2002). Several studies have been conducted using samples and data obtained in these two surveys. In general the two-year feasibility study was necessary as the research priority shifted from stock structure in JARPN to feeding ecology and ecosystem in JARPN II. In particular the feasibility study was necessary i) to evaluate the performance of the concurrent prey and whale surveys and ii) to investigate whether or not information on feeding ecology can be obtained for the new added target species (Bryde's and sperm whales) in the same way as it had been obtained for the minke whale under JARPN. iii) to confirm whether or not sperm whale has a substantial relation to the epi-pelagic ecosystem in this area.

In this report the results of the JARPN II feasibility study in 2000 and 2001 are presented in the context of the objectives established in 2000 (Government of Japan, 2000). These results are discussed in the context of the implementation of the full-scale JARPN II.

OBJECTIVES

The objectives of the JARPN II for the two-year feasibility study (2000 and 2001) were established in Government of Japan (2000). As mentioned earlier the top priority in JARPN II deal with feeding ecology and ecosystem studies. The other two objectives were stock structure and environmental effects on cetaceans and marine ecosystem. While most of the studies conducted under JARPN II in 2000 and 2001 are within the 'feasibility' category, there are some others that are a continuation of the studies initiated under JARPN. In that context these studies are not within the 'feasibility' category.

Feeding ecology and ecosystem studies
This research item has the top priority under JARPN II. As mentioned above, this research item has three main components: prey consumption by cetaceans, prey preference of cetaceans and ecosystem model.

Prey consumption by cetaceans
Under JARPN prey consumption in minke whales was examined by qualitative and quantitative analysis of stomach content. Thus these studies on minke whales in JARPN II in 2000 and 2001 were a continuation of those started under JARPN.

To investigate whether or not these analyses are possible for the new targeted species, thus research objective involve several feasibility studies: (i) to determine whether information on the diet composition and daily and seasonal consumption can be obtained with adequate precision through the examination of stomach contents of the targeted whales; (ii) to evaluate whether the weights of the stomach contents can be measured for large whales such as Bryde's and sperm whales in the same way as it was made for minke whales under JARPN; (iii) to evaluate whether or not the total body weight of these larger species can be obtained in the same way as it was obtained for minke whales under JARPN. Point iii) is important as the stomach content weight is expressed as the proportion of the total body weight, iv) whether or not sperm whale has a substantial relation to the epi-pelagic ecosystem in this area..

Prey preference of cetaceans
This is a key parameter in most ecosystem models. The basic idea here is the conduction of parallel qualitative and quantitative analyses of prey species in both the stomach of the whales sampled and in the surrounding area where these whales were sampled. To cover this objective concurrent whale and prey surveys are conducted. The feasibility study in 2000 and 2001 were focused: (i) to examine the performance and practicability of the concurrent whale and prey surveys using a total of six research vessels, and (ii) to assess whether such concurrent survey provide enough data to determine prey preferences. Item i) above was one of the most important objectives of the two-year feasibility study.

The feasibility study also involved an evaluation of the performance of the whale survey when the number of target specie increased from one in the JARPN to three in the JARPN II. This evaluation was important given the practical and logistical problems involved when the number of target species is increased.

Ecosystem model
The performance of the combined use of two ecosystem models, ECOPATH and MULTSPEC, had to be investigated during the feasibility surveys. The ECOPATH model would be used to find out the keystone species and encourage the simplification of entries. The MULTSPEC model would be used to include many other species. The final model should be able to describe the interaction among multi-species and the relation between fisheries and top predators. Also it should be able to predict the dynamic changes and gives us reasonable advises for the strategy and tactics for multi-species management.

Stock structure
Regarding the stock structure of minke whale, following the discussions and conclusions of the JARPN review meeting, the objective under JARPN II was focused to investigate whether or not the W Stock exist in sub-area 9, and if so, to investigate the spatial and temporal extent of its occurrence. It was decided that the survey should be conducted in sub-area 12 and/or portions of sub-areas 7, 8 and 9 in the Russian EEZ if permission is obtained from the Russian Government. The mixing rate between O and J Stocks in sub-area 7 was other objective under JARPN II. The objectives on stock structure in minke whales were established following the recommendations derived from the JARPN review meeting. In that context this study was not a feasibility study.

Regarding Bryde's whale, genetic and non-genetic studies on stock structure in the Bryde's whale were conducted in the past using historical samples (past commercial samples). In 1999 some members of the Committee expressed their concern that sub-area 1 is very large and that there is limited information for some parts (IWC, 2000). Therefore, the objective of the feasibility study was (i) to obtain biological samples for stock structure studies from areas not covered in the previous studies.

Environmental effects on cetaceans and marine ecosystem
The feasibility study was aimed (i) to evaluate whether or not a comprehensive monitoring of pollutants in the marine ecosystem is possible. Such monitoring include analysis of DDTs and PCBs in several whale species (species having different feeding habitat), as well in the environment surrounding these species.

RESULTS

Results presented here involve both those derived from the feasibility studies (as defined in the above section) as well those that are a continuation of previous studies initiated under JARPN.

1. Outline of JARPN II feasibility surveys in 2000 and 2001

1.1 2000 survey
The first feasibility survey of the JARPN II was conducted from 1 August to 16 September 2000. Sub-areas 7, 8 and 9, excluding the EEZ zones of foreign countries, were designed as the research area (Fig. 1.1.1).

In this survey, three sighting/sampling vessels (SSVs), one scientific eco-sounder survey vessel (ESV), one trawl survey vessel (TSV) and one research base ship (RB) were used. The scientific echo-sounder survey vessel (ESV) also acted as a dedicated sighting vessel. These vessels are as follows:

SSVs: *Yushin Maru* (YS1), *Kyo Maru No.1* (K01) and *Toshi Maru No.25* (T25).
ESV: *Kyoshin Maru* No.2 (KS2)
TSV: *Shunyo Maru* (SYO)
RB: *Nisshin Maru* (NM)

In this survey two main components are identified. One is the co-operative survey on the prey species and ecosystem research. The other is the whale survey. For the co-operative survey on ecosystem research, seven small blocks were defined in sub-area 7 based on satellite information on surface temperature (upper side of Fig. 1.1.2). Allocation of the vessels was determined in the following manner. On the predetermined track line the ESV (KS2) conducted the echo sounder survey as well sighting survey under passing mode. The TSV (SYO) followed the path of ESV. If ESV detected the occurrence of prey species by echo sounder then the TSV conducted the trawl survey at the target depth to identify the prey species (Fig. 1.1.3). Echo sounder recording was made normally on the designed track line. Three types of trawl hauls were made: normal, target and night trawl hauls. The normal trawl haul was conducted at the scheduled time and location. The target trawl haul was conducted after the echo sounder survey indicated the occurrence of prey species. In such case the SYO conducted trawling at the target depth in which the prey species was detected by the echo sounder. The prey species were identified from the catches by the trawling. The night trawl haul was that conducted at a time after sunset on the same point of the normal trawling in daytime (Fig. 1.1.4).

The total searching effort by the SSVs was 7,284 n.miles during which 68 common minke, 188 Bryde's and 400 sperm whales were sighted (Table 1.1.1, Fig. 1.1.5 and Fig. 1.1.6). A total of 40 common minke whales was sampled, 34 during the whale survey component and 6 during the co-operative survey component. The six whales sampled during the co-operative survey were from small blocks 1 and 2. If we consider the sub-areas, 24 were sampled in sub-area 7 and 16 in sub-area 9. The whales sampled were examined on board the research base ship. The figure of 40 common minke whales consisted of 35 males and 5 females (Fig. 1.1.7 and Table 1.1.2). A total of 43 Bryde's whales were sampled in sub-area 7, 23 during the whale survey component and 20 during the co-operative survey component. The whales sampled during the co-operative survey component were from small blocks 4 and 7. Even number of male and female Bryde's whales were observed in the samples (Figs. 1.1.8 and Table 1.1.3), consisting of 21 males and 22 females, including one mother/calf pair. A total of five sperm whales were sampled in sub-area 7, one during the whale survey component and four during the co-operative survey component. During the co-operative survey component the sperm whales were sampled from small blocks 1, 4, 6 and 7. The figure of five animals consisted of three males and two females (Fig.1.1.9 and Table 1.1.4). A clear segregation in the pattern of distribution of common minke and Bryde's whales, was observed. Sperm whales were amply distributed in the research area.

Prey species found in the stomach content of common minke whale were Japanese anchovy, walleye Pollock and Japanese common squid; Japanese anchovy and krill in Bryde's whale and deep-sea squid and some fishes in the sperm whale (See Appendices 1, 2 and 3). The possibility of direct and indirect competition between these whale species and commercial fisheries is discussed in the cruise report of the 2000 JARPN II survey (Fujise *et al.*, 2001).

1.2 2001 survey

JARPN II 2001 feasibility survey was conducted from 14 May to 3 August in 2001 in sub-areas 7, 8 and 9 (Fig. 1.1.1). The research period was about 2.5 months (77 days) earlier than that in the 2000 survey. The research vessels were the same used in the previous survey with the exception of *Syunyo Maru*, which was replaced by *Torishima* (TOR). Like the previous survey, the survey consisted of two research components. Five small blocks were defined in sub-area 7 for the co-operative survey on ecosystem research (bottom in Fig. 1.1.2). A similar trawl and scientific echo-sounder surveys were conducted in the sub-area 7 (Fig. 1.1.10).

A total of 14,359.6 n.miles of searching effort was covered in 82 days. A total of 136 common minke, 77 Bryde's and 948 sperm whales were sighted (Table 1.1.1, Fig. 1.1.5 and Fig. 1.1.6). During these sightings 100 common minke, 50 Bryde's and 8 sperm whales were sampled. A single sei whale was accidentally sampled by miss-identification. The whales sampled were examined on board the research base ship same as in the previous survey. In the case of the common minke whale, mature males were abundant (Fig. 1.1.7 and Table 1.1.2). Almost an even number of males and females of Bryde's whales were observed (Fig. 1.1.8 and Table 1.1.3). Similar trend of sex composition was observed for sperm whales sampled (Fig. 1.1.9 and Table 1.1.4).

Major food species of common minke whales were the Japanese anchovy in sub-area 7 and Pacific saury in sub-areas 8 and 9. Also Walleye pollack were found in coastal area in Pacific side of Hokkaido (Northern part of sub-area 7). In the stomach of Bryde's whales, krill and small Japanese anchovy were observed. Dominant prey species in eight sperm whales consisted of numerous squids, which inhabit the mid-and deep-water. Krill was observed in the stomach content of a sei whale. Details of the JARPN II 2001 cruise will be available as a cruise report document (SC/54/Oxx). See also Appendices 1, 2 and 3.

1.3 Concurrent prey and whale surveys

The co-operative survey on ecosystem research was conducted between the prey species vessels (TSV and ESV) and the whale vessels (SSVs and RB). In most of the small blocks both surveys were conducted within a one-week period (while the prey survey is rather independent from the weather conditions, progress in the whale survey depend on the weather conditions).

The feasibility surveys revealed that minke whales fed on dominant fishes (Japanese anchovy and walleye pollock) that formed large schools. Krill seems to be avoided by minke whales when fish are present. This situation is similar to finding in the Norwegian water (Skaug *et al.*, 1997; Lindstrom and Haug, 2000). In the coastal part of sub-area 7, it seems that dominant prey of minke whale reflects the abundance of the prey in a spatial temporal scale (e.g. walleye pollock and Japanese anchovy).

Although the sample size is small, other information on prey preference is as follow: 1) a minke whale fed on large size classes prey that was not caught by trawling; 2) size class proportion of walleye pollock in minke whale stomach was different from the proportion in trawl samples in the same region.

The feasibility survey also showed that minke and Bryde's whales did not feed on meso-pelagic fishes and squids which migrate into the upper layer at night and are important prey of many marine mammals (Ohizumi, 1998). This result suggests that minke and Bryde's whales usually do not feed at night.

It can be concluded that in both years the co-operative surveys were successfully conducted.

1.4 Sampling strategy in the feasibility survey

In order to avoid sampling bias calf/cow pairs were sampled if they were sighted during the normal sighting survey along the trackline. In such a case calf was sampled first followed by the mother. Under this scheme one calf/cow pair of Bryde's whale was sampled in the 2000 JARPNII survey and seven calf/cow pairs and a single calf were sampled in the 2001 JARPNII survey. Body length for these calves ranged from 6.70m to 8.57m. Details of biological parameters and their prey species are shown in the later sections.

Regarding the sperm whale the sampling in the two surveys was conducted for only individuals smaller than 10m of body length due to the capability of the research mother ship (NM). Thus larger singleton individuals were not sampled in these surveys.

2. Results of studies conducted under JARPNII

2.1 Feeding ecology and ecosystem studies

2.1.1 Food consumption of cetaceans

The prey species of common minke whales (Appendices 1 and 4) in the western North Pacific and southern Okhotsk Sea during May and September from 1994 to 2001, were various pelagic prey species of zooplankton, squid and fishes. Prey species of common minke whales varied both geographically and temporally. In the Pacific side of Japan, the dominant prey species was Japanese anchovy during May and June, Pacific saury during July and August and krill in September. In the southern Okhotsk Sea, krill was the dominant prey species in July and August. However, in 2000 research (JARPN II), during August and September, Japanese anchovy was the most important prey species. Furthermore, Walleye pollack was also important prey species in sub-area 7. In sub-area 9, Japanese anchovy was the most important prey species in August, 2000. On the other hand, Pacific saury consumed by common minke whales was low proportion. There are yearly changes of prey species of common minke whales in the research area. Therefore, further research might be necessary to understandthe nature of this yearly variation. Furthermore, some examples of competition between common minke whales and commercial fisheries were observed in the research area and this topic need to be addressed with further research in the future.

Minke whale:

Daily prey consumption of minke whale in the western North Pacific was estimated using two methods (Appendix 4): 1) diurnal change in the forestomach and fundus content weight and 2) field metabolism. A total of 116 forestomach and fundus of minke whales sampled by JARPNII surveys from 2000 to 2001 were examined. Estimations were made by sexual maturity stage. Estimates of the daily prey consumption rate obtained by the method-1 were 4.6 of body weight if the proportion of the rest of prey after 8 hours was 20 %. Estimates of the daily prey consumption rate obtained by the method-2 ranged from 1.4 to 8.2 % of body weight. It might be necessary to obtain more information on the caloric value of prey species by seasons, and areas. At the same time, more data are needed on seasonal, local and annual variations in the prey of minke whales before conclusions can be drawn with regard to their food consumption of minke whales in western North Pacific from spring to autumn.

Bryde's whale:

The major prey species of Bryde's whale were krill, Japanese anchovy and juvenile of Chub mackerel (Appendices 2 and 4). It was confirmed that there was no change about prey species of Bryde's whale between previous reports and this research. In the Pacific side of Japan, the dominant prey species was krill during May and June and Japanese anchovy during July and August. Differences in the *CRI* (???) between krill and Japanese anchovy might reflect local changes in the relative abundance of these species in the area. Prey species of Bryde's whales varied both geographically and temporally. More data are needed to better understand the seasonal change of prey species in this research area. Most of the Bryde's whale sightings occurred close to the fishing grounds of skipjack tuna. Both Bryde's whales and skipjack tuna feed mainly on Japanese anchovy. Further research is necessary to understand the nature of this interaction.

Daily prey consumption of Bryde's whale in the western North Pacific was estimated using two methods (Appendix 4): 1) diurnal change in the forestomach and fundus content weight and 2) field metabolism. A total of 90 forestomach and fundus of Bryde's whales sampled by JARPNII surveys from 2000 to 2001 were examined. Estimations were made by sexual maturity stage. Estimates of the daily prey consumption rate obtained by the method-1 were 4.0 % of body weight if the proportion of the rest of prey after 8 hours was 20 %. Estimates of the daily prey consumption rate obtained by the method-2 ranged from 3.3 to 8.2 % of body weight. It might be necessary to obtain more information on seasonal, spacial and yearly changes of the caloric value of prey species. More data are needed on seasonal, local and annual variations in the prey of Bryde's whales before conclusions can be drawn with regard to their food consumption of Bryde's whale in western North Pacific from spring to autumn.

Eight cow/calf pairs were targeted, 8 calves and 7 mother whales were sampled in 2000 and 2001 JARPNII. The stmach content of the mother and the calf was confirmed. Almost of the individuals, which were under 8.0 m of body length, did not feed on prey. They feed mainly on mother's milk. However, the individuals, which are over 8.0 m of body length feed on only krill as their prey.

Sperm whale:

In 2000 and 2001 JARPNII surveys, deep-sea squids were most dominant prey in the stomach contents of sperm whales (Appendix 3). The important prey species in JARPNII surveys are one fish (*Trachipterus ishikawae*) and 3 squids (*Ancistrocheirus lesueuri*, *Histioteuthis dofleini* and *Ommastrephes bartrami*). Their prey species could be identified from beaks of squid and otolith of fishes. The body length and body weight of some prey species from the otolith length or beak lower rostral length could be estimated using regression equation. In JARPNII, the stomach contents weight ranged from 9.0 kg to 236.7 kg. These weights were equivalent to under 1.0% of body weight. Most of stomach contents were in good condition (lightly digested). The sperm whale seems to feed on

prey during day in the mesopelagic and/or bottom. The contribution of sperm whales for surface ecosystem was not drawn clearly, as the sample size was very low. Therefore, further research might be necessary to understand better their relation to the epi-pelagic ecosystem..

2.1.2 Prey preference of cetaceans (Appendix 5)

The prey preference of cetaceans to be estimated in JARPN II is not that for an individual animal but that for the group as an input parameter to the ecosystem models. In most of the ecosystem models, the population models for each fish and marine mammal are integrated with the prey and predator interactions. Prey and predator interactions are defined with several factors; abundance of predators, days staying in the area, daily rations and diet compositions. Diet compositions could be estimated directly from the stomach contents. Diet compositions would be affected by the biomass of each prey, distributional overlap with predator and prey, and prey preference of predator. Therefore prey preference of in the ecosystem model should be an effective parameter to adjust the difference between diet composition in the stomach and prey composition in the sea, with reflecting the distributional overlap. As the target area is stratified in most of the ecosystem models to express the distribution pattern and migration, distributional overlap will be considered on a stratum basis.

Usually the prey preference could be estimated with the concurrent whale and prey surveys (Lindstrom and Haug, 2001). Practicality of concurrent whale and prey surveys was tested in the two-year feasibility study as the surveys are the first try in the North Pacific and involve many research vessels at the same time (Government of Japan, 2000 and 2001). Several small blocks with ca. 100x100 square nautical miles were set in sub-area 7, within each of them a zigzag track line was drawn. The concurrent surveys were conducted on the same track line within one week in each small block. Diet compositions and body size composition of each prey species were estimated with digested stomach contents using hard tissues such as fish otoliths and squid beaks. Biomass of each prey in the sea was estimated acoustically and the species was identified with the mid-water trawl, IKMT and plankton nets. For squids with low acoustic reflection and saury in the surface layer, the biomass was estimated with the mid-water trawling from a 100m depth to surface at predetermined stations. The body size compositions were obtained with the direct measurement for catches.

There were no serious practical problems in the concurrent whale and prey surveys. Depending on weather conditions and distribution patterns of whales and preys, the progress of two surveys was different each other. Therefore the close cooperation between two surveys is indispensable. Preliminary results suggested that minke whale preferred to Japanese anchovy while they seemed to avoid krill. Preference to pelagic shoaling fish was similar to that in the eastern North Atlantic. Bryde's whale preferred to feed on Japanese anchovy in August in 2000 but such a preference could not be detected from May to July in 2001. In earlier season, Japanese anchovy was less abundant except for the larva in Bryde's whale distribution area. Minke and Bryde's whales did not feed on lanternfishes that migrate to the surface layer at night. In fact lanternfishes were taken in the nighttime mid-water trawlings from a depth of 100m (Fujise et al., 2001; 2002). It seems that minke and Bryde's whales feed only during the daytime and the preference to lanternfishes is judged as zero. The size of anchovy in the stomach of Bryde's whales is usually larger than that in the sea (See Appendix 2). Bryde's whales may prefer to larger anchovy. The distributional pattern of each prey species is closely related to the depth zones in the inshore areas and the complex water masses in the offshore areas (Appendix 5). The local distributional patterns of cetaceans and prey and degree of overlapping between them may affect the effective prey preference.

In conclusion the prey preference of cetaceans could be estimated if the present concurrent whale and prey surveys continue. On the diet composition, the hard tissue technique to identify the species and estimate the body size is almost completed. Data on Target Strength (TS) for estimating prey biomass acoustically are being collected for most fisheries resources in Japan. A trawl net suitable to saury is now under construction by one of the National Fisheries Research Institute. Also to estimate effective prey preference, the local distribution pattern and abundance of cetaceans is needed. The information should be collected in JARPN II. Finally GIS technique is inevitable to combine and analyze the information on oceanographic conditions, preys and cetaceans.

2.1.3 Small cetaceans from commercial harvest

In the western North Pacific, not only minke, Bryde's and sperm whales but also many species of cetaceans inhabit. Among these species, Baird's beaked whales, northern form short-finned pilot whales and Dall's porpoises are frequently distributed in the research area of JARPN II, and taken by the small-type whaling and the dolphin fisheries in Japan. To evaluate ecological role of these species as additional information in the ecosystem model of JARPN II, the qualitative and quantitative studies on feeding habits is needed. However, since the surveys of these hunted whales and dolphins have been conducted mainly for stock management purpose (for stock identification, life history, and the monitoring of the population status), the information of the feeding habits is still poor

especially for Baird's beaked whales and northern form short-finned pilot whales. Thus, we conducted stomach contents surveys for these species as a part of the feasibility studies of JARPN II.

Through May in 1999 to November in 2001, the small-type whaling caught a total of 184 Baird's beaked whales and 157 northern forms of short-finned pilot whales in the coastal waters of Japan (Fig. 2.1.1) and all hunted whales were surveyed for biological information such as a body length, age, maturity, external morphology and genetics. Among them, stomach contents samples were collected from 76 Baird's beaked whales and 27 pilot whales. Up to the present, we finished the analyses of the stomach samples in 26 Baird's beaked whales and all pilot whales, and obtained the tentative result as follows.

Baird's beaked whale
Important prey items varied among local areas (Table 2.1.1: Ohizumi, *et al.* 2002; Ohizumi *et al.*, unpublished data). At Hakodate, most important prey was *Gonatopsis makko*, which occupied 95% of contribution in weight and 60% in number. Although we could investigate only 2 animals, in Abashiri, *Galiteuthis* squid was the most important in weight followed by *Theragara chalcogramma* and *G. makko*. In Wada, deep-sea cods and rat-tails were important prey, especially *Coryphaenoides longifilis* contributed about 70% of the prey weight. *Coryphaenoides acrolepis* was also one of the main pray. Sometimes unidentified crabs were found from the stomach contents, but in Wada, crabs were found also from the stomach contents of prey fishes.

Northern form short-finned pilot whale
Almost all of the prey items were squids. Fishes were few, and most of them were smaller fish such as myctophids. Most important prey squids in weight were *Todarodes pacificus* and *Ommastrephes bartrami*. *Eucleoteuthis luminosa* was also an important prey in numerical contribution (Table 2.1.2: Ohizumi, unpublished data).

Dall's porpoise
In the case of Dall's porpoise, we conducted biological surveys mainly for life historical study, and collected samples from 488 porpoises taken by the hand-harpoon fisheries thorough September in 1999 to June in 2001. Among them, 124 porpoises were aged, and we confirmed that the porpoises less than 10 years could be aged. The Analyses of stomach contents are on going in Hokkaido University by using the part of specimens obtained from the surveys.

In addition to stomach contents surveys, we tried to collect fish specimens as many as possible to make an otolith reference for prey fish identification and reconstitution of fish body length and weight. We collected especially otoliths of macrourid fishes (rat-tails) that are main prey of Baird's beaked whales off central Japan, under cooperation of Tohoku National Fisheries Research Institute, Hokkaido National Fisheries Research Institute, and Suzuki Gyogyo Co. Ltd. We could successfully collect the otoliths of macrourid fishes for most of the species inhabiting the Pacific coast of the Tohoku region, and we could identify the species with the otoliths. For the cephalopod prey, the National Science Museum has recently developed squid beak collection under cooperation of NRIFSF, which enable us to squid identification by beaks. This squid beak collection covers many species of squids inhabiting the western North Pacific, but stomach contents sometimes included possibly new species or unreported species from the study area. Therefore, further collection of beaks is needed. We could estimate body length and body weight of prey for most of the species from the otolith length or beak lower rostral length. However, for some cases, the regression equation provided a rough estimation, or we could not avoid using regression obtained from other species in the Genus or Family.

Progress in the methods of prey species identification and the reconstruction of the body weight could make us to evaluate the quantitative importance of each species. However, we still have problems of sample bias and small sample size. Due to the limitations of the commercial fishing seasons and grounds, the data from the surveys are seasonally and spatially biased. This aspect should be taking into account when these data will apply to the ecosystem model in JARPN II. Sample size of stomach contents surveys is relatively small compared with the total number of the catch. One of the reasons is logistic problem such as a shortage of researchers and fund, and other reason is related to the habitual behavior of fishermen, i.e. they incise the belly of carcass and often discard the stomach contents to the sea in order to keep the meat fresh. Small sample size also prevents us from the estimation of the daily prey consumption rate and the digestion rate. To solve this point, it will be necessary to construct the metabolic models based on the captive experiments.

In conclusion, the following approaches will be necessary, 1) to continue the present surveys, 2) to increase the sample size, and 3) to utilize the commercial catch samples for the ecosystem modeling as effectively as possible.

2.1.4 Ecosystem model

It is essential to learn roles and dynamics of key-species in the ecosystem for multispecies management. Demand in multispecies management is increasing these days and also supply of models is increasing accordingly. Ulltang (1995) noted that the revised management procedure (RMP) will become sterile and lose its scientific credibility if RMP in its future development does not in some way adopt important results from progress in the biological sciences, including multispecies research. Some outputs that multispecies model gives can contribute the settlement on management problems of aquatic animals and fishes without doubt. We had Ecopath (Christensen et al. 2000) and Multspec (Bogstad et al. 1997) as candidates of present available ecosystem models to throw light on key-species in the ecosystem, their interactions and roles. Ecopath is widely used all over the world along with its variants, Ecosim and Ecospace. Multspec gave some promising results and improved along with similar programs such as Bormicon (Stefansson et al. 1998). For the present, Ecosystem models suitable to the western North Pacific has been being developed based on the models such as Ecopath, as just an initial work. In the future, Ecopath is made use of to give overall impression on the ecosystem and make clear key species in the ecosystem. On the one hand, Multspec is used to treat detailed dynamics for the interactions of selected key species and the effects of migration and prey preference. We have just undertaken the development of Multspec-type model. In dealing with uncertainty in the ecosystem model, Multspec model is very promising. From the next paragraph, we will introduce the developments of Ecopath-type model and Multspec-type model in two years JARPNII feasibility study in short.

Ecopath-type model

The Ecopath-type model has had the purpose to illustrate the trophic flows in the ecosystem of interest. It is being recognized in recent years that it is useful to construct food web and trophic structure using known data from fisheries and research activities. As a rule, Ecopath needs to postulate equilibrium of biomass, and interactions that are resulted from the analyses are extremely complicated so that indirect impacts often have a big effect. Therefore, we made use of it to evaluate the relative importance of predator species and to know the distinction between keystone predators at the first stage. Ecosim and Ecospace are also used and examined to grasp dynamic change including changes in exploitation rates, predator-prey interactions, environment and population size etc. Ecosim is a dynamic simulation module for predicting results of human and climatic impact on ecosystem components. Ecospace is a spatial equilibrium model and predicts biomass and exploitation distribution over two-dimensional space.

Some initial analyses from Ecopath and Ecosim were presented to IWC/SC in 2000 (Okamura et al. 2001, Appendix 6). Especially, the paper focused on the application of Ecosim into the North Pacific model to examine the interactions between fisheries and cetaceans. The Ecosim simulations were done under the following 4 scenarios:

Scenario 1: Fishing rate of cetaceans = 0,
Scenario 2: Fishing rate of fishes = 0,
Scenario 3: Doubling the fishing rate of cetaceans,
Scenario 4: Doubling the fishing rate of fishes.

Because Ecosim is very sensitive to the vulnerability parameter, each simulation was carried out under two settings of the vulnerability parameters of 0.3 and 0.6. The vulnerability of 0.3 is the default value in Ecosim and 0.6 is twice the default value. When the vulnerability parameter is large, the ecosystem approaches top-down control such as Lotka-Volterra dynamics. The vulnerability parameter is estimated from fitting our Ecosim model to available time series data. For analytical simplicity, only the overall vulnerability parameter was estimated, i.e. a single parameter under the assumption that all the groups have the same value. The employed time series data were taken from fishing rates and biomass estimates of sardine, chub mackerel and common squid from 1987 to 1999. To supplement the result of estimation of the vulnerability parameter, an evolutionary criterion to search for an optimum estimate was used.

The results of the simulations showed a clear change of biomasses, especially when the vulnerability parameter was high. When there was no catch of cetaceans in future 50 years (Scenario 1), relative biomass of some fishes decreased in the order of several ten percent, and some whales increased in the similar order (Figs. 2.1.2 and 2.1.3). Without fisheries except whaling in future 50 years (Scenario 2), relative biomass of some fishes increased in the order of several hundred percent and some whales increased in the order of several ten percent (Figs. 2.1.4 and 2.1.5). With double fishing rate for cetaceans in future 50 years (Scenario 3), some fishes increased in the order of several ten percent. Some squids showed different dynamics from those fishes, probably because of indirect effects (Figs. 2.1.6 and 2.1.7). With double fishing rate for fishes in future 50 years (Scenario 4), many fishes became extinct. Some cetaceans decreased in the order of a few ten percent, probably because of lack of prey (Figs. 2.1.8 and 2.1.9).

Fitting the model to available time series data of some fishes showed that the vulnerability parameter in the model was likely to be high. The vulnerability parameter estimated through fitting time series data was about 0.6 and the value obtained through searching for the evolutionarily stable strategy was some 0.5. Among three species employed in time series fitting, the relative biomass trend of sardine was not successfully fitted.

The results of simulations indicated that there is a possibility that cetaceans and fisheries are competing each other in the western North Pacific because the search of the vulnerability parameter in the model resulted in relatively high value. Therefore, the ecosystem of the western North Pacific may be affected on a large scale by trophic interactions and changes of fishing.

Further, some Ecosim run was done with some alterations of input data to investigate a role of sperm whale in the ecosystem (Appendices 7 and 8). Main alterations are to separate deep-sea squids into vertical migrators between the deep sea (say, deeper than 400m in depth) and surface layer (shallower than 200m), and real deep-sea squids that do not migrate to the surface. Sperm whales eat mainly real deep-sea squids based on the results of two-year feasibility JARPN II surveys. The simulation showed that sperm whales have large effects on some direct and indirect prey species as before. Especially, there existed several species targeted by commercial fishing in strongly influenced prey by sperm whales. It means that sperm whale can still be important in the ecosystem as minke whales.

Many test runs suggested the applicability of our Ecopath and Ecosim models to the western North Pacific. Cetaceans, especially minke whales and sperm whales, are probably important key species in the western North Pacific ecosystem because removals of minke whales and sperm whales brought large fluctuations to direct and indirect prey species biomasses when the vulnerability parameter is supposed to be high. One of reasons why Bryde's whales showed little effect is shortage of information, especially their diet composition and accurate biomass. Furthermore, the habitat of Bryde's whales is more offshore than our designed area. Therefore, biomass of Bryde's whales is very small.

Future works will increasingly improve our model for the western North Pacific Ecopath model. On the other hands, the examination based on the Ecopath-type model clarified deficiencies of Ecopath with Ecosim, and discrepancies between Ecopath and our intention. Ecosim has not yet had the function to include uncertainty of many parameters completely. Espaecially, because the choice of the vulnerability parameter is important, more precise estimation of it should be developed. In the future, accuracy and precision of important parameters should be improved and uncertainty of parameters should be reasonably incorporated into the western North Pacific Ecopath/Ecosim model. Shortage of seasonal data caused some problems, for example most of cetaceans migrate south to north. This had us recognize the importance of including seasonal effect such as migration and spatial expansion, e.g. Ecospace.

Multspec-type model

The Multspec model is achieving some success in the Norwegian aquatic ecosystem (Ulltang, 1995; Bogstad et al., 1997; Tjelmeland and Bogstad, 1998). The model is age- and area-structured multispecies model that integrates the dynamic of each fish and marine mammal (Although Norwegian Multspec model includes length information, the our present model doesn't include it). The details of the developed model are shown in the JARPN II Plan (Government of Japan, 2002). Unlike Ecopath, it has some difficulties to include many species and complicated food web because it has complicated dynamics model for each component. However, it is possible to examine the dynamic changes of each entry in details. At the first stage we will consider a simple model to include minke whale, Pacific saury, Japanese anchovy and krill. This enables us to utilize available information at maximum, describe dynamic change including various uncertainties, carry out extensive sensitivity analyses and predict future interactions among whales and fisheries. The model is being coded with EXCEL VBA according to the specification.

Comparison and integration of Ecopath and Multspec models

Ecopath is a complex-structured ecosystem model that consists of simple dynamic equations. On the one hand, Multspec is simple-structure model that consists of detailed dynamic models for each component. Aydin and Friday (2001) examined the difference between multi-species and single-species models under uncertainty of parameters using simple Ecosim model. They pointed out from their results that multi-species management was very sensitive to the difference of parameters and a complicated model might put this behavior out of sight. Putting our and their results together, it is plausible that multi-species management by Ecopath and Ecosim is still too early. Although Multspec has detailed single species dynamics model, the overall structure is simple. The impacts that

changes of population size and prey preference gives on the ecosystem are extensively and explicitly examined using Multspec (Bogstad et al. 1992). Therefore, sensitivity analyses by Multspec are carried out in a relatively easy way and its graphical outputs can be easily interpreted. Consequently, the study on the uncertainty of parameters will be started based on the Multspec model.

The effects of migration can also be examined based on Multspec model, which is area-structured model and monthly age-specific migration rate is constructed using transition matrices. This directly deals with migration. On the other hands, Ecopath is extended spatially to Ecospace. Ecospace cannot deal with migration directly. However, constructing Ecopath-type model based on spatially separate parameters and modelling interactions among areas are to make average spatial structure clearly understandable.

Multspec has the simple structure of multispecies, and the extension of the model is gradually done, because the complicated dynamics of each component in the model makes extension of the structure difficult. Ecopath is easier than Multspec in terms of including new components. And the characteristics that Ecopath has the bottom such as detritus to the top such as tuna and whales can give overall impression on the ecosystem and suggest the importance of indirect effects and interactions. Therefore, the development of Ecopath, Ecosim and Ecospace in the western North Pacific in parallel with Multspec is still more important.

For our purpose, such as explication of the existence of the competition between fishery and the consumption of whales, impacts of whales on their prey species, and management advice to single species management of fishes from multispecies models, combinations of advantages for both models, Ecopath and Multspec, through improvements of their merits and demerits are necessary in the future. After going through various improvements of our present models, the integration of the Ecopath-type model and the Multspec-type model will be searched thoroughly and elaborately.

Input of data needed for Ecopath-type model:
Ecopath model for the western North Pacific consisted of 30 groups. Ecopath basically requires biomass (*B*), production/biomass (*P/B*), consumption/biomass (*Q/B*), diet composition (weight-base), fished biomass (= catches), for each group. The input parameters for *B*, *P/B* and *Q/B* in the model are shown in Table 2.1.3. Diet composition and fished biomass are shown in Table 2.1.4 and Table 2.1.5 respectively. Most of them were gathered from published sources. The information of biomass for whales was taken from data of Area 7 in Table 1 of Appendix 1 of the Government of Japan (2000), and the information of diet composition was taken from Appendix Table 10.11 and 10.12 of Hunt and Kato (2000). The information of fishes was collected from a great variety of literature. When there was no appropriate literature, the parameters of Trites et al. (1999) or FishBase on the web (http://www.fishbase.org/search.cfm) were used.

Arranging data needed for Ecopath came up with various problems, e.g. a shortage of data, incorporation of uncertainty of parameters, specification of seasonality, utilization of prey preference information, and inconvenient treatment of migration. These problems will be resolved through long-term development of model and data collection. The Multspec model is expected to handle uncertainty of parameters easily by the simple description of ecosystem model unlike Ecopath type model.

Okamura (2000) showed that the relations between whales and fishes could be strongly influenced by the diet composition of whales. Therefore, the long-term information on diet composition is needed to clarify the characteristics of the ecosystem. Of course, more precise estimates of other biological parameters are also necessary. Especially, it is plausible that temporal and spatial migration and prey preference of cetaceans have a big impact on the ecosystem. The information on migration and prey preference, and time-series data of diet composition collected from historical literature, small-type coastal whaling, and researches help develop more realistic and useful model very much. It goes without saying that long-term monitoring of cetacean population is needed in the light of conservation. Precise abundance estimates and its trend are not only important parameters, but also very useful information for estimating the vulnerability parameter which is one of most important parameters in the Ecosim run. It is impossible to overemphasize the importance of collecting and utilizing the synthetic research data including historical ones and samples form survey other than JARPN II.

Input of data needed for Multspec-type model:
The process of initial Ecopath model construction and the results made clear still remaining several problems to resolve in the future. For example, necessity of information on detailed diet composition, migration and long-term spatially extensive biological information such as biomass, its trend and consumption, establishment of sensitivity analysis method, the development of estimation procedure of robust vulnerability parameters, and incorporation of

environmental factors. It is expected that the developing Multspec-type model resolves some of these problems. After we complete initial Multspec-type model, we will brush up both western North Pacific Ecopath and Multspec models based on all the results obtained from some suggestive simulation runs. Afterwards, we will undertake to develop new ecosystem models that are useful for multi-species management.

2.2 Results of stock structure studies

2.2.1. Genetics

Minke whale (Appendix 9):

First objective for the stock structure study under JARPNII feasibility survey was to investigate the possibility of an additional structure (i.e., W Stock) in the western North Pacific, specially in offshore sub-area 9. To test this hypothesis, we collected samples from sub-area 9 during the JARPNII 2000 and 2001 surveys and looked for any evidence of genetic differences among the samples from sub-areas 7, 8, and 9, including those collected during 1994-1999 for JARPN, using both mitochondrial DNA (mtDNA) sequencing and microsatellites.

Mitochondrial DNA control region sequencing was conducted on the total JARPN and JARPN II samples from 1994 to 2001 in order to examine the stock structure of western North Pacific minke whales. Following a recommendation from the 53rd IWC/SC meeting, a genetic criterion was used to identify the animals belonging to the J-Stock and these animals were excluded from the analysis. The source of some degree of mtDNA heterogeneity found was attributed to whales sampled in the western part of sub-area 9 in 1995, 2000 and 2001. While the sample size in 1995 was relatively large (n=78), the sample size in 2000 (n=16) and 2001 (n=29) are small. Thus no definitive conclusion could be obtained for these two years. If samples from sub-area 9W in 1995, 2000 and 2001 were excluded from the analysis, no mtDNA heterogeneity was found in sub-areas 7, 8, 9 and 11 for the different groupings used. These results supported the one-stock scenario in sub-areas 7, 8, 9 and 11 but the possibility that a different stock occurs sporadically in sub-area 9W, cannot be discarded.

Seven microsatellite loci were used to examine the genetic stock structure of minke whales collected from sub-areas 7, 8, 9, and 11 in the western North Pacific during JARPN and JARPNII from 1994 to 2001. No evidence of genetic differences was detected among the samples from different sub-areas, indicating existence of a single stock in the study area. No evidence of genetic differences was also detected from all comparisons conducted between different combinations of the samples from different sub-areas: SA (7+11) vs SA8, SA (7+11) vs SA9, and SA (7+8+11) vs SA9. No evidence of genetic difference was detected between samples collected from east and west of longitude 153 degree. Our results did not support additional boundaries in the western North Pacific.

Conclusion that the W Stock exists in the eastern side of western North Pacific is still tentative, however. Sample sizes of some samples are so small that they may not adequately represent the genetic composition of a population.

Second objective for the stock structure study under JARPNII feasibility survey was to estimate mixing rate between O and J Stocks in the coastal area of Japan, i.e., sub-area 7. Using the same maximum likelihood method for estimating the mixing rate in sub-area 11 (Kishino *et al.*, 1994; Pastene *et al.*, 1998), we observed the mixing rate of 0.08 (SE:0.08) for the 2000 sample and 0.07 (SE:0.04) for the 2001 sample both taken from the sub-area 7 during the JARPNII survey. These rates are much smaller than that observed from the samples in the sub-area 11, indicating very few J-type individuals migrate into the sub-area 7. Fluctuation of the mixing rates we observed from 1994 to 2001, however, indicates proportion of the J-type individuals entering the sub-area 7 might differ year by year.

The JARPNII 2000 and 2001 surveys definitely make us believe that further analysis should be done for a better understanding of stock structure of minke whales in the western North Pacific. In order to further test the multiple stock hypotheses in the east side of western North Pacific, more samples should be collected from sub-area 9 and possibly 13. In order to accomplish effective management of minke whales inhabiting coastal area, long-term genetic monitoring of the J Stock in the sub-area 7 is necessary.

Although we proposed to analyse minke whales inhabiting sub-area 12 during JARPNII, we were not able to collect any samples from the area because permission for the survey in Russian EEZ was not granted from Russian Government. This is definitely an important area to be studied for conducting sound management of minke whales because members of O, J, and putative W Stocks may coexist in the area. We thus propose again the scientific survey in the sub-area 12.

Bryde's whale (Appendix 10):

The JARPN II in 2000 and 2001 sampled Bryde's whales in regions sub-area 1 not covered previously. Samples taken by JARPN II in 2000 and 2001 were examined using mtDNA and microsatellite. Calf whales were exclude from the analysis, thus the sample sizes from these surveys were 42 and 43 whales, respectively. We included into the analysis historical samples taken around the Ogasawara Island in 1983 and 1984 (n= 103) and in a pelagic whaling operation in 1979 (n= 95). All these samples are within sub-area 1 defined for the Western North Pacific Stock (WNP). For comparative purpose we also included into the analysis samples from other previously recognized stocks of Bryde's whale: Western South Pacific (WSP) (n= 24), Eastern South Pacific (ESP) (n= 33) and Eastern Indian Ocean (EIO) (n= 23). The total number of sample examined was 363 whales.

MtDNA data was analyzed using the Analysis of Molecular Variance (AMOVA) for both PHIst and Fst statistics. The hierarchical analysis showed striking differences among WNP, WSP, ESP and EIO but no significant genetic heterogeneity was found within the WNP nor within the ESP. We also used a chi-square test to compare localities within the WNP. In the comparison between Ogasawara and JARPN II a low P value was found using chi-square (P= 0.022). However, in the comparisons between Ogasawara and Pelagic and between JARPNII and Pelagic no significant differences were found.

Five microsatellite loci were used to examine a sub-set of the samples used in the mtDNA analysis. A total of 220 whales were examined: WNP (n= 185 as follow: JARPN II, n= 85, Ogasawara, n= 50 and Pelagic, n= 50); WSP (n= 25) and EIO (n= 10). Two statistical tests were used: chi-square test by the Markov chain method for the Hardy-Weinberg proportion and heterogeneity test using probability test by the Markov chain method. No significant heterogeneity was found within the WNP. In contrast, striking differences were found among WNP, WSP and EIO.

In conclusion, different populations of the ordinary Bryde's whale are confirmed for the WNP, WSP, ESP and EIO. Based on the mtDNA analysis, which was more extensive than microsatellite, genetic differences are larger between oceans i.e. between Indian Ocean and Pacific Ocean than within ocean i.e. among localities within the Pacific Ocean. No shared haplotypes were found between the two oceans while some haplotypes were shared among different populations within the Pacific Ocean.

Even by adding samples from previously uncovered regions in sub-area 1, no strong evidence of additional stock structure within the Western North Pacific Bryde's whale Stock was found.

Regarding future research need, JARPN II in 2000 and 2001 covered some portions of sub-area 1, for which no previous information on stock structure was available. There are other portions within this sub-area, which need to be covered for the objective of stock structure. The genetic analysis based on the feasibility surveys revealed a weak mtDNA heterogeneity between recent JARPN II samples and historical samples from Ogasawara. This heterogeneity should be tested with the additional samples from the same region.

Until now all lines of evidence indicate that sub-area 1 contains a single stock. Information on stock structure from sub-area 2 (east of 180°) is necessary in future, as no available genetic information from that sub-area is available.

During the JARPN II feasibility surveys several cow/calf pairs were sampled (one in 2000 and seven in 2001). Calf animals were not included into the genetic analysis to avoid bias due to close related individuals. This meant that the sample size used in the analysis decreased. We recommend that during the full JARPN II surveys, sampling of cow/calf pairs be avoided.

Sperm whale (Appendix 11):
A total of 31 sperm whales including 18 biopsies taken during JARPNII survey in western North Pacific were analyzed using 340bp sequencing of mitochondrial DNA control region and seven microsatellite loci. The level of genetic variability observed in these 31 sperm whales was compared to that observed from minke and Bryde's whales similarly collected from the western North Pacific during JARPN and JARPNII.

2.2.2. Biological parameter
Minke whale (Appendix 12):
To clarify some degree of genetic heterogeneity by the mtDNA analysis found in western part of sub-area 9, the present study examines biological parameters such as; (1) conception date (the relations between the sampling date and the foetal body length) that is one of biological parameters which provides a clear key to discriminate two different stock of minke whales, (2) growth curve and mean body length in physically mature animals (mean body

length of animals older than 14 years) that are biological parameters which have supported stock identification by genetic markers, (3) scars of bite marks by *Isistitus* sp. which are useful in determining stocks that are separated by different habitat. We used the biological data from 213 individuals (188 males and 25 females) from sub-area 7, 112 individuals (106 males and 6 females) from sub-area 8, 149 individuals (134 males and 15 females) from sub-area 9W and 84 individuals (72 males and 12 females) from sub-area 9E collected during JARPN surveys from 1994 to 1999 and JARPN II surveys from 2000 to 2001.

Through the present study, no difference has been found in above biological parameters among these sub-areas. Conception date shows that, as well as the results of JARPN surveys, six foetuses (sub-area 7: 3 foetuses, sub-area 8: one featus, sub-area 9W: 2 foetuses) collected during JARPN II surveys were considered to have roughly the same conception date as the Okhotsk-Western North Pacific Stock (O Stock). No specific differences of growth curves of males among sub-areas were found. For female, it was difficult to compare growth curve between sub-areas due to extremely small sample sizes. Analysis of variance in the mean body length for physical mature males revealed no statistical significant difference by local and yearly. As well, no statistical difference among sub-areas was found for females. For the observation of scars on the skin of whales collected during JARPN II surveys from 2000 to 2001, the scars were found on the skin of all mature animals. This finding from the scars indicates that mature animals were considered O stock animals. From the maturity status composition, it was clear that minke whales collected in sub-areas 8 and 9W during JARPN II surveys also showed incomplete composition of sex and sexual status (dominant mature males, few mature females and few immature animals). Relatively more immature animals were found in the coastal sub-area 7 during JARPN II surveys compared with JARPN surveys. Incomplete representation (few mature females and few immature animals) of sex and maturity status of minke whales found in sub-area 7, 8, 9W and 9E indicate that the existence of one independent stock in every sub-area is highly unlikely.

In conclusion, the present analysis of above biological parameters also could not confirm the existence of another independent stock in sub-area 9. It is reasonable to consider that one independent stock of western North Pacific minke whales distributes widely from coastal sub-area 7 to offshore sub-area 9E.

2.3 Environmental changes

2.3.1. Contamination level of minke, Bryde's and sperm whales (Appendix 13)

For the environmental issues of this research plan, it was planned to monitor several types of whales, which have different feeding habitat as well as to monitor for other marine organisms (e.g. prey species). From these monitoring, information have been accumulated for constructing a comprehensive monitoring and assessment system for pollution for the marine ecosystem in the western North Pacific.

We constructe a comprehensive monitoring system of pollutants in marine ecosystem of North Pacific Ocean on the JARPN II survey, which was described under the third sub-goal in SC/52/O1. This report is preliminary analysis of accumulation features and temporal trend of trace elements, such as Mn, Fe, Cu, Zn, Se, Cd, Pb and Hg (total and organic form), in minke whale collected from western North Pacific on the JARPN and JARPN II surveys during 1994 and 2000 (Table 1 of Appendix 10). The relationship between trace element concentrations and biological data, such as sex, body length and age are examined, and furthermore, temporal trend of the levels and stock estimate with those in sub-area 7, 8 and 9 are examined.

Table 2 of Appendix 11 shows the gender differences of the trace elements in the liver, kidney and muscle. No significant gender differences were found for most trace elements each year, whereas some gender differences were found in Cd concentrations of liver and Total Hg (THg) concentrations of liver, kidney and muscle. Significant correlations were observed between THg of liver, kidney and muscle, and body length, however, differences were not observed between those, except for liver and kidney of male, and age (Table 3 and Fig. 1 in Appendix 11). No significant correlations were observed between Cd of liver, kidney and muscle, and body length, except for hepatic Cd concentrations and body length (Table 3 and Fig. 2 in Appendix 11). Figs 3-4 of Appendix 11 show temporal trend in hepatic THg and Cd concentrations of NP minke whales during 1994-2000. Incidentally, sample in 1995 is divided into western sub-area 9 that might exist of W stock and other sample.

In general, gender differences of trace elements are not observed in wildlife, compared with organochlorines. However, significant difference was found between sexes for some trace elements, especially THg and Cd, in the liver, kidney and muscle of NP minke whales. NP minke whales have different migration pattern between genders or growth stages, and are opportunistic feeders with a broad diet and with flexible feeding habits. These factors might be attributable to gender difference of NP minke whales. Trace element levels of their food item are reported

that total Hg level is higher in fish sample and Cd level is higher in squid sample. Consequently, food items of NP minke whales should be revealed.

2.3.2. Contamination level of air and seawater (Appendix 14)
In this program, it was also planned to monitor the pollution of seawater and air. This information was not available after the 1980s. This comprehensive monitoring is being conducted.

Persistent organochlorines, such as polychlorinated biphenyls (PCBs), DDTs, hexachlorocyclohexane (HCHs), hexachlorobenzene (HCB) and chlordane compounds (CHLs) levels of North Pacific mink whale, were continually monitored in JARPN survey (1994-1999). Additionally, these organochlorine concentrations of air and surface seawater have been measured in JARPN II surveys for monitoring the global transport and fate of them.

2.3.3. An examination of usefulness of skin samples for pollution study (Appendix 15)
Furthermore, it was requested from the members of SWG of environmental concerns in 52nd IWC/SC that calibration study was needed, which used tissue samples from previously harvested whales to evaluate whether biopsy samples can be used to monitor and assess contaminant levels in cetaceans.

In response to request from the IWC/SC members, skin tissue concentrations of trace elements were compared with the liver, kidney and muscle concentrations and the body burdens that are generally used to monitor and assess trace elements. Concentrations of Mn, Cu, Zn, Se, Cd, Hg (total and organic form) and Pb were determined in the liver, kidney, muscle and skin of 15 minke whales taken from western North Pacific by JARPN survey in 1995 and 1999 (Tables 1 and 2 in Appendix 11).

Concentrations of trace element, except for Se, in North Pacific minke whales were highest in liver or kidney and were comparatively lower in skin (Table 3 of Appendix 11). In generally, liver was used for heavy metal monitoring and blubber was used for organochlorine, as these tissues were higher accumulation parts. Accordingly, skin tissue could be not reasonable as the indicator of monitoring for trace elements. Table 5 shows relationship between trace element concentrations of skin and other parameters. Toxic elements in some organs were found significant correlation between the skin and, internal organs (e.g. liver and kidney) and body burdens of the pollutants, whereas essential elements were not found. In the liver, these results are coincided with the results of Antarctic minke whales for toxic elements, but are not coincided with those for essential elements (Kunito *et al.*, 2002). About the parameters with significant correlation, it is examined with Stepwise analysis whether liver, kidney and muscle concentrations and burdens of trace elements are related with skin concentrations, body length (proxy of age) or research years (1995= sub area 9, 1999= sub-area 11) and sex. The results showed that significant correlations were observed between the skin concentrations and them by the Spearman's correlation analysis, as follows:

Cd: Liver (log (μg/g))=0.744 × Skin (log (μg/g)) + 4.86
Muscle (log (μg/g))=0.643 × Skin (log (μg/g)) - 0.262
THg: Kidney (log (μg/g))=0.797 × Skin (log (μg/g)) + 2.93
Muscle (log (μg/g))=0.643 × Skin (log (μg/g)) + 0.198 × Body length (log (m)) - 0.370 × Sex - 0.268 × Area - 2.86
Body burden (log(g)) = 0.634 × Skin (log (μg/g)) - 0.366 × Area + 0.741
OHg: Liver (log (μg/g))= - 0.778 × Area + 0.057
Kidney (log (μg/g))= 0.540 × Skin (log (μg/g)) - 0.460 × Area + 0.62

The hepatic and muscular Cd and hepatic total Hg (THg) were significantly not only obtained regression equations, but also were selected only the skin concentration as a parameter. Some parameters of toxic elements from skin might be useful for monitoring of these levels in minke whales. However, the results of present study are not necessarily coincided with them in Antarctic minke whales. The application of biopsy sample for trace element monitoring of cetaceans is further needed to examine.

2.4 Oceanographical study (Appendix 16)

RESULTS AND CONCLUSIONS DERIVED FROM THE FEASIBILITY STUDIES

As mentioned earlier the two-year feasibility study aimed mainly i) to evaluate the performance of the concurrent prey and whale surveys and ii) to evaluate whether or not information on feeding ecology can be obtained for the new target species (Bryde's and sperm whales) in the same way as it had been obtained for the minke whale under JARPN. There were no serious practical problems in the conduction of the concurrent prey and whale surveys. Preliminary analysis suggests that the data obtained from these concurrent surveys are useful to determine the prey preference of cetaceans. Information on feeding ecology of Bryde's and sperm whales could be obtained in the same way as it has been obtained for minke whale.

1. Feeding ecology and ecosystem studies

1.1 Food consumption

The feasibility studies under this item were defined as follows:

'(i) To determine whether information on the diet composition and daily and seasonal consumption can be obtained with adequate precision through the examination of stomach contents of the targeted whales'

In general there was no problem to get the information on prey composition for the three target whale species. There are two issues, however, which should be considered in future studies. One of them deals with the number of individuals with empty stomachs and how this information should be taken into account in future analyses. In particular in the case of the Bryde's whale a considerable number of animals had empty stomachs. The rate of empty stomach should be considered in future studies of food consumption, including estimations of sample sizes for such studies. The other item deals with information on diurnal changes in food composition and whether or not whales feed during the night. The direct evidence could not be obtained under JARPN II in 2000 and 2001 and effort to get such information including in-direct one should be made in future surveys.

During the JARPN II feasibility studies, a total of nine calves of Bryde's whale were collected with cows. The examination of these individuals for feeding ecology showed that the stomach contents of cows were not different from other animals and calves under 8.0m of body length only had milk in the stomach. Consequently, it is concluded that calf samples are of less value for the studies of feeding ecology.

It is concluded that useful data on food habit of sperm whales in the western North Pacific was obtained during the feasibility study. The food habit of sperm whales from spring to summer was confirmed. Prey species were identified from examination of beaks in the case of squid and otoliths in the case of fish. The body length and body weight of some prey species could be estimated using regression equation.

One of the purposes of JARPNII research was to obtain an estimate of the daily and/or yearly consumption for each prey species with adequate precision. Estimate of the daily prey consumption rate of common minke and Bryde's whales was estimated using two methods and the results were similar to previous estimates. The estimation of daily prey consumption was successful, but there are some limitations. Daily prey consumption should be estimated for each area and each season with yearly variation. Although results showed that most of food were meso-pelagic/deep sea squids and fishes, the sample size is too small and we have not information in other seasons. Such detailed information is necessary for ecosystem model such as Ecopath-type and Multspec-type models.

'(ii) To evaluate whether the weights of the stomach contents can be measured for large whales such as Bryde's and sperm whales in the same way as it was made for minke whales under JARPN'

The weights of the stomach contents could be obtained for these larger species. Maximum weights of stomach contents in the Bryde's and sperm whales were 541kg and 160kg, respectively.

'(iii) To evaluate whether or not the total body weight of these larger species can be obtained in the same way as it was obtained for minke whales under JARPN'

Body weights of Bryde's and sperm whales sampled could be obtained. It should be noted here that only sperm whales smaller than 10m of body length were targeted for sampling.

1.2 Prey preference of cetaceans

The feasibility studies under this item were defined as follows:

(i) To examine the performance and practicability of the concurrent whale and prey surveys using a total of six research vessels'

There were no serious problems in the conduct of this concurrent survey. Both prey and whale surveys in the 2000 and 2001 surveys were conducted in a given small block within a same week. Both surveys were not conducted exactly at the same time as progress of the whale survey depends on the weather condition, which is not a limiting factor for the prey survey. In the full JARPN II both surveys should be conducted as close as possible (temporal and spatially). A close cooperation between the prey and whale surveys is indispensable for a good performance.

'(ii) To assess whether such concurrent survey provide enough data to determine prey preferences'

Some preliminary results on prey preference of cetaceans were obtained: negative preference of minke and Bryde's whales to lanternfishes and Bryde's whale preference to larger fish among the small-sized anchovy. These results are encouraging but more data from the concurrent surveys are needed. Also direct observation of feeding behavior and integrated analysis combined with oceanographic data may be needed to understand the prey preference of cetaceans.

2. Stock structure (Bryde's whale)

The feasibility studies under this item were defined as follows:

'(i) To investigate whether or not biological samples for stock structure studies can be obtained from areas not covered in the previous studies'

In general sampling of Bryde's whales was successfully conducted in regions within sub-area 1 not covered in previous studies on stock structure. A total of 93 samples was collected in the northern part of sub-area 1. Genetic analysis of samples from these previously no surveyed regions within sub-area 1 was completed. Other regions within sub-area 1 not covered previously should be considered in future surveys. Also sub-area 2, for which no genetic material is available, should be considered in future surveys.

From each calf/cow pairs sampled only one individual was used in the study of stock structure. Sampling of cow/pairs are not desirable in future surveys.

3. Environmental effects on cetaceans and marine ecosystem

The feasibility studies under this item were defined as follows:

(i) To evaluate whether or not a comprehensive monitoring of pollutant in the marine ecosystem is possible'

Information on the accumulation levels of contaminants in the targeted whale species as well in the surrounding environment have been obtained and analyses are underway. Several biological parameters are considered for an adequate interpretation of the level of pollutants found in whales. On the basis of these preliminary analyses it is concluded that a comprehensive monitoring of pollutant in the marine ecosystem is possible.

REFERENCES

Aydin, K. and Friday, N. (2001) The early development of Ecosim as a predictive multi-species fisheries management tool. Paper SC/53/E3 presented to the IWC Scientific Committee, July 2001 (unpublished). 8pp.

Bogstad, B., Tjelmeland, S., Tjelta, T. and Ulltang, , Ø. (1992) Description of a multispecies model for the Barents Sea (MULTSPEC) and a study of its sensitivity to assumptions on food preferences and stock sizes of minke whales and harp seals. Paper SC/44/O9 presented to the IWC Scientific Committee, May 1992 (unpublished). 47pp.

Bogstad, B., Hauge, K. H., and Ulltang, Ø. (1997) MULTSPEC - A multi-species model for fish and marine mammals in the Barents Sea. J. North. Atl. Fish. Sci. 22. 317-41.

Christensen, V, Walters, C. J. and Pauly. D. (2000) Ecopath with Ecosim: a User's Guide, October 2000 Edition. Fisheries Centre, University of British Columbia, Vancouver, Canada and ICLARM, Penang, Malaysia. 130pp.

Government of Japan. 2002. Progress report of the feasibility study of the Japanese whale research program under special permit in the western North Pacific-phase II (JARPN II). Paper SC/54/Oxx presented to the IWC Scientific Committee, May 2002 (unpublished). xxpp.

Hunt, Jr., G. L. and Kato, H. (eds.) (2000) Predation by marine birds and mammals in the subarctic North Pacific Ocean. PICES Scientific Report No. 14. 165pp.

Lindstrøm, U. and Haug, T. 2001. Feeding strategy and prey selectivity in common minke whales (*Balaenoptera acutorostrata*) foraging in the southern Barents Sea during early summer. *J. Cetacean Res. Manage.* 3:239-49.

Okamura, H. (2000) Consideration for modeling to incorporate prey consumption by marine birds and mammals (W6-183). Extended Abstract, North Pacific Marine Science organization (PICES), Ninth Annual Meeting, Hakodate, Japan. 2pp.

Okamura, H., Yatsu, A., Miyashita, T., and Kawahara, S. (2001) The development of the ecosystem model for the western North Pacific area off Japan. Paper SC/53/O9 presented to the IWC Scientific Committee, July 2001 (unpublished). 36pp.

The Government of Japan (2000) Research plan for cetacean studies in the western North Pacific under special permit (JARPN□) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC Scientific Committee, June 2000 (unpublished). 68pp.

Trites, A. W., Livingston, P. A., Vasconcellos, M. C., Mackinson, S., Springer, A. M., and Pauly, D. (1999) Ecosystem change and the decline of marine mammals in the Eastern Bering Sea: testing the ecosystem shift and commercial whaling hypotheses. Fishereies Centre Research Reports 1999, Vol. 7. 100pp.

Table 1.1.1. List of large cetacean species and number of sightings (no. schools/no. individuals) were made by three sighting/sampling vessels in the 2000 and 2001 JARPN II surveys (Total area: 2000/7/30- 9/16, 2001/5/14- 8/3).

Whale species	2000 JARPN II						2001 JARPN II					
	Primary		Secondary		Total		Primary		Secondary		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Common minke whale	31	31	35	37	66	68	73	75	60	61	133	136
Like minke whale	3	3	2	2	5	5	6	6	15	15	21	21
Blue whale	17	22	3	3	20	25	20	28	3	3	23	31
Fin whale	11	12	3	4	14	16	11	17	4	6	15	23
Sei whale	16	30	2	3	18	33	96	130	14	18	110	148
Bryde's whale	87	111	55	77	142	188	34	42	30	35	64	77
Humpback whale	1	3	1	1	2	4	9	12	6	6	15	18
Right whale	0	0	0	0	0	0	1	2	1	1	2	3
Sperm whale	112	225	53	175	165	400	224	506	102	442	326	948
Unidentified large cetacean	26	31	14	16	40	47	10	11	8	8	18	19
Unidentified cetacean	46	48	17	17	63	65	90	90	34	39	124	129

Table 1.1.2. Compositon of sex and sexual maturity of minke whales collected by the 2000 and 2001 JARPN II surveys.

Sub- area		2000 JARPN II											
		Male			Female					Combined	Sex ratio	Maturity		Pregnancy
		Imm.	Mat.	Total	Imm	Rest.	Preg.	Unk	Total		(% males)	Male	Female	rate*)
7	first	2 (33.3)	3 (50.0)	5 (83.3)	0 (0.0)	0 (0.0)	1 (16.7)	0 (0.0)	1 (16.7)	6 (100.0)	83.3	60.0	100	100
	second	6 (33.3)	8 (44.4)	14 (77.8)	0 (0.0)	1 (5.6)	2 (11.1)	1 (5.6)	4 (22.2)	18 (100.0)	77.8	57.1	100	66.7
	Combined	8 (33.3)	11 (45.8)	19 (79.2)	0 (0.0)	1 (4.2)	3 (12.5)	1 (4.2)	5 (20.8)	24 (100.0)	79.2	57.9	100	75.0
9		2 (12.5)	14 (87.5)	16 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	16 (100.0)	100.0	87.5	-	-
Combined		10 (25.0)	25 (62.5)	35 (87.5)	0 (0.0)	1 (2.5)	3 (7.5)	1 (2.5)	5 (12.5)	40 (100.0)	87.5	71.4	100	75.0

Sub- area	2001 JARPN II											
	Male			Female					Combined	Sex ratio	Maturity		Pregnancy
	Imm.	Mat.	Total	Imm	Rest.	Preg.	Unk	Total		(% males)	Male	Female	rate*)
7	11 (22.0)	36 (72.0)	47 (94.0)	3 (6.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (6.0)	50 (100.0)	94.0	76.6	0.0	-
8	0 (0.0)	20 (95.2)	20 (95.2)	0 (0.0)	0 (0.0)	1 (4.8)	0 (0.0)	1 (4.8)	21 (100.0)	95.2	100.0	100.0	100.0
9	0 (0.0)	26 (89.7)	26 (89.7)	1 (3.4)	0 (0.0)	2 (6.9)	0 (0.0)	3 (10.3)	29 (100.0)	89.7	100.0	66.7	100.0
Combined	11 (11.0)	82 (82.0)	93 (93.0)	4 (4.0)	0 (0.0)	3 (3.0)	0 (0.0)	7 (7.0)	100 (100.0)	93.0	88.2	42.9	100.0

*) Apparent pregnancy rate

Table 1.1.3. Compositon of sex and sexual maturity of Bryde's whales collected by the 2000 and 2001 JARPN II surveys.

Sub- area	Small Block	2000 JARPN II													
		Male			Female							Combined	Sex ratio (% males)	Maturity		Pregnancy rate*)
		Imm.	Mat.	Total	Imm	Ovu.	Rest.	Preg.	Lact.	P&L	Total			Male	Female	
7	6	2 (50.0)	0 (0.0)	2 (50.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (25.0)	2 (50.0)	4 (100.0)	50.0	0.0	50.0	100
	4 (E)	5 (25.0)	3 (15.0)	8 (40.0)	3 (15.0)	0 (0.0)	3 (15.0)	6 (30.0)	0 (0.0)	0 (0.0)	12 (60.0)	20 (100.0)	40.0	37.5	75.0	66.7
	4 (L)	2 (10.5)	9 (47.4)	11 (57.9)	2 (10.5)	0 (0.0)	2 (10.5)	3 (15.8)	1 (5.3)	0 (0.0)	8 (42.1)	19 (100.0)	57.9	81.8	75.0	50.0
Combined		9 (20.9)	12 (27.9)	21 (48.8)	6 (14.0)	0 (0.0)	5 (11.6)	9 (20.9)	1 (2.3)	1 (2.3)	22 (51.2)	43 (100.0)	48.8	57.1	72.7	62.5

Sub- area	2001 JARPN II														
	Male			Female							Combined	Sex ratio (% males)	Maturity		Pregnancy rate*)
	Imm.	Mat.	Total	Imm	Ovu.	Rest.	Preg.	Lact.	P&L	Total			Male	Female	
7 First	7 (17.9)	2 (5.1)	9 (23.1)	12 (30.8)	2 (5.1)	0 (0.0)	8 (20.5)	8 (20.5)	0 (0.0)	30 (76.9)	39 (100.0)	23.1	22.2	60.0	44.4
7 Second	6 (54.5)	2 (18.2)	8 (72.7)	0 (0.0)	0 (0.0)	0 (0.0)	2 (18.2)	1 (9.1)	0 (0.0)	3 (27.3)	11 (100.0)	72.7	25.0	100.0	66.7
Combined	13 (26.0)	4 (8.0)	17 (34.0)	12 (24.0)	2 (4.0)	0 (0.0)	10 (20.0)	9 (18.0)	0 (0.0)	33 (66.0)	50 (100.0)	34.0	23.5	63.6	47.6

*) Apparent pregnancy rate

Table 1.1.4. Compositon of sex and sexual maturity of Sperm whales collected by the 2000 and 2001 JARPN II surveys.

Sub- area	2000 JARPN II													
	Male			Female							Combined	Sex ratio	Maturity		Pregnancy
	Imm.	Mat.	Total	Imm	Ovu.	Rest.	Preg.	Lact.	P&L	Total		(% males)	Male	Female	rate*)
7	3	0	3	0	0	2	0	0	0	2	5	60.0	0.0	100.0	0
	(60.0)	(0.0)	(60.0)	(0.0)	(0.0)	(40.0)	(0.0)	(0.0)	(0.0)	(40.0)	(100.0)				

Sub- area	2001 JARPN II													
	Male			Female							Combined	Sex ratio	Maturity		Pregnancy
	Imm.	Mat.	Total	Imm	Ovu.	Rest.	Preg.	Lact.	P&L	Total		(% males)	Male	Female	rate*)
7	2	0	2	1	0	0	4	1	0	6	8	25.0	0.0	83.3	80.0
	(25.0)	(0.0)	(25.0)	(12.5)	(0.0)	(0.0)	(50.0)	(12.5)	(0.0)	(75.0)	(100.0)				

*) Apparent pregnancy rate

Table 2.1.1. Prey species contributions in the stomach contents of Baird's beaked whales (after Ohizumi *et al.*, 2002; Ohizumi *et al.*, unpublished).

Family	Prey items Species	% Occurrence Hakodate	% Occurrence Abashiri	% Occurrence Wada	% Number Hakodate	% Number Abashiri	% Number Wada	% Weight Hakodate	% Weight Abashiri	% Weight Wada
	Teleosts									
Moridae	*Antimora microlepis*	-	-	8.33	-	-	0.97	-	-	3.75
	Laemonema longipes	-	50.00	45.83	-	33.33	6.11	-	3.25	4.07
	Moridae sp	-	-	25.00	-	-	1.51	-	-	NA
Gadidae	*Theragra chalcogramma*	-	50.00	-	-	13.13	-	-	26.10	-
	Gadus macrocephalus	-	-	-	-	-	-	-	-	-
	Gadidae sp	-	-	12.50	-	-	1.24	-	-	NA
Macrouridae	*Coryphaenoides pectoralis*	-	50.00	4.17	-	4.04	0.27	-	6.43	NA
	Coryphaenoides longifilis	-	-	37.50	-	-	29.62	-	-	67.95
	Coryphaenoides acrolepis	-	-	20.83	-	-	4.49	-	-	16.46
	Coryphaenoides cinereus	-	50.00	37.50	-	3.03	8.86	-	1.91	3.43
	Macrouridae sp	-	-	4.17	-	-	0.05	-	-	NA
	Bentholocara molle	-	-	4.17	-	-	0.05	-	-	NA
Zoarcidae	Zoarcidae sp	28.57	-	-	4.29	-	-	NA	-	-
Engraulidae	*Engraulis japonicus*	-	-	4.17	-	-	0.16	-	-	NA
Unknown families	Type 112	28.57	-	-	1.29	-	-	NA	-	-
	Type 113	14.29	-	-	0.09	-	-	NA	-	-
	Type 114	-	-	4.17	-	-	0.05	-	-	NA
	Type 115	-	-	4.17	-	-	0.05	-	-	NA
	Type 116	-	-	4.17	-	-	0.05	-	-	NA
	Type 117	-	-	4.17	-	-	0.11	-	-	NA
	Type 119	28.57	-	-	0.69	-	-	NA	-	-
	Type 120	14.29	-	-	0.17	-	-	NA	-	-
	Type 123	14.29	-	-	0.09	-	-	NA	-	-
	Type 124	14.29	-	-	0.17	-	-	NA	-	-
	Unknown eroded otoliths	42.86	100.00	75.00	2.92	22.22	20.54	NA	NA	NA
	Cephalopods									
Ommastrephidae	Ommastrephidae sp.	-	-	4.17	-	-	0.11	-	-	0.01
	Ommastrephes bartrami	-	-	4.17	-	-	0.11	-	-	0.04
	Ornithoteuthis volatilis	-	-	4.17	-	-	0.11	-	-	0.01
	Todarodes pacificus	-	-	4.17	-	-	0.11	-	-	0.09
Onychoteuthidae	*Onychoteuthis banksi*	-	-	8.33	-	-	0.32	-	-	0.10
	Onychoteuthis borealijaponica	-	-	4.17	-	-	0.11	-	-	0.10
	Moroteuthis loennbergi	-	-	8.33	-	-	0.32	-	-	0.23
Gonatidae	*Gonatus onyx*	-	50.00	16.67	-	2.02	1.19	-	0.56	0.16
	Gonatus berryi	-	50.00	20.83	-	2.02	0.76	-	1.62	0.22
	Gonatus madokai	-	-	4.17	-	-	0.11	-	-	NA
	Gonatus pyros	-	-	16.67	-	-	0.65	-	-	0.22
	Gonatopisis borealis	-	-	25.00	-	-	0.86	-	-	0.42
	Gonatopsis makko	100.00	50.00	-	59.40	6.06	-	96.02	11.39	-
	Gonatopsis octopedatus	71.43	-	-	28.33	-	-	2.88	-	-
	Berryteuthis magister	57.14	-	-	2.23	-	-	1.08	-	-
	Gonatus sp.	-	-	37.50	-	-	5.30	-	-	0.53
	Gonatus spp. juvenile	28.57	-	16.67	0.34	-	0.86	0.02	-	0.02
Enoploteuthidae	*Enoploteuthis chuni*	-	-	12.50	-	-	1.08	-	-	NA
	Watasenia scintillans	-	-	4.17	-	-	0.11	-	-	NA
Ancistrocheiridae	*Ancistrocheirus lesueuri*	-	-	4.17	-	-	0.11	-	-	0.13
Histioteuhidae	*Histioteuthis dofleini*	-	-	4.17	-	-	0.11	-	-	0.10
	Histioteuthis c. inermis	-	-	4.17	-	-	0.32	-	-	0.13
Chiroteuthidae	*Chiroteuthis imperator*	-	-	25.00	-	-	3.24	-	-	0.11
	Chiroteuthis calyx	-	-	4.17	-	-	0.22	-	-	NA
	Chiroteuthis sp.	-	-	8.33	-	-	0.22	-	-	NA
	Valbyteuthis?	-	-	8.33	-	-	0.22	-	-	NA
Grimalditeuthidae	*Grimalditeuthis bonplandi*	-	-	4.17	-	-	0.11	-	-	NA
Cranchiidae	*Taonius pavo*	-	50.00	66.67	-	2.02	7.46	-	1.40	1.01
	Galiteuthis phyllura	-	-	25.00	-	-	1.08	-	-	0.15
	Galiteuthis large Sp.	-	50.00	4.17	-	12.12	0.22	-	47.34	0.57
Octopus	*Ciirothauma* sp.	-	-	4.17	-	-	0.11	-	-	NA
	Octopus spp.	-	-	8.33	-	-	0.32	-	-	NA

Table 2.1.2. Prey species contributions in the stomach contents of the northern form short-finned pilot whales (after Ohizumi, unpublished data).

Family	Prey Sp.	% Occ.	% Number	% Weight
	Cephalopods			
Architeuthidae	Architeuthidae sp.	3.70	0.07	0.06
Ommastrephidae	*Ommastrephes bartrami*	81.48	23.51	33.02
	Eucleoteuthis luminosa	55.56	12.87	5.39
	Todarodes pacificus	44.44	44.40	45.71
	Ommastrephidae sp.	11.11	0.33	-
Onychoteuthidae	*Moroteuthis robusta*	18.52	0.39	1.92
	Moroteuthis loennbergi	29.63	0.72	0.79
Gonatidae	*Gonatus onyx*	14.81	0.39	0.03
	Gonatus berryi	29.63	1.77	0.91
	Gonatus pyros	14.81	0.39	0.29
	Gonatopisis borealis	11.11	0.20	0.02
	Berryteuthis magister	44.44	3.02	6.94
	Gonatidae sp.	3.70	0.07	-
Enoploteuthidae	*Enoploteuthis chuni*	11.11	0.26	0.02
	Watasenia scintillans	37.04	2.04	0.01
	Enoploteuthidae sp.	3.70	0.07	-
Octopoteuthidae	*Octopoteuthis sicula*	7.41	0.13	0.03
	Octopoteuthidae sp.	7.41	0.13	0.20
Histioteuhidae	*Histioteuthis dofleini*	37.04	2.96	3.18
	Histioteuthis c. inermis	18.52	0.46	0.29
Chiroteuthidae	*Chiroteuthis imperator*	3.70	0.07	0.02
	Chiroteuthis calyx	3.70	0.07	0.04
	Chiroteuthis sp.	3.70	0.13	-
Cranchiidae	*Helicocranchia pfefferi*	11.11	0.99	0.01
	Megalocranchia maxima	11.11	0.39	0.14
	Taonius pavo	25.93	1.71	0.35
	Galiteuthis phyllura	18.52	0.53	0.19
	Cranchiidae sp.	3.70	0.07	-
Octopus	Octopus spp.	22.22	0.46	0.46
	Teleosts			
Myctophidae	*Symbolophorus californiensis*	3.70	0.07	-
	Diaphus theta	3.70	0.66	-
	Myctophum asperum	7.41	0.07	-
	Stenobrachius leucopsarus	7.41	0.07	-
	Lampanyctus jordani	3.70	0.03	-
	Ceratoscopelus warmingii	7.41	0.07	-
Gadidae	*Theragra chalcogramma*	3.70	0.03	-
Unknown families	type 108	3.70	0.03	-
	type 109	3.70	0.03	-
	Unknown eroded otoliths	29.63	0.36	-

Table 2.1.3. Basic input parameters. Habitat area is the fraction of the total area in which the group occurs, B is biomass (t/km^2), P/B is production/biomass (/year), Q/B is consumption/biomass (/year), EE is ecotrophic efficiency, P/Q is production/consumption, BA is biomass accumulation (t/km2/year), Unassimil./Q is the fraction of the food that is not assimilated in consumption, and Detr.imp is the import of detritus to the system.

Group name	Habitat area	B	P/B	Q/B	EE	P/Q	BA	Unassimil./Q	Detr.imp
Minke whale	1	0.035	0.02	6.44			0	0.2	
Bryde's whale	1	0.002	0.02	5.444			0	0.2	
Other Baleen whale	1	0	0.02	4.688			0	0.2	
Sperm whale	1	0.024	0.02	4.594			0	0.2	
Baird's beaked whale	1	0.04	0.02	5.791			0	0.2	
Dall's porpoise	1	0.017	0.06	14.39			0	0.2	
Short-finned pilot whale	1	0.036	0.06	8.399			0	0.2	
Other toothed whale	1	0.1	0.06	11.657			0	0.2	
Northern fur seal	1	0.001	0.06	18.744			0	0.2	
Sea birds	1	0.003	0.8	34.375			0	0.2	
Albacore	1	0.004	0.54	2.5			0	0.2	
Swordfish	1	0	0.6	6.4			0	0.2	
Skipjack tuna	1	0.025	1.08	32.57			0	0.2	
Blue Shark	1	0.059	0.48	1.5			0	0.2	
Pollock	1	1.339	0.5	2.64			0	0.2	
Lanternfish	1	5.2	0.9	25.276			0	0.2	
Common squid	1	0.109	3.2	10.667			0	0.2	
Flying squid	1	0.073	3.2	10.667			0	0.2	
Deep sea squid	1		1.6	5.333	0.95		0	0.2	
Micronectonic squid	1	2.042	3.2	10.667			0	0.2	
Mackerel	1	0.134		9.3		0.3	0	0.2	
Pomfret	1	0.047		6		0.3	0	0.2	
Sardine	1	0.986	1.04	22			0	0.2	
Anchovy	1	1.666	2.15	23			0	0.2	
Saury	1	1.71	1.05	5			0	0.2	
Benthic invertebrates	1		1.48	7.69	0.95		0	0.2	
Large zooplankton	1	50	5	22			0	0.2	
Small zooplankton	1	55	6	22			0	0.2	
Phytoplankton	1	33.083	97.482				0		
Detritus	1	165.415							0

Table 2.1.4. Diet composition. The columns sums up 1.

Prey＼Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Minke whale																												
Bryde's whale																												
Other Baleen whale																												
Sperm whale																												
Baird's beaked whale																												
Dall's porpoise																												
Short-finned pilot whale																												
Other toothed whale								0.00																				
Northern fur seal								0.00																				
Sea birds								0.00																				
Albacore																												
Swordfish																												
Skipjack tuna																												
Blue Shark																												
Pollock	0.10																											
Lanternfish	0.10	0.20	0.05	0.05	0.20	0.70	0.10	0.17			0.05		0.05	0.02	0.02		0.10	0.10	0.10		0.02	0.15						
Common squid					0.10	0.05	0.10		0.15	0.09		0.20	0.02	0.20			0.05				0.01	0.45						
Flying squid				0.05	0.05		0.10		0.15	0.05		0.20	0.02	0.20				0.02			0.01	0.10						
Deep sea squid				0.60	0.10		0.20	0.20		0.05		0.20	0.02	0.20				0.30			0.01	0.10						
Micronectonic squid			0.05	0.05	0.10	0.05	0.20	0.30	0.16	0.09		0.20	0.02	0.20			0.05	0.05	0.05		0.01	0.05						
Mackerel	0.10	0.20	0.05	0.10	0.10	0.10	0.20	0.15	0.30		0.05	0.20	0.01	0.02														
Pomfret					0.05	0.05		0.01	0.06	0.14	0.05		0.01	0.04														
Sardine	0.20	0.10			0.05		0.03	0.03	0.06	0.14	0.05		0.40	0.04	0.02			0.10			0.02	0.02						
Anchovy	0.20	0.10	0.05	0.10	0.10	0.05	0.05	0.10	0.06	0.14	0.05		0.40	0.04	0.04		0.10	0.10	0.10		0.12	0.10						
Saury	0.20				0.05		0.03	0.03	0.06	0.14	0.40			0.04	0.02		0.20	0.10	0.20		0.02	0.01						
Benthic invertebrates				0.05	0.10			0.02		0.04					0.10		0.10		0.10									
Large zooplankton	0.05	0.30	0.40							0.10	0.03		0.05		0.45	0.60	0.30	0.10	0.30	0.60	0.50	0.02		0.20	0.10			
Small zooplankton	0.05	0.10	0.40							0.03	0.32				0.35	0.40	0.10	0.10	0.10	0.40	0.30		0.30	0.80	0.90		0.10	
Phytoplankton																							0.70				0.80	0.90
Detritus																		0.03	0.05							1.00	0.10	0.10
Import																												
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2.1.5. Catches for whales and fishes separately. The unit is t/km^2/year.

Group name	Whale Catch	Fishery	Total
Minke whale	0.0005	0	0.0005
Bryde's whale	0	0	0
Other Baleen whale	0	0	0
Sperm whale	0	0	0
Baird's beaked whale	0.0005	0	0.0005
Dall's porpoise	0.00063	0	0.00063
Short-finned pilot whale	0.0005	0	0.0005
Other toothed whale	0.0005	0	0.0005
Northern fur seal	0	0	0
Sea birds	0	0	0
Albacore	0	0.00123	0.00123
Swordfish	0	0.00005	0.00005
Skipjack tuna	0	0.00492	0.00492
Blue Shark	0	0.01767	0.01767
Pollock	0	0.40167	0.40167
Lanternfish	0	0	0
Common squid	0	0.03284	0.03284
Flying squid	0	0.02178	0.02178
Deep sea squid	0	0	0
Micronectonic squid	0	0.61261	0.61261
Mackerel	0	0.04031	0.04031
Pomfret	0	0.01405	0.01405
Sardine	0	0.39454	0.39454
Anchovy	0	0.74959	0.74959
Saury	0	0.76957	0.76957
Benthic invertebrates	0	0.1	0.1
Large zooplankton	0	0	0
Small zooplankton	0	0	0
Phytoplankton	0	0	0
Detritus	0	0	0
Sum	0.00263	3.16083	3.16346

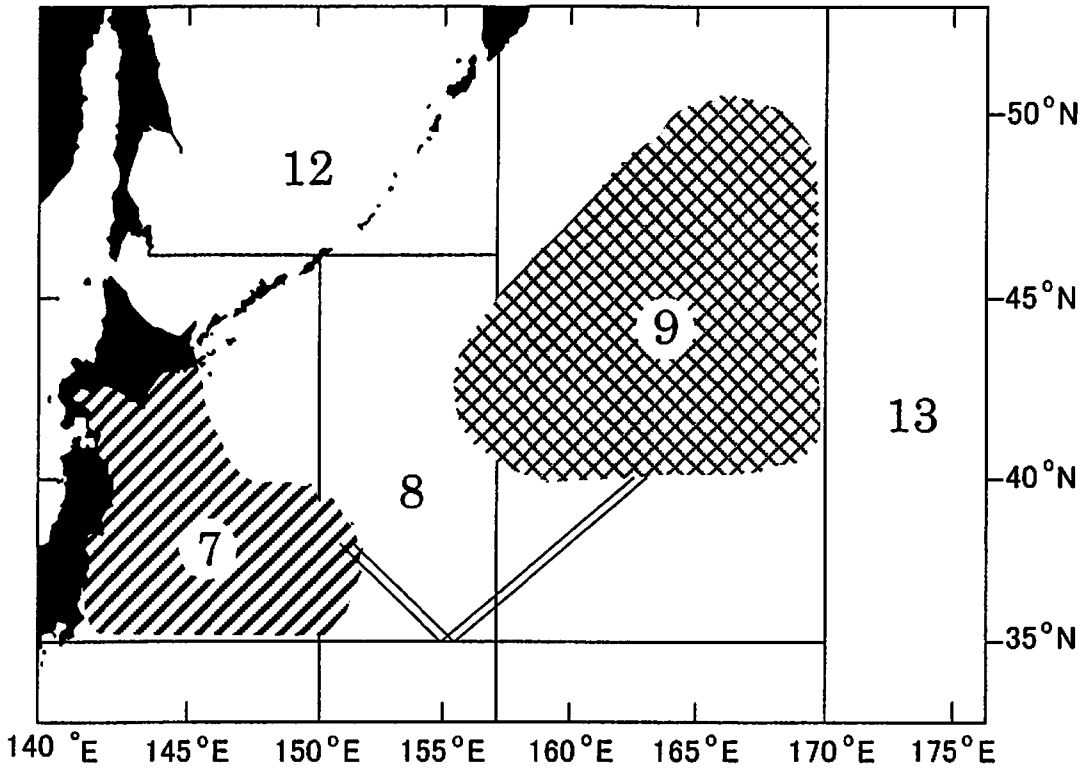


Fig. 1.1.1. Map showing the IWC sub-areas and the general research area (sub-areas 7, 8 and 9) of the feasibility JARPN II surveys in 2000 and 2001.

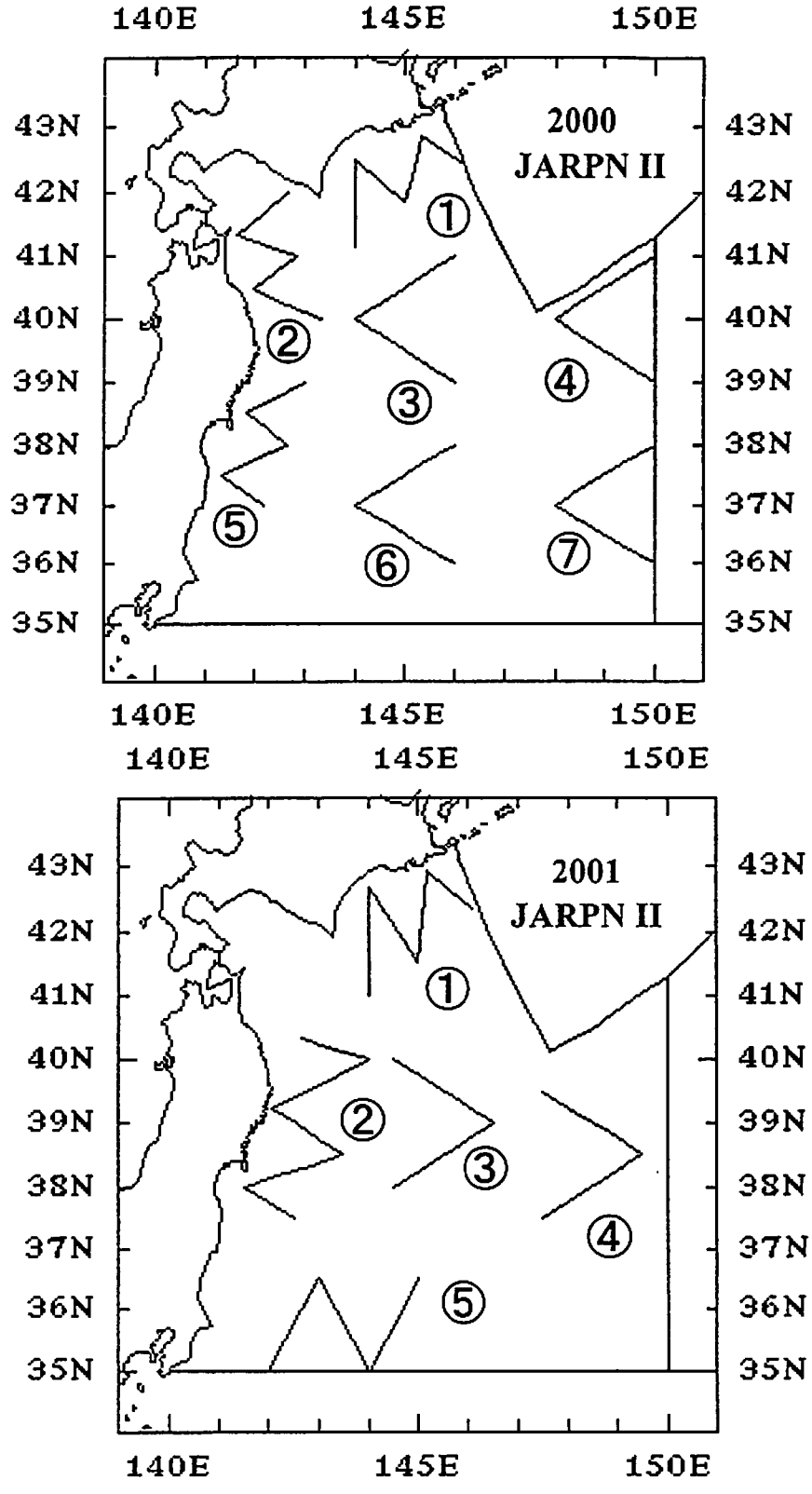


Fig. 1.1.2. Map showing the small blocks allocated in sub-area 7 in 2000 and 2001 surveys (upper and bottom).

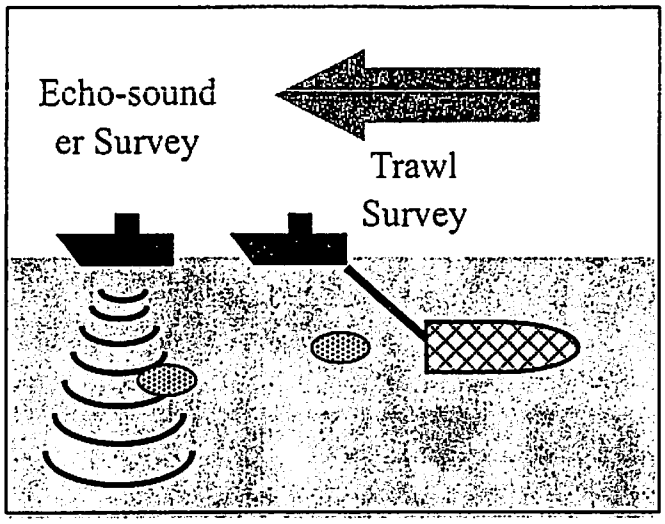


Fig 1.1.3. Schematic diagram of the scientific echo-sounder and trawl surveys.

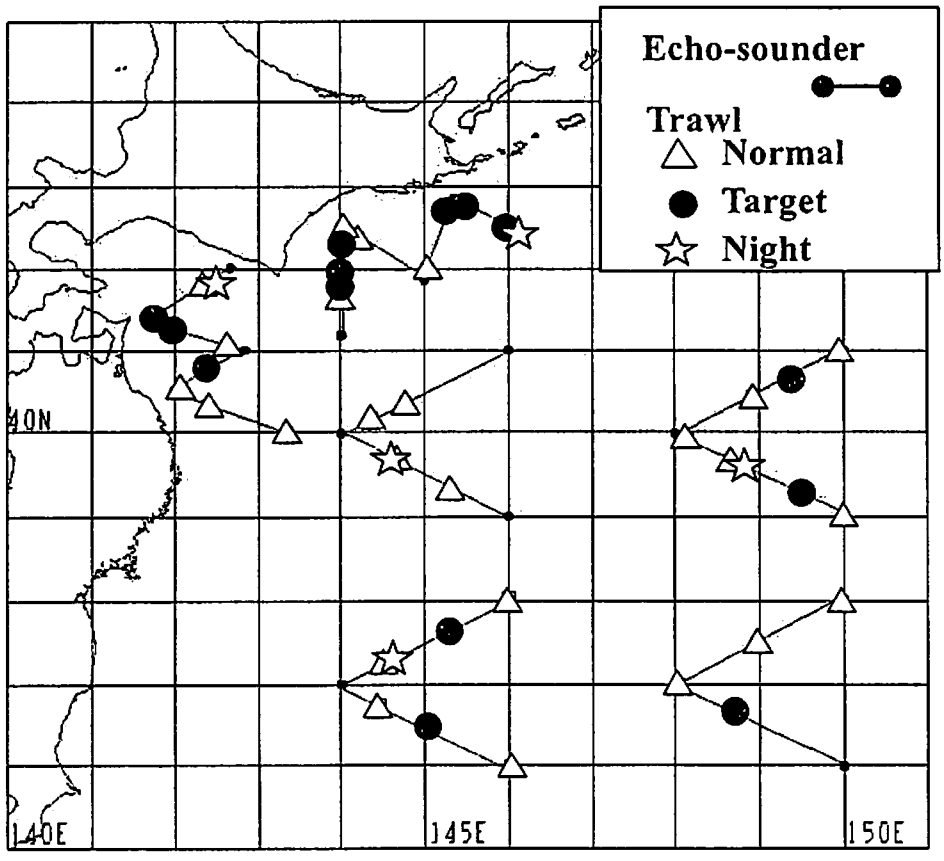


Fig. 1.1.4. Outline of the prey species survey in JARPN II 2000.

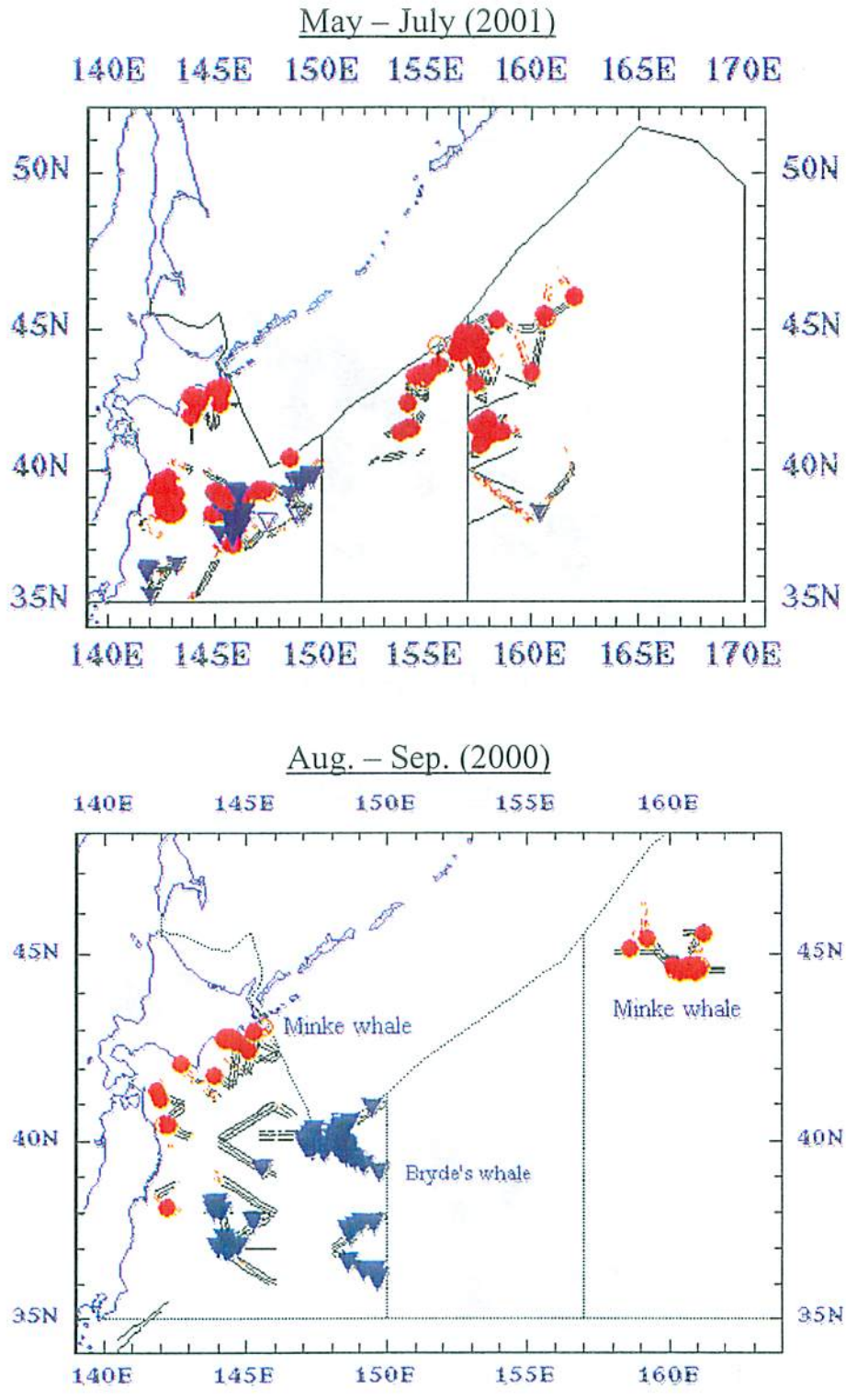


Fig. 1.1.5. Distribution of minke (●) and Bryde's (▼) whales sightings.

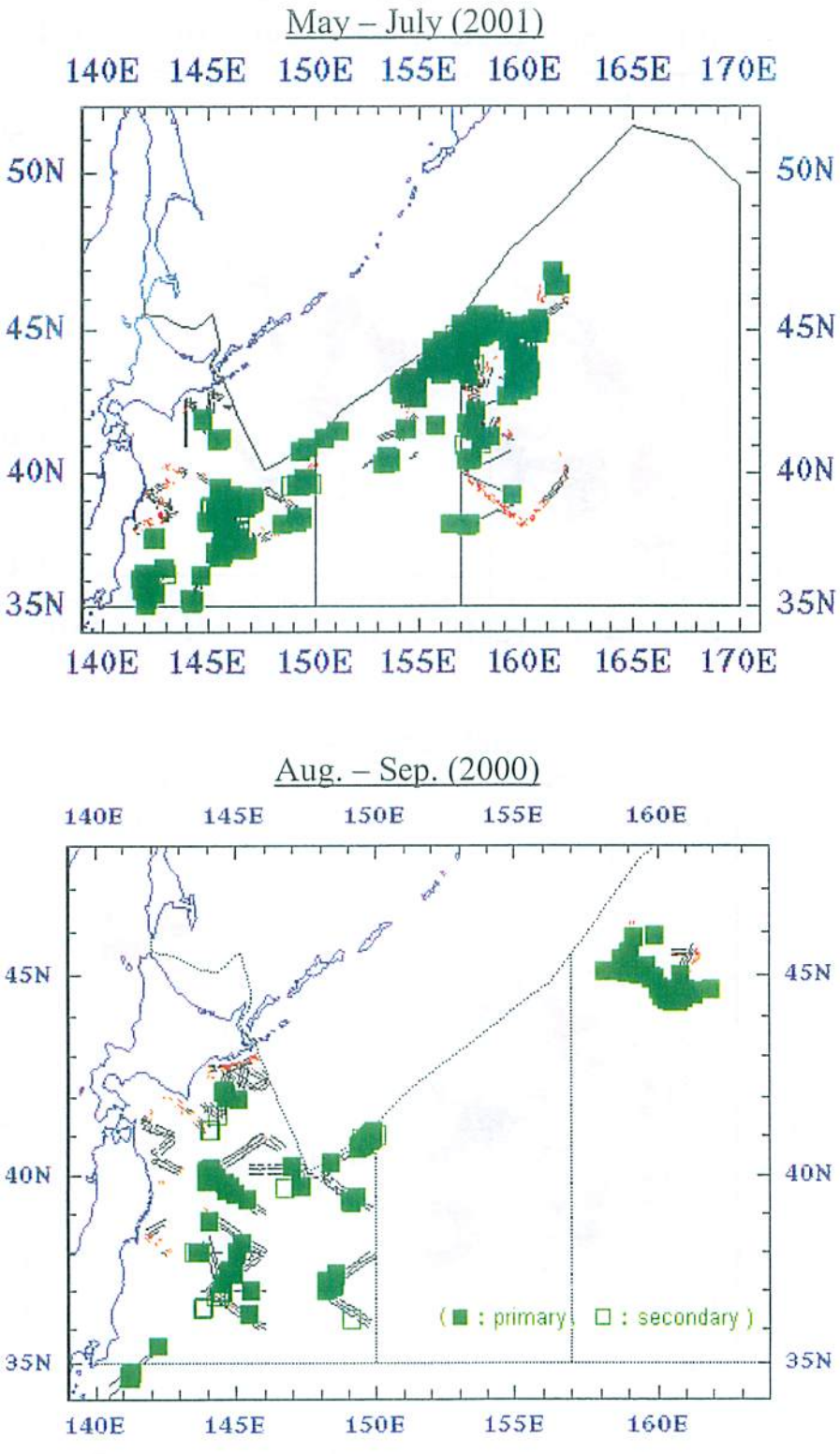


Fig. 1.1.6. Distribution of sperm whale (■) sightings.

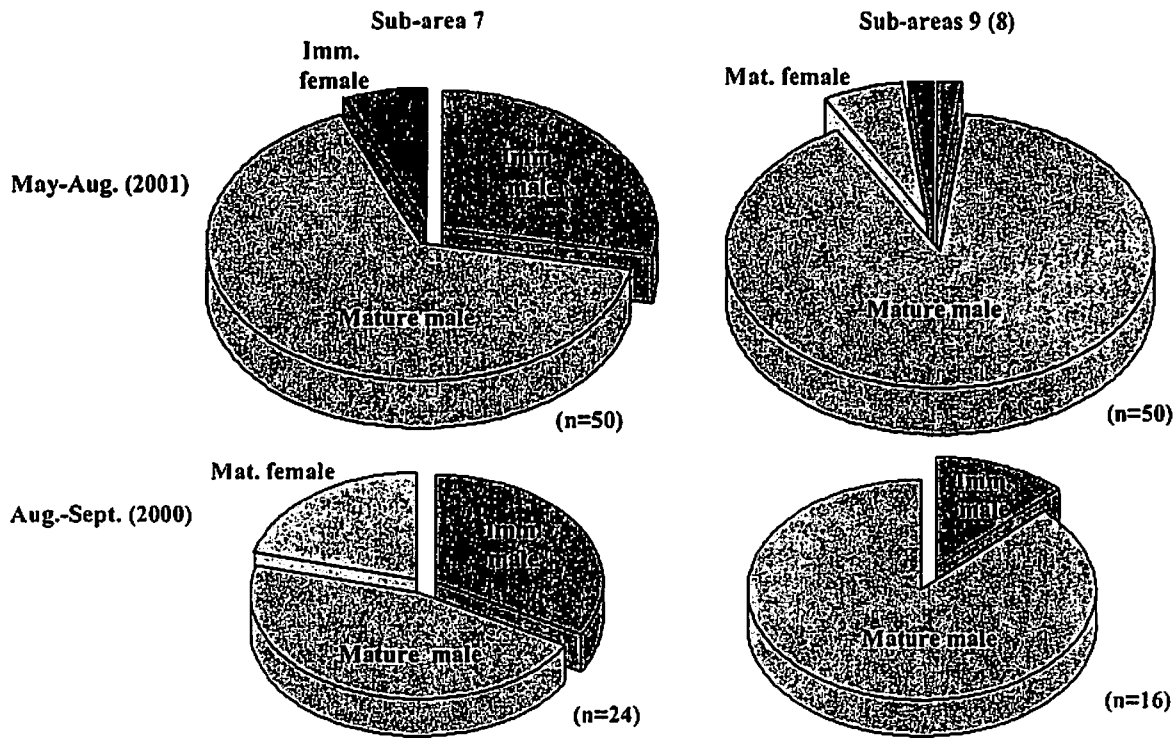


Fig. 1.1.7. Sex and maturity of common minke

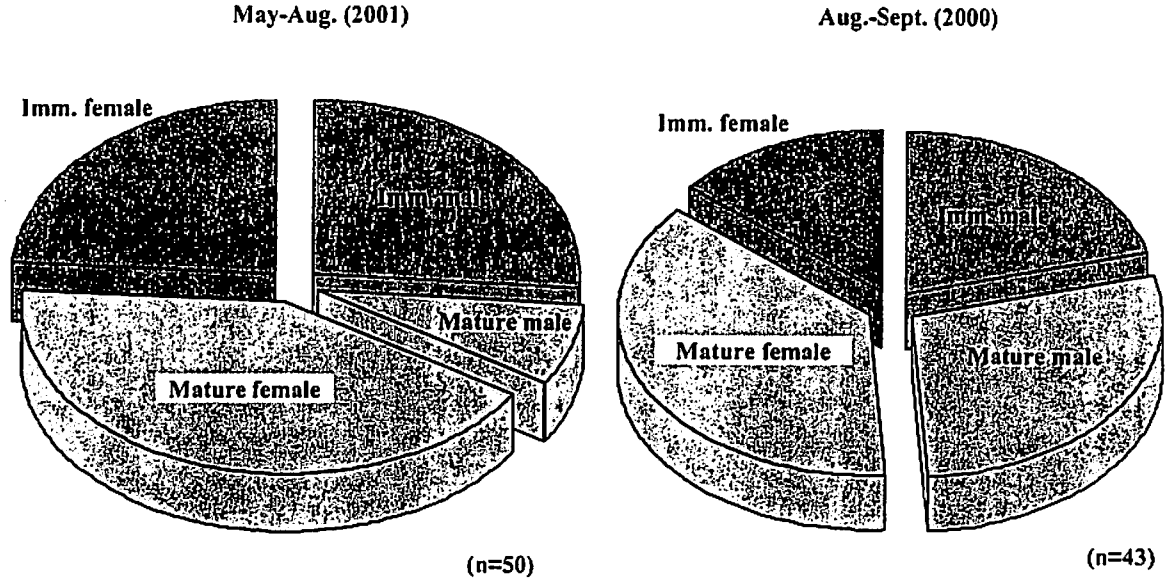


Fig. 1.1.8. Sex and maturity of Bryde's whales.

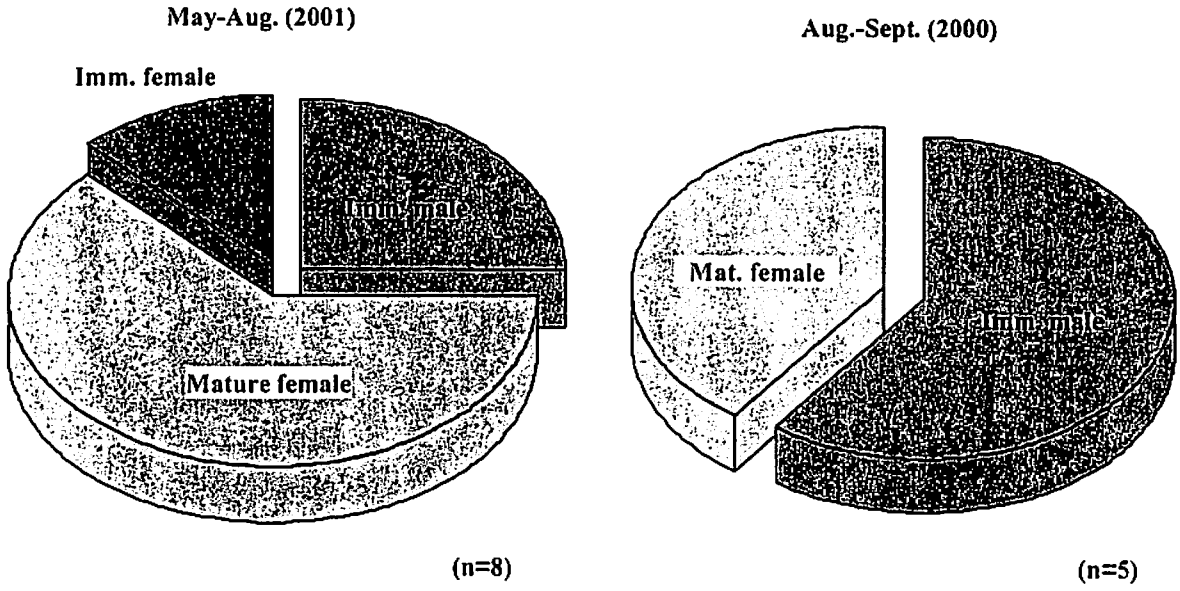


Fig. 1.1.9. Sex and maturity of Sperm whales.

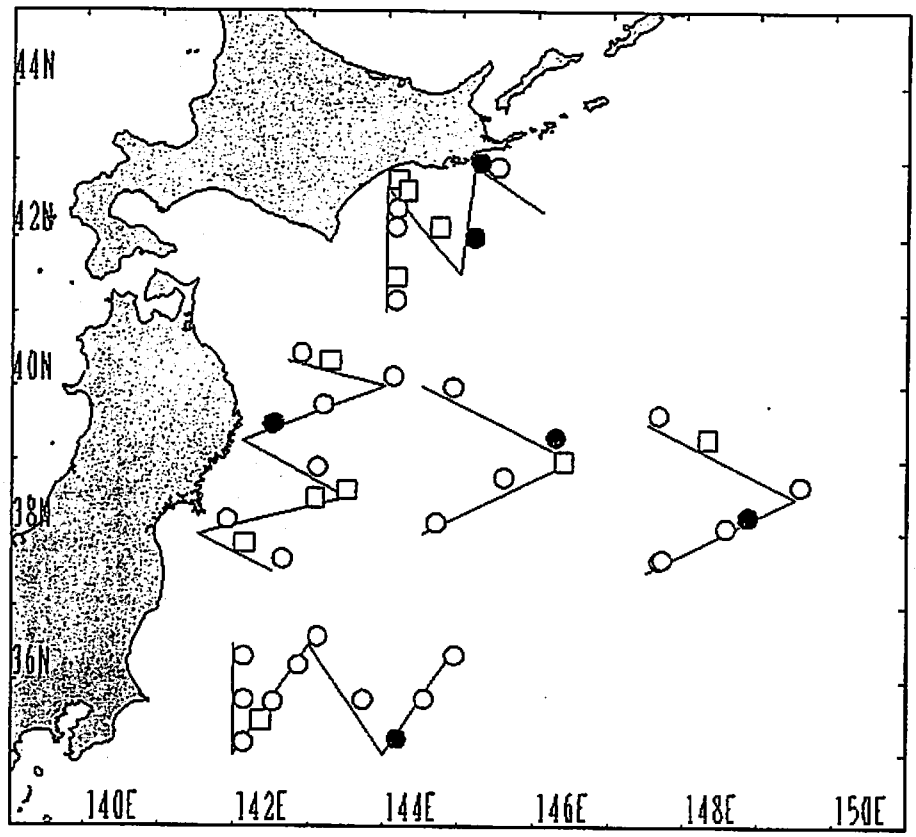


Fig. 1.1.10. Outline of the prey species survey in JARPN II

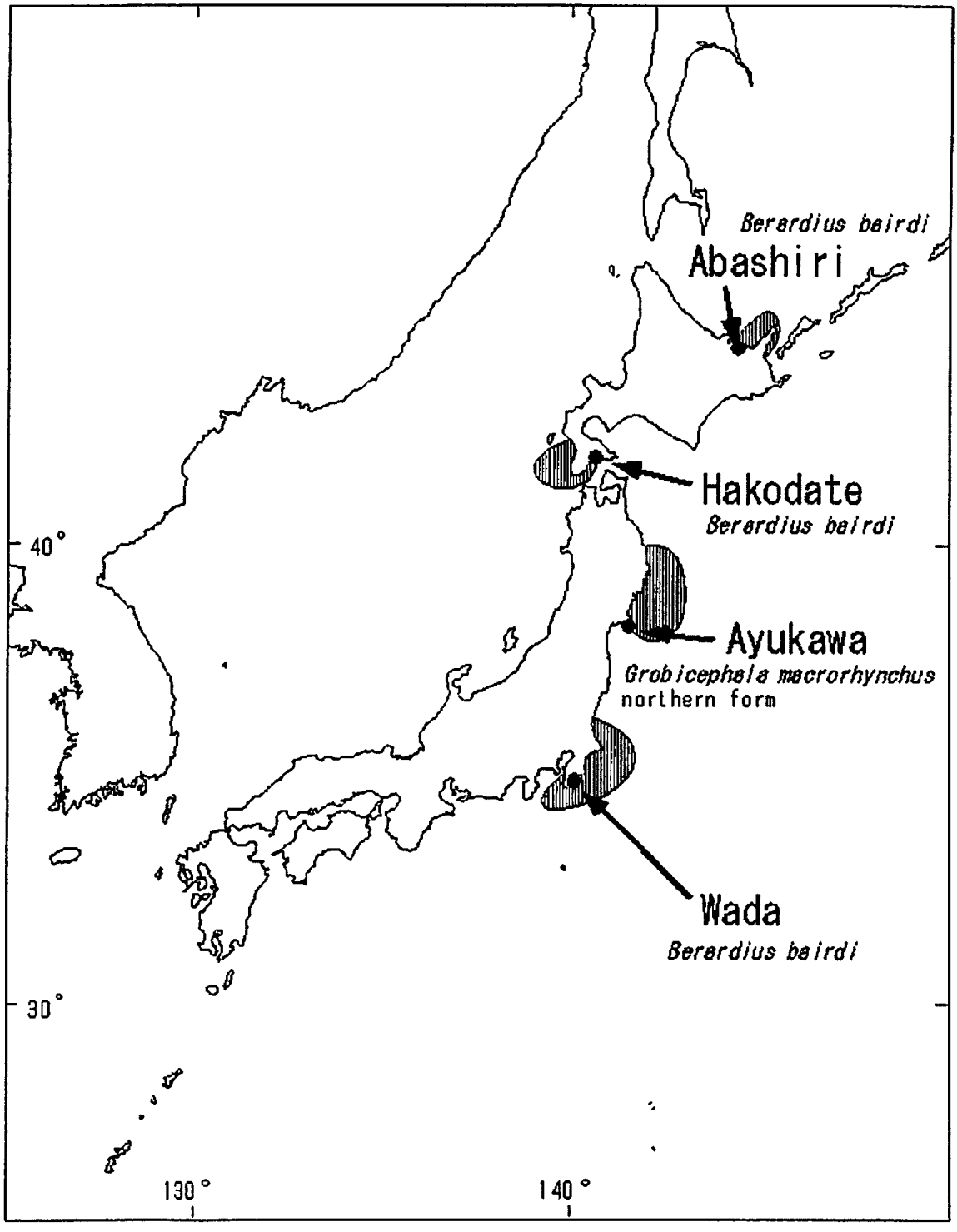


Fig. 2.1.1. Geographical locations of Baird's beaked whales and northern forms of short-finned pilot whales caught by the small-type whaling in the coastal waters of Japan during May in 1999 to November in 2001.

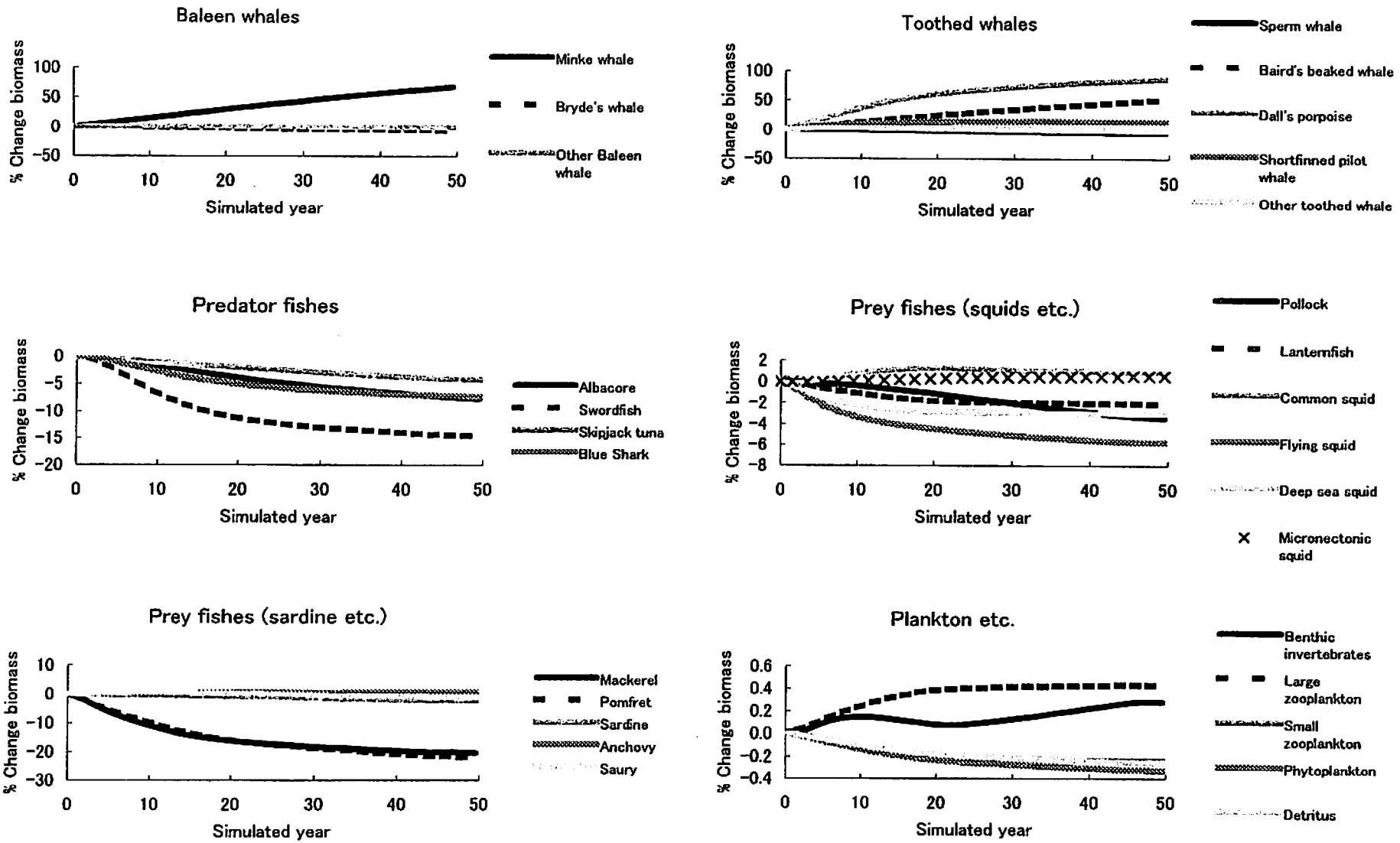


Fig. 2.1.2. The result of Ecosim dynamic simulation. The change of relative biomass without catches for whales during future 50 years (v = 0.3).

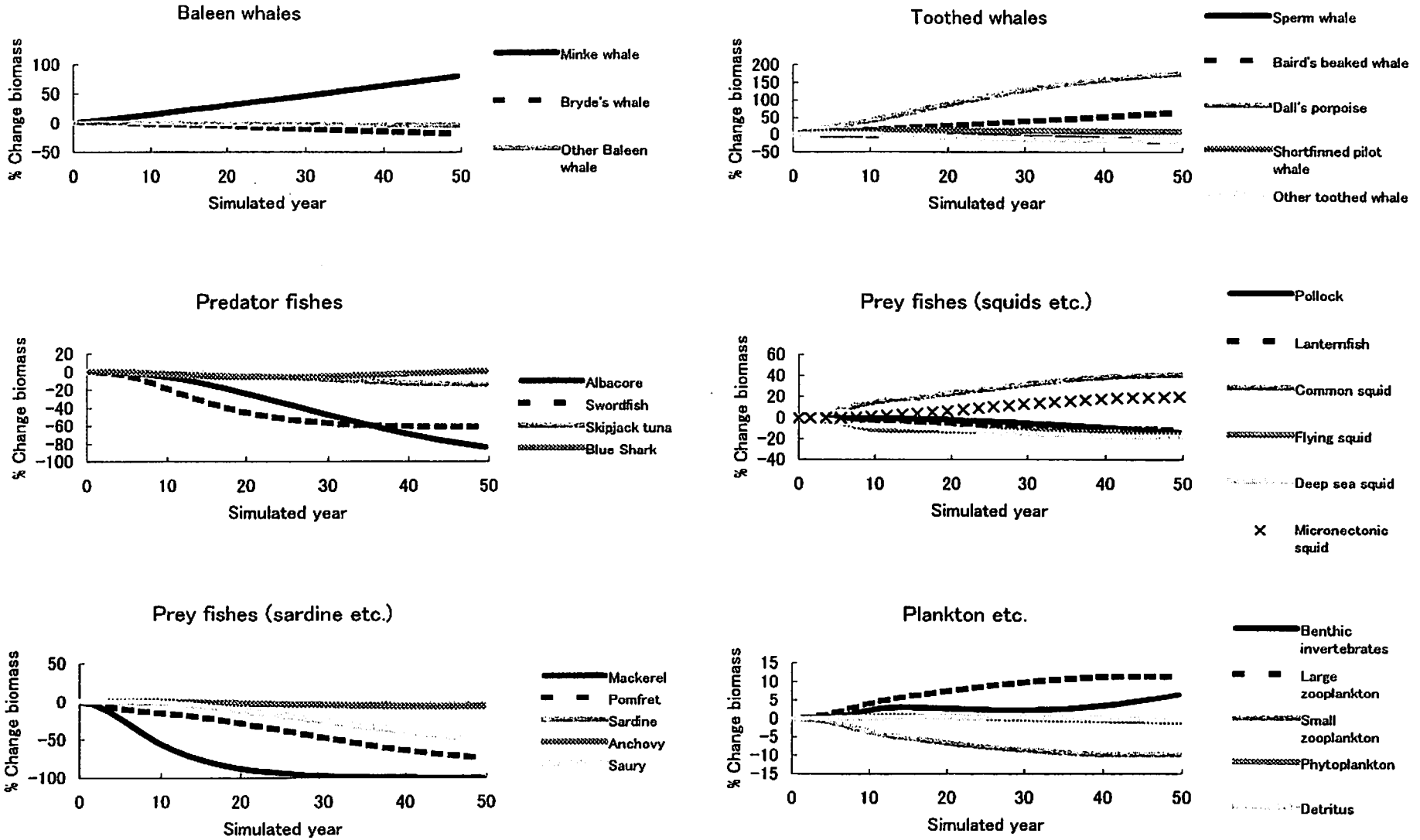


Fig. 2.1.3. The result of Ecosim dynamic simulation. The change of relative biomass without catches for whales during future 50 years (v = 0.6).

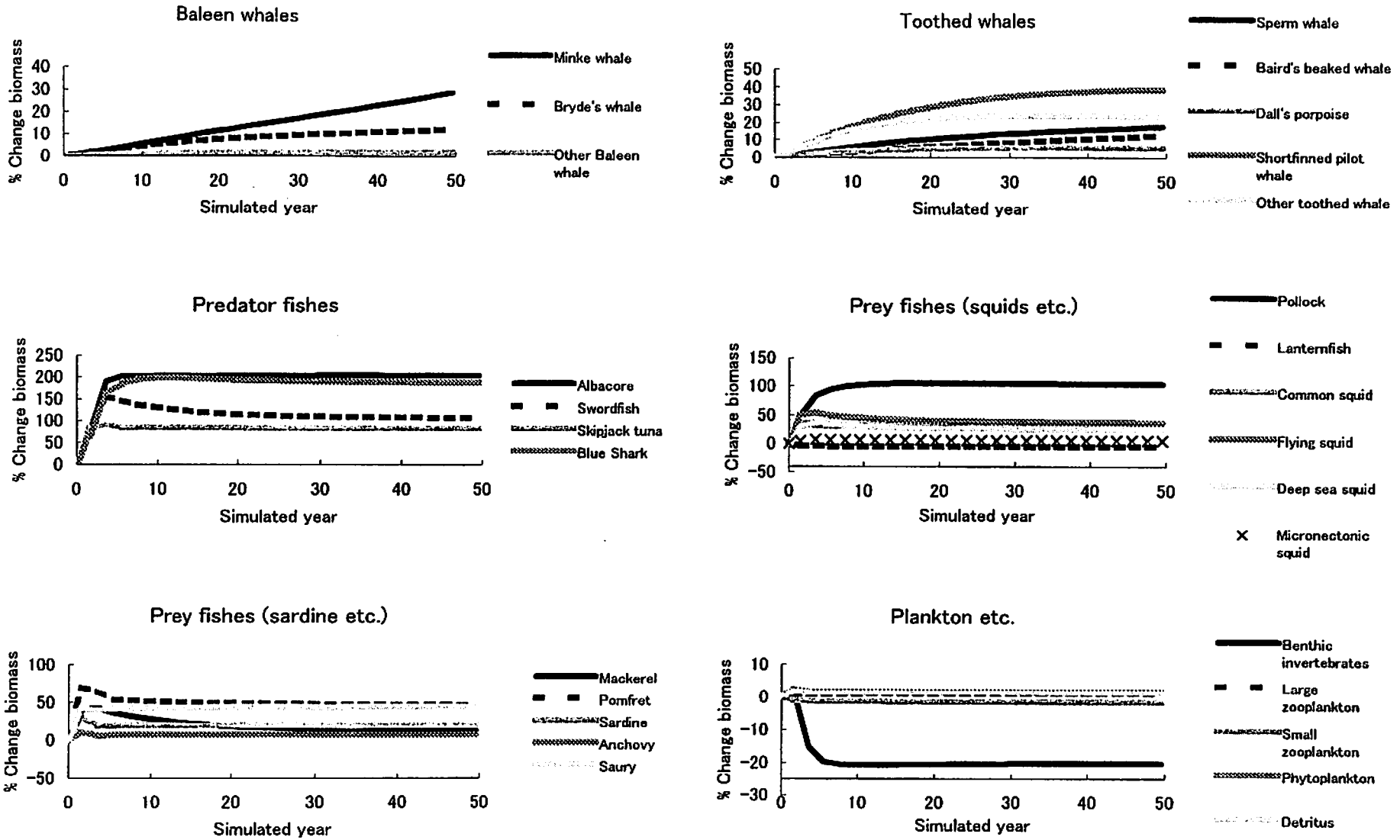


Fig. 2.1.4. The result of Ecosim dynamic simulation. The change of relative biomass without any fisheries except whaling during future 50 years (v = 0.3).

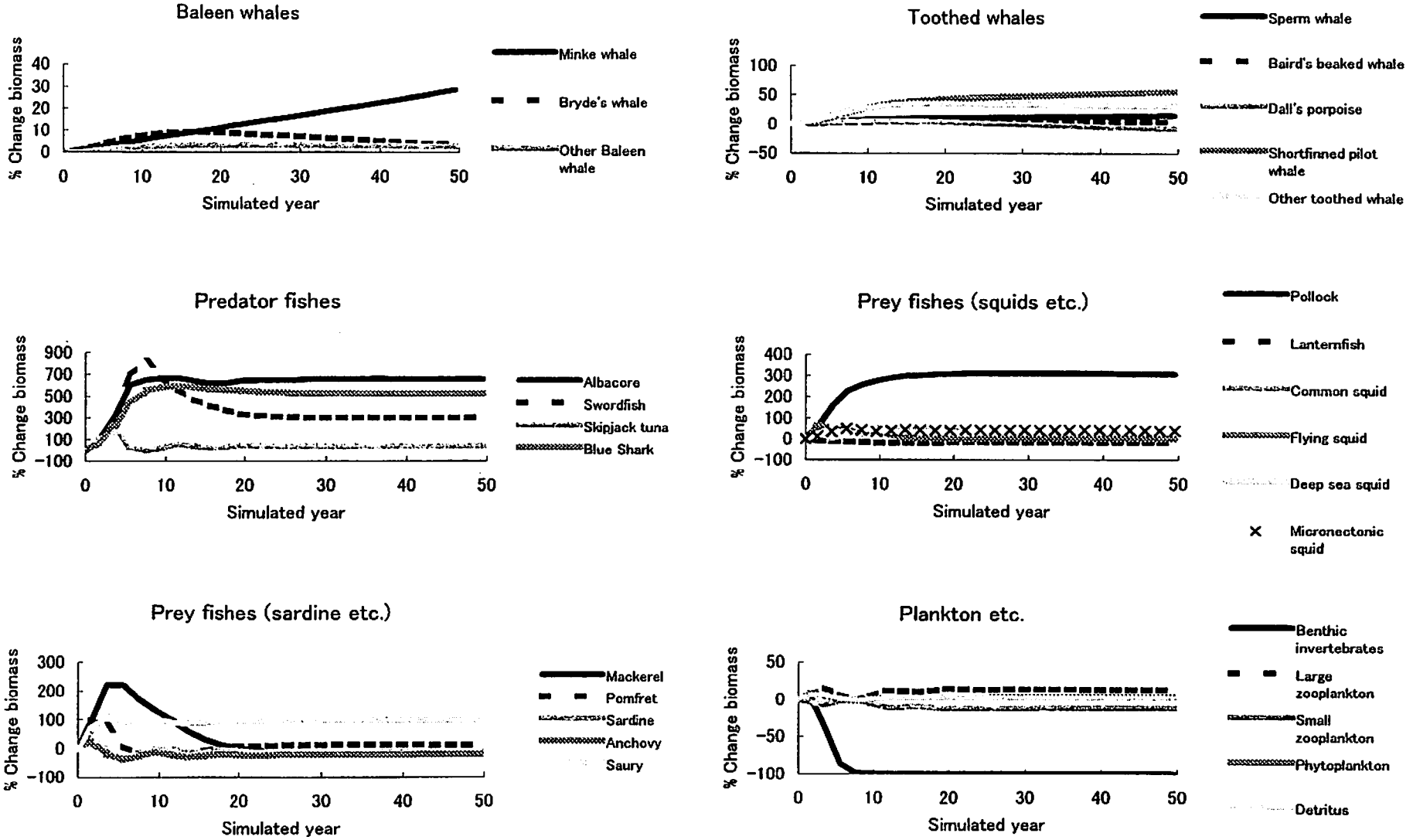


Fig. 2.1.5. The result of Ecosim dynamic simulation. The change of relative biomass without any fisheries except whaling during future 50 years (v = 0.6).

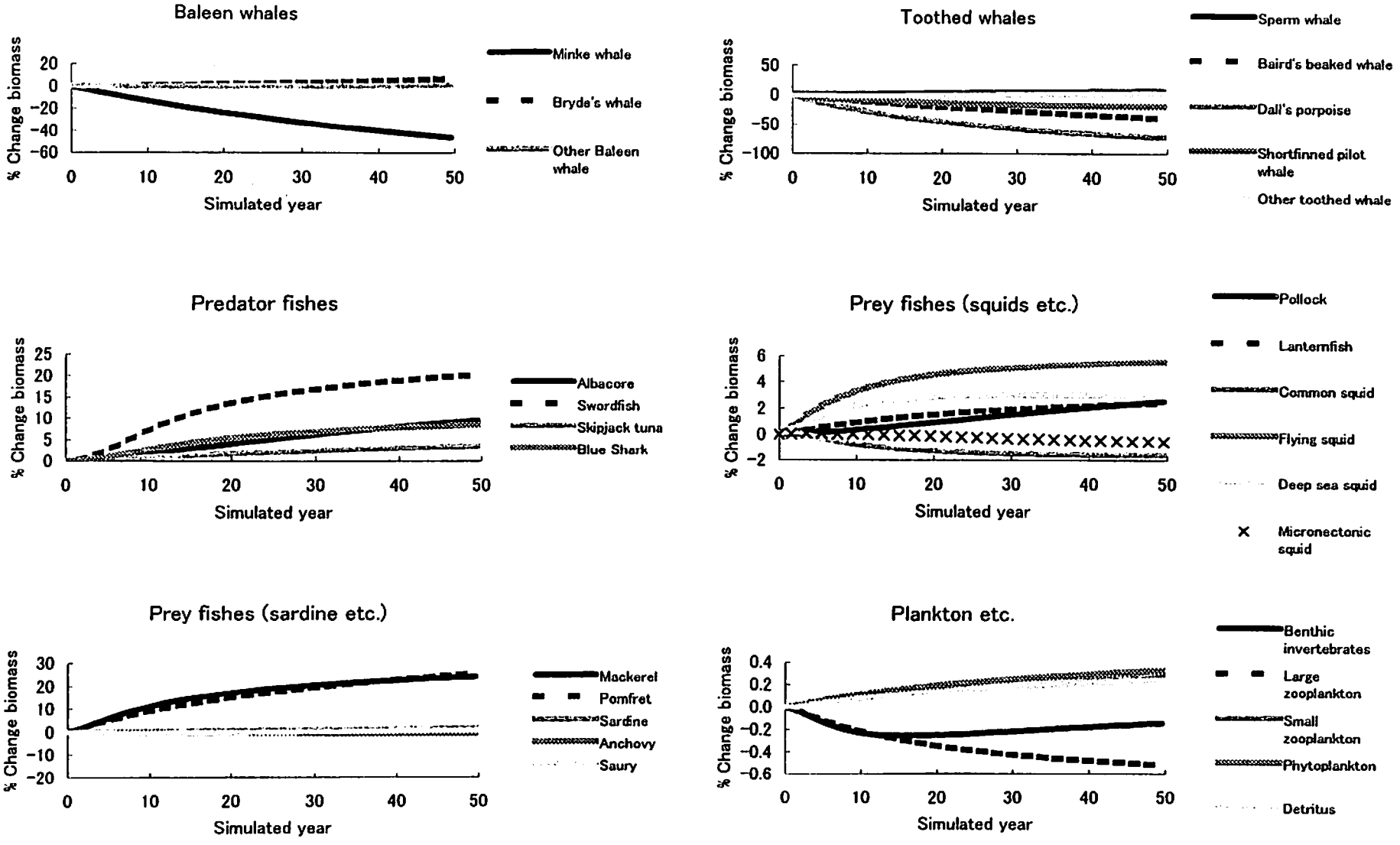


Fig. 2.1.6. The result of Ecosim dynamic simulation. The change of relative biomass with double fishing rate for whales during future 50 years (v = 0.3).

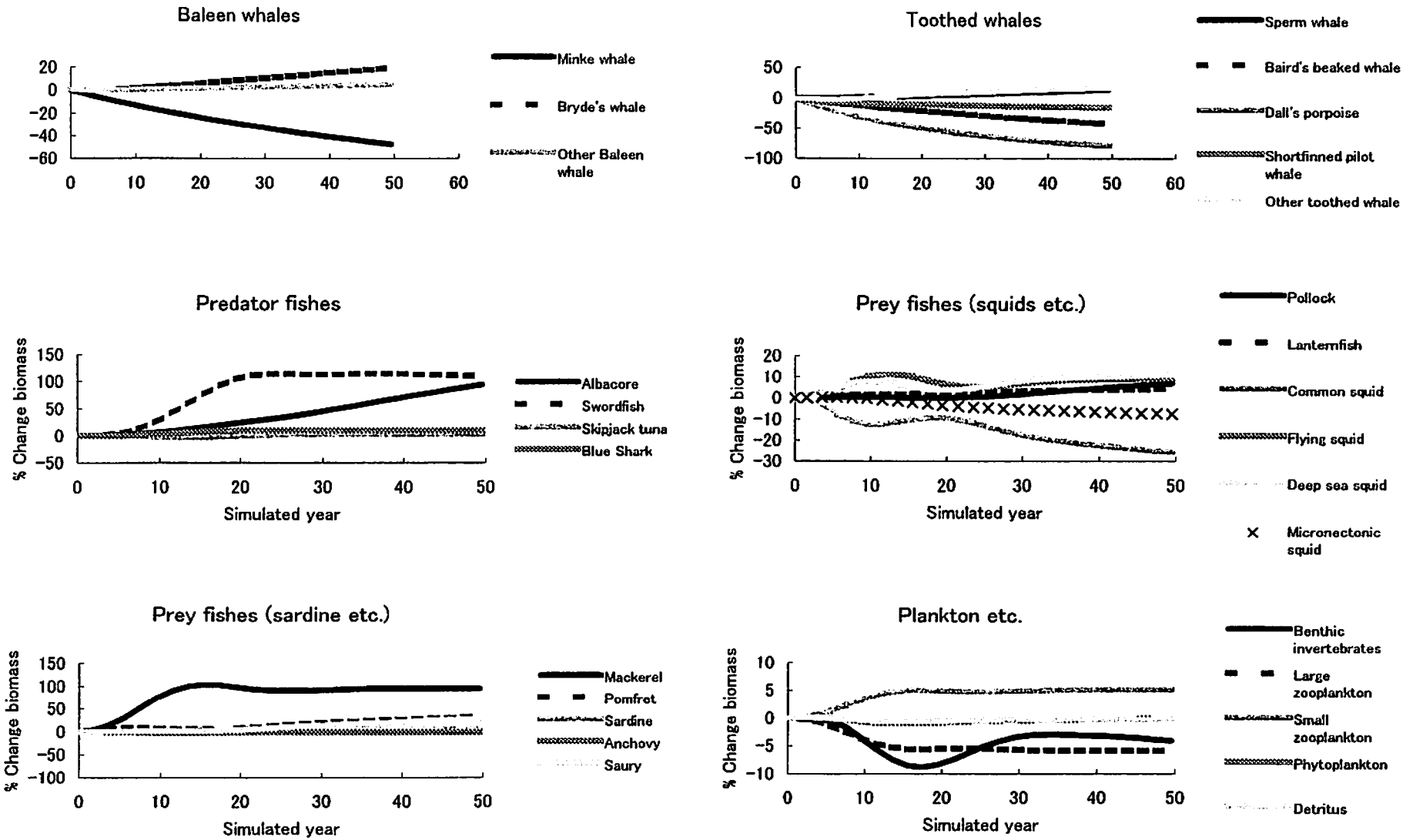


Fig. 2.1.7. The result of Ecosim dynamic simulation. The change of relative biomass with double fishing rate for whales during future 50 years (v = 0.6).

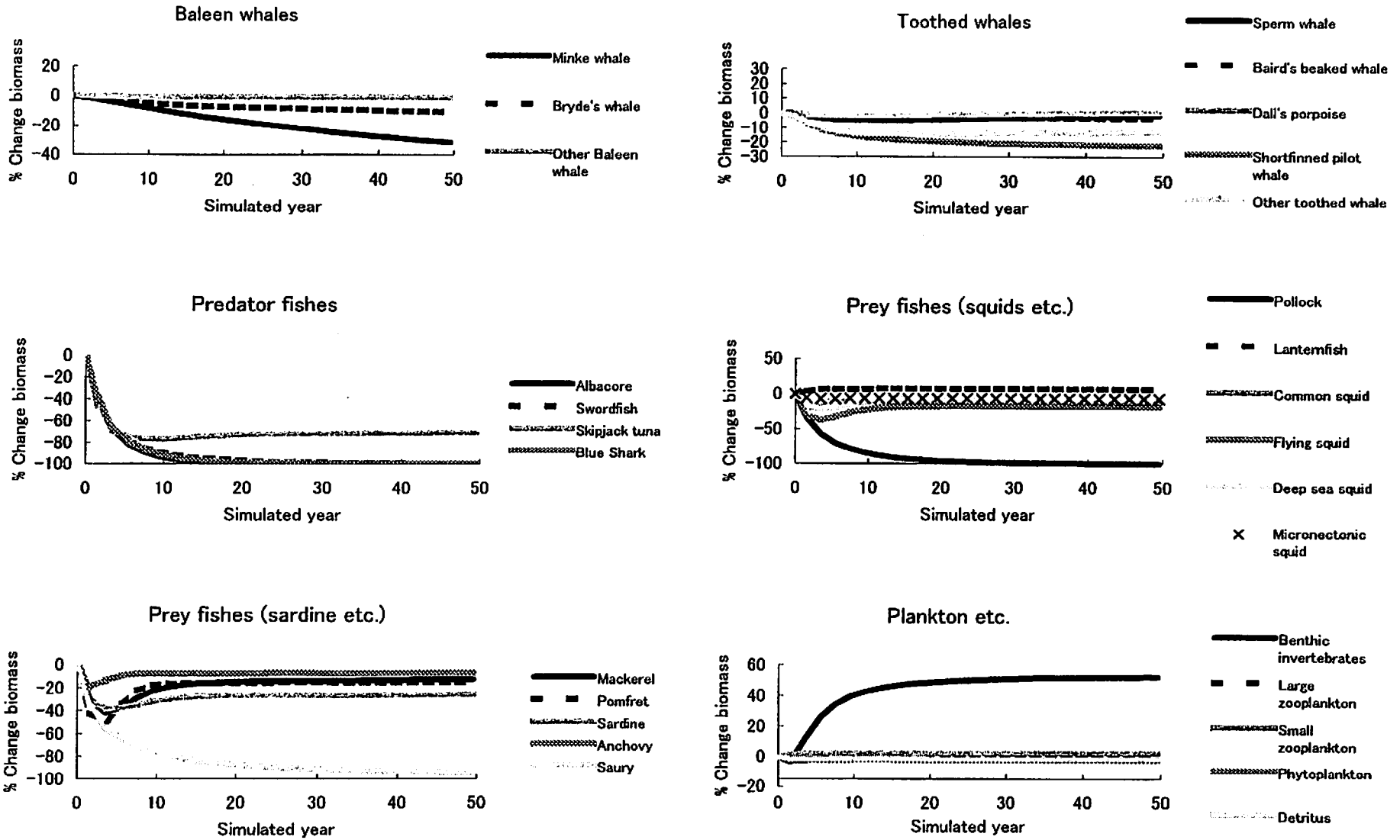


Fig. 2.1.8. The result of Ecosim dynamic simulation. The change of relative biomass with double fishing rate for fishes during future 50 years (v = 0.3).

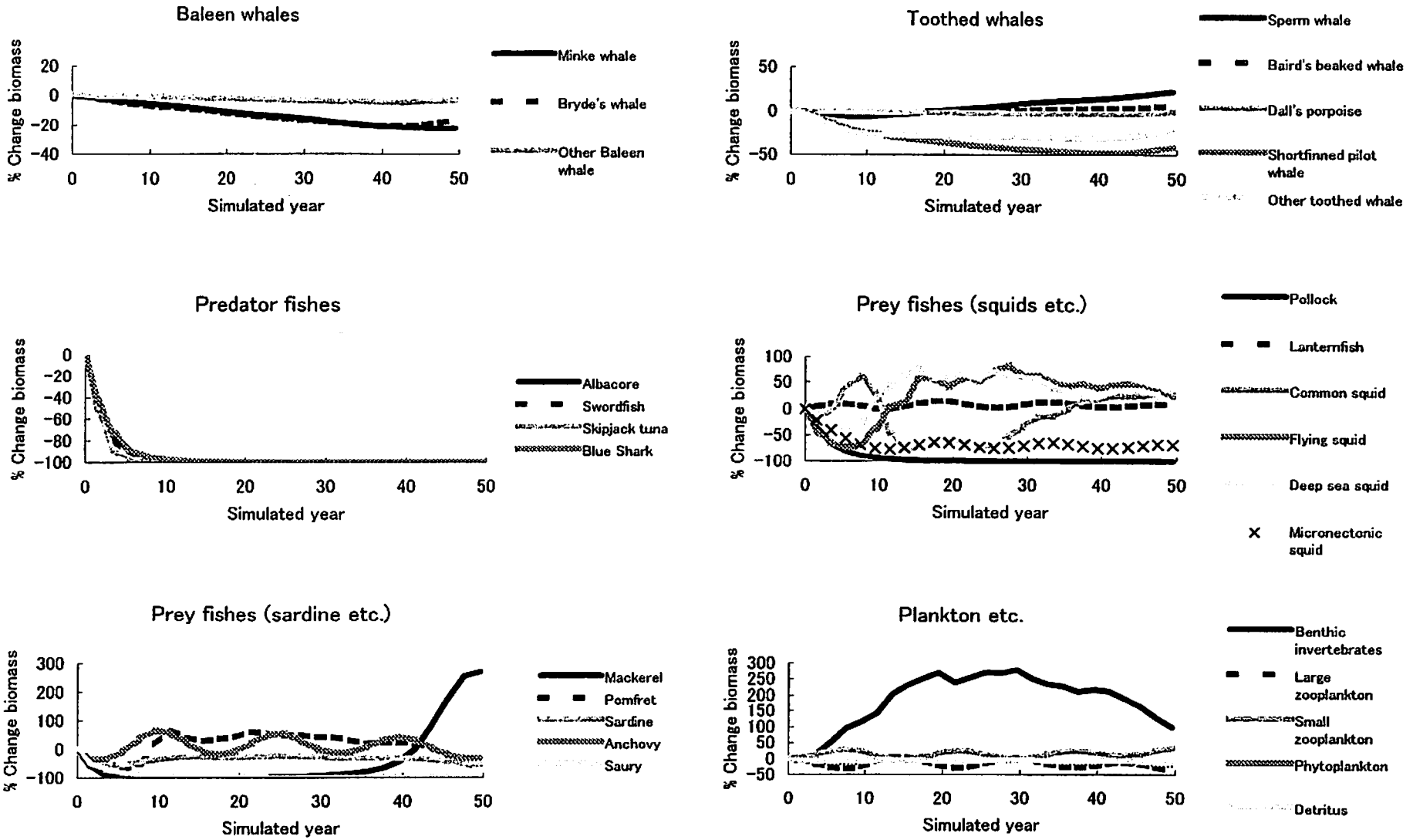


Fig. 2.1.9. The result of Ecosim dynamic simulation. The change of relative biomass with double fishing rate for fishes during future 50 years (v = 0.6).

Appendix 1

Food habit of common minke whales based on JARPN II

Tsutomu Tamura and Yoshihiro Fujise

The Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

The forestomach contents of 140 common minke whales (*Balaenoptera acutorostrata*) sampled in the western North Pacific from May to September through 2000 - 2001 JARPN II feasibility surveys, were analyzed. Seven prey species consisting of 1 euphausiids, 1 squid and 5 fishes were identified. Results of JARPN surveys between 1994 and 1999 showed geographical and seasonal changes of prey species of minke whales. In the Pacific side of Japan, the dominant prey species was Japanese anchovy (*Engraulis japonicus*) in May/June and Pacific saury (*Cololabis saira*) in July/August. In the southern Okhotsk Sea, krill was the dominant prey species in July and August. However, in 2000, during August and September, Japanese anchovy was the most important prey species. Furthermore, walleye pollock (*Theragra chalcogramma*) was also important prey species in sub-area 7. In sub-area 9, Japanese anchovy was the most important prey species and Pacific saury consumed by minke whales was low proportion in August in 2000. On the other hand, Pacific saury was the most important prey species in July and August in 2001. These changes in the prey species of minke whales probably reflect changes in the availability of prey species in these areas. In the sub-area 7, remarkable spatial segregation was observed between minke and Bryde's whales (*B. edeni*). They feed mainly on Japanese anchovy and/or krill. But the standard lengths of Japanese anchovy consumed by two whales are deferent. This deference is caused by the deference of the size of prey species distributed in each area.

INTRODUCTION

The common minke whale (*Balaenoptera acutorostrata*) is widely distributed in the world. In the western North Pacific two stocks have been recognized: one in the Sea of Japan - Yellow Sea - East China Sea (J stock) and the other in the Okhotsk Sea – West Pacific (O stock) (IWC, 1983). The abundance of minke whales was estimated to be 19,209 animals with 95 % confidence interval (10,069 – 36,645) in the Okhotsk Sea and 5,841 animals with 95 % confidence interval (2,835 – 12,032) in the Northwest Pacific during August and September in 1989 and 1990 (IWC, 1992).

In the western North Pacific, minke whales are opportunistic feeders with a broad diet and 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). They seem to play an important role in the food web from spring to autumn.

The Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) began in 1994 to elucidate the stock structure of western North Pacific minke whale. In 1996 a new objective related to elucidate the feeding ecology of minke whales, was added and then more data on this subject were accumulated from this year.

In February 2000, an IWC/SC workshop was held in Tokyo. Aims of the workshop is to: a) review

methods and results of the JARPN, b) assess the further potential of existing data and c) evaluate whether the main objectives have been achieved. On the feeding ecology study the workshop considered the study to be successful. The results of JARPN surveys between 1994 and 1999 showed that most of minke whales pursued single prey species aggregations and the main prey species changed seasonally and geographically, for example, Japanese anchovy (*Engraulis japonicus*) in May/June and Pacific saury (*Cololabis saira*) in July/August (Tamura and Fujise, 2000a). The estimated prey consumption by minke whales was comparable to that of the commercial fisheries (Tamura and Fujise, 2000b). The workshop agreed that, if ecological studies are to be conducted in the area, the sampling regime must be designed to allow for a quantitative estimation of temporal and geographical variation in diet. It was also recommended that acoustic and trawl surveys should be conducted concurrently with future whale surveys, if possible.

Following this, Japanese government planned to develop the existing research plan (JARPN) as a two-year feasibility study plan for cetacean studies in the western North Pacific under special permit, so called JARPN II (Government of Japan, 2000). The overall goal of the JARPNII was to contribute to the conservation and sustainable use of marine living resources including whales in the western North Pacific, especially within Japan's EEZ. For the overall goal, it was important to gather the information on resources and to merge it as a whole ecosystem. In this research special attention was paid to the ecosystem surrounding cetaceans, and the data and materials related to cetaceans, prey species and oceanographic conditions were collected.

One of the purposes of JARPNII research was to estimate the daily and/or yearly prey consumptions in each prey species with good precision. Furthermore, the data from this research will be used for ecosystem model such as Ecopath-type model and Multspec-type models.

In this study, prey species and prey size based on the stomach contents of minke whales sampled by JARPN II in the western North Pacific in 2000 and 2001 were examined. Furthermore, the interactions between minke whale and fisheries of Pacific saury or minke whales were discussed.

MATERIALS AND METHODS

Research area and periods

The research area of the JARPN II in 2000 and 2001 was sub-areas 7, 8 and 9 excluding the EEZ of foreign countries, which were established by the IWC (IWC, 1994). Furthermore, sub-area 7 was divided into 7 small blocks in 2000 and 5 small blocks in 2001 (Fig. 1, 2). To obtain the random samples of whales, a searching procedure for whales along randomly predetermined transects within each sub area was used. When a whale was observed during the survey, every effort was made to catch that particular whale. These transects were designed in saw-tooth patterns. However, to improve the efficiency of the search operations, a certain degree of modification of transect lines during the course of operations, depending on factors such as bad weather conditions and occurrences of whales.

The whales were sampled using one research base vessel (*Nisshin Maru*) and three sighting/sampling vessels (*Kyo Maru No.1*, *Toshi Maru No.25* and *Yushin Maru*). The whales were sampled according to sampling procedures described by Kato *et al* (1989). Sampled whales were immediately transported to a research base vessel, where biological measurements and sampling were carried out. A summary of the survey months, years and sample size in each sub-area is shown in Table 1. The sighting position of sampled minke and Bryde's whales is shown in Fig. 3.

Sampling of stomach contents

Minke whales have a 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). The prey composition between forestomach and fundus were very similar in this study. Therefore, this study was based on contents from forestomach.

In the 2000 and 2001 JARPN II surveys, we examined 140 stomach contents of minke whales. Of them, 15 stomachs had been destroyed by the harpoon, and their contents were lost. Also, in the case of 2 of the 140 minke whales sampled, the stomachs were empty. Then an analysis was based on 123 forestomach contents. Each stomach contents (both cases of including and excluding liquid) were weighed to the nearest 0.1 kg. Then, a sub-sample (3-4 kg) of forestomach contents was removed and frozen for later analyses. The stomach contents were transferred to a system consisting of three sieves (20 mm, 5 mm and 1 mm), which were applied in the Norwegian scientific research to filter off liquid from the rest of the material (Haug *et al.* 1995).

Data analyses

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

When undigested fish or squid were found, standard length, mantle length or the weights were measured to the nearest 1 mm and 1 g, respectively.

The total number of each fish or squid species in the sub-sample were calculated by adding to the number of undigested fish or squid, undigested skulls or buccal and half the total number of free otoliths or beaks. 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 forestomach were estimated by using the figures obtained from the sub-sample and the total weight of forestomach contents. The total weight of each zooplankton was estimated by using an assimilation efficiency of 84 % (Lockyer, 1981).

Feeding Indices

The importance of each dominant prey species was evaluated by using the Combined Rank Index (*CRI*: Pitcher 1981).

In order to simplify the comparison of feeding indices, prey species were divided into the following prey groups: copepods (*Calanus* spp.), krill (*Euphausia pacifica*), Japanese common squid (*Todarodes pacificus*), Japanese anchovy, Japanese pilchard (*Sardinops melanostictus*), Pacific saury, walleye pollock (*Theragra chalcogramma*), Chub mackerel (*Scomber japonicus*), Salmonidae and other fishes. The *CRI* was calculated for each month, sub area and year.

First, we calculated the relative frequency of occurrence of each prey species (*RF*) as follows:

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

Ni = the number of stomachs containing prey group i

N_{all} = the total number of stomachs analyzed.

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 weight of contents containing prey group *i*

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

The *CRI* was then calculated as follows:

$$CRI = \text{rank of } RF \times \text{rank of } RW \quad (3)$$

RESULTS

Diversity of prey species

A total of seven prey species, including 1 euphausiids, 1 squid and 5 fishes were identified in the 123 stomachs of minke whales based on JARPN II surveys. Major prey species were krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese common squid. Minor prey species were Japanese pilchard, Chub mackerel, unidentified daggertooth and unidentified salmon (Table 2).

Geographical and seasonal changes in dominant prey species in the forestomach

From 1994 to 1999 results of JARPN, in the Pacific side, Japanese anchovy was the most important prey species in May and June (Early period), while Pacific saury was the most important one in July and August (Late period).

However, in 2000 research (JARPN II), during August and September, walleye pollock was the most important prey species. Furthermore, Japanese common squid was also important prey species in sub-area 7. In sub-area 9, Japanese anchovy was the most important prey species in August. On the other hand, Pacific saury consumed by minke whales was low proportion (Table 3).

On the other hand, in 2001, Pacific saury was the most important prey species in July and August in sub-areas 8 and 9.

Standard length frequency of dominant prey species ingested by minke whales

Japanese anchovy

In early period, the standard length of Japanese anchovy ingested ranged from 125 to 149 mm with average length at 133 mm in small block 1,from 118 to 155 mm with average length at 132 mm in small block 2, from 132 to 152 mm with average length at 141 mm in small block 3-4, from 128 to 150 mm with average length at 140 mm in small block 4-5 in sub area 7.

In late period, the standard length of Japanese anchovy ingested ranged from 120 to 150 mm with average length at 133 mm in small block 1, from 54 to 137 mm with average length at 89 mm in small block 5 in sub area 7. The standard length of Japanese anchovy ingested ranged from 86 to 132 mm with average length at 105 mm in sub area 9 (Fig. 4-1). Minke whales consumed large size of Japanese anchovy in both season.

Pacific saury

In late period, the standard length of Pacific saury ingested ranged from 126 to 350 mm with average length at 278 mm in sub area 9 (Fig. 4-2).

Walleye pollock

In early period, the standard length of walleye pollock ingested ranged from 177 to 485 mm with average length at 361 mm in small block 1.

In late period, the standard length of walleye pollock ingested ranged from 313 to 480 mm with average length at 396 mm in small block 1 (Fig. 4-2).

Japanese common squid

In late period, the standard length of Japanese common squid ingested ranged from 196 to 258 mm with average length at 221 mm in small block 1 (Fig. 4-4).

Size Comparison of prey species between stomach contents and trawl net samples

Japanese anchovy

In early period, the standard length of Japanese anchovy ingested ranged from 118 to 155 mm with average length at 132 mm in small block 2. On the other hand, the standard length of Japanese anchovy sampled by trawl ranged from 117to 141 mm with average length at 127 mm.

In late period, the standard length of Japanese anchovy ingested ranged from 120 to 150 mm with average length at 133 mm in small block 1. On the other hand, the standard length of Japanese anchovy sampled by trawl ranged from 30 to 140 mm with average length at 123 mm. (Fig. 5). Length modes of both stomach contents and trawled samples well coincided.

Interaction between Bryde's whale and minke whale

In the sub-area 7, remarkable spatial segregation was observed between minke and Bryde's whales (*B. edeni*). In minke whales, the sightings are limited along coastal region of Japan. In contrast, sightings of Bryde's whales are made in offshore region of the sub-area 7 (Fig. 3).

DISCUSSIONS

Prey species

The prey species of minke whales in the western North Pacific and southern Okhotsk Sea during May and September from 1994 to 2001, were occupied various pelagic prey species of zooplankton, squid and fishes. Prey species of minke whales varied both geographically and temporally. In the Northern Hemisphere, minke whales consumed various pelagic prey species of zooplankton, squid and fishes (Kasamatsu and Tanaka, 1992; Haug *et al.*, 1995, 1996; Tamura, 1998; Tamura *et al.*, 1998). On the other hand, in the Southern Hemisphere minke whales consumed Antarctic krill (*Euphausia superba*) (Ichii and Kato, 1991; Tamura, 1998). It was confirmed that minke whales in the western North Pacific are euryphagous, similar to those in Northeast Atlantic, but unlike the stenophagous in the Antarctic.

Geographical and seasonal changes of prey species

Results of JARPN surveys between 1994 and 1999 and of JARPN II in 2000 and 2001 showed geographical and seasonal changes of prey species in the western North Pacific.

Pacific saury and Japanese anchovy migrate to this research area to feed copepod and krill from June through September (Kondo, 1969; Odate, 1977). Minke whales probably feed on those at the surface during their seasonal migration to high latitude. Differences in the *CRI* between Pacific saury and Japanese anchovy might reflect to local changes in the relative abundance of these species in the area.

In sub-area 7W (small block 1) walleye pollock was also an important prey species during June and September. 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). Minke whales probably feed on at the surface groups. They are important prey species for minke whale in coastal waters over the continental shelf. It is needed more research about the interaction between minke whales and walleye pollock.

Yearly changes of prey species

Kasamatsu and Hata (1985) reported that Chub mackerel was the most important prey species of minke whales in western Pacific (a part of sub-area 8) in August, and walleye pollock was the most important one for minke whales in east Sakhalin (a part of sub-area 12) between June and August from 1973 to 1975 data. Kasamatsu and Tanaka (1992) examined annual changes of prey species in the seven whaling grounds off Japan, from 1948 to 1987 data. In Pacific coast of Hokkaido (a part of sub-area 7W) from April to October, prey species recorded were krill, squid, Japanese pilchard, Japanese anchovy, Chub mackerel, walleye pollock, cod, sand lance (*Ammodytes personatus*), Pacific saury and so on. They noted that the change of prey of minke whales from Chub mackerel to Japanese pilchard in 1977 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976. On the other hand, Kasamatsu and Tanaka (1992) reported krill was dominant prey species from 1964 to 1987 in the Okhotsk Sea.

In addition, we examined the yearly change of prey species of minke whales in sub-area 7W. Fig. 6 shows the relative frequency of occurrence of each dominant prey species consumed by minke whales in sub-area 7W (A) and the catch data of Japanese pilchard, Chub mackerel and Pacific saury in the Pacific side of Japan (B). The change of prey species of minke whales from Chub mackerel to Japanese pilchard in 1977, from Japanese pilchard to Pacific saury in 1996 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976, 1996, respectively. However, in 2000 research (JARPN II), during August and September, walleye pollock was the most important prey species. Furthermore, Japanese common squid was also important prey species in sub-area 7W. On the other hand, Pacific saury consumed by minke whales was low proportion

Since it is reasonable to assume that minke whales do not have a strong preference for a particular prey species (Jonsgård, 1982; Kasamatsu and Tanaka, 1992), changes in the prey of minke whales probably reflect changes in the abundance of available prey species in this area. The fork length of prey species consumed by minke whales in this study and previous ones indicates that the minke whales fed primarily on adult of these species, Japanese anchovy (Kondo, 1969), Pacific saury (Odate, 1977) and walleye pollock (Maeda, 1988). These fishes support important commercial fisheries.

In these results, there are yearly changes of prey species of minke whales in the research area. Therefore, further research might be necessary to make clear and to monitor their feeding ecology in the future.

Interaction between minke whale and Bryde's whale

In the sub-area 7, remarkable spatial segregation was observed between minke and Bryde's whales. In minke whales, the sightings are limited along coastal region of Japan. In contrast, sightings of Bryde's whales are made in offshore region of the sub-area 7. They feed mainly on Japanese anchovy and/or krill. But the standard lengths of Japanese anchovy consumed by two whales are

deferent. This deference is caused the deference of the size of prey species distributed in each area. However, there is deference of the standard length of Japanese anchovy between stomach contents sampled and samples by trawled net, but their cause was not clear whether it is to dependent on size preference of Bryde's whales. Therefore, further research might be necessary to clear their interaction in the future.

Interaction between minke whale and commercial fisheries

Fig. 7 shows the fishing grounds of Pacific saury and the positions of minke whales sightings in sub-area 7W in the survey conducted during 24 August and 5 September 1996 (Fujise *et al.*, 1997). In this season the fishing grounds make two spots off south of Erimo, off Kushiro and Nemuro in days 22 – 25 August. After that, the spot off Erimo Point disappeared and the ground off Kushiro and Nemuro were combined and expanded until September. Most of the minke whales sightings occurred close to these fishing grounds. This observation seems to suggest the relationship between minke whales and Pacific saury from summer to autumn in the western North Pacific.

In Japan, Pacific saury is an important fish for the commercial fishery, their fisheries catch of this species in Japan was about 0.2 million tones in recent year. Tamura and Fujise (2000b) estimated the prey consumption by minke whale in the western North Pacific. The estimated Pacific saury's consumption by minke whales were $2.8 - 6.2 \times 10^4$ tones equivalent to 14 – 31 % of the catch of Pacific saury in Japan.

In these results, there are some examples of direct competition between minke whales and commercial fisheries in the research area. Therefore, further research might be necessary to clear their interaction in the future.

ACKNOWLEDGEMENTS

We are indebted to R. Zenitani, H. Isikawa, M. Goto, T. Bando, T. Mogoe, S. Otani, N. Kanda and G. Yasunaga of the Institute of Cetacean Research (ICR) who collected and weighed the stomach contents in JARPN and JARPNII surveys. We would like to thank all captains, crews and researchers, who were involved in JARPN and JARPNII surveys from 1994 to 2001. Our sincere thank to Dr. H. Hatanaka of the Fisheries Research Agency and 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 shyuuhennkaiiki ni seisokusuru gyorui no jiseki no hikakukeitaigakuteki kenkyuu [Preliminary keys to otoliths of fishes of Usujiri and adjacent waters in Southern Hokkaido, Japan]. Graduation Thesis, Hokkaido University. 98pp. [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. 96pp.

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)

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

Fujise, Y., Shimada, H., Zenitani, R., Goto, M., Matsuoka, K., Tamura, T., Lindstrøm, U., Uchida, A.,

Yoshida, H., Shimamoto, K., Yuzu, S., Kasai, H., Kinoshita, T., Iwata T. and Tohyama, D. 1997. Cruise report of the Japanese whale research program under a special permit in the North Pacific (JARPN) in 1996 with some preliminary analyses of data collected during the 1994-1996 JARPN surveys. Paper SC/49/NP 8 presented to the IWC Scientific Committee, September 1997 (unpublished). 38pp.

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 J. mar. Sci.* 52:77-86.

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

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

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

Ichii, T. and Kato, H. 1991. Food and daily food consumption of southern minke whales in the Antarctic. *Polar Biol.* 11:479-87.

International Whaling Commission. 1983. Report of the Sub-Committee on minke whales. *Rep. int. Whal. Commn.* 33:91-122.

International Whaling Commission. 1992. Report of the Sub-Committee on North Pacific minke whale. *Rep. int. Whal. Commn.* 42:156-77.

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

Jonsgård, Å. 1982. The food of minke whale (*Balaenoptera acutorostrata*) in northern North Atlantic waters. *Rep. int. Whal. Commn.* 32:259-62.

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.

Kato, H., Hiroyama, H., Fujise, Y. and Ono, K. 1989. Preliminary report of the 1987/88 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. Report of the International Whaling Commission, 39: 235-248.

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

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. 65pp. [In Japanese].

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.

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

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

pollock.325-47.

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. 378pp.

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

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

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:3. 53-81.Ohe, F. 1984. Otoliths of the coastal fishes along Japanese Islands and of fishes of adjacent seas. *Reprint. Bull. 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*). *J. Zool., Lond* 234:55-74.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. *Fishery Bulletin*. 79:467-72.

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

Tamura, T. and Fujise, Y. 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.

The Government of Japan. 2000. Research plan for cetacean studies in the western North Pacific under special permit (JARPNII) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC IWC Scientific meeting (unpublished). 68pp.

Table 1. Years, sub areas, small blocks, months of surveys and sample size used in this study.

Year (Numbers)	Sub area (Numbers)	Small block	Month	Sample size	Empty stomachs	Broken stomachs
2000	7	1	August	1	0	0
(40)	(24)		September	17	1	0
		2	August	5	0	0
		5	September	1	0	1
	9 (16)		August	16	0	4
2001	7	1	June	10	0	0
(100)	(50)	2	May	24	0	5
		3	May	4	0	0
		3-4	June	10	0	1
		4-5	June	2	0	0
	8 (21)		July	21	0	3
	9		July	24	0	1
	(29)		August	5	1	0

Table 2. Prey species found in stomach of minke whales sampled in this study.

Major prey species		
Krill		*Euphausia pacifica*
Squid	Japanese common squid	*Todarodes pacificus*
Pisces	Pacific saury	*Cololabis saira*
	Japanese anchovy	*Engraulis japonicus*
	Walleye pollock	*Theragra chalcogramma*
Miner prey species		
Pisces	Japanese pilchard	*Sardinops melanostictus*
	Chub mackerel	*Scomber japonicus*
	Unidentified daggertooth	*Anotopterus* sp.
	Unidentified salmon	*Oncorhynchus* sp.

Table 3. Geographical and temporal changes in stomach contents of 140 minke whales sampled by JARPNII surveys in 2000 and 2001.

Year (Numbers)	Sub area (Numbers)	Small block	Month	Sample size	Empty stomachs	Broken stomachs	Prey species	Occurrence %	weight ingested %	CRI
2000	7	1	Aug.	1	0	0	Japanese anchovy	100.0	100.0	1
(40)	(24)		Sept.	17	1	0	Krill	18.8	9.5	9
							Japanese anchovy	6.3	6.3	20
							Pacific saury	18.8	8.4	12
							Walleye pollock	62.5	55.2	1
							Common squid	31.3	20.6	4
		2	Saug.	5	0	0	Japanese anchovy	100.0	100.0	1
		5	Sept.	1	0	1	(Japanese anchovy)			
	9		Aug.	16	0	4	Krill	8.3	7.8	6
	(16)						Japanese anchovy	100.0	89.2	1
							Pacific saury	8.3	1.4	9
							Chub mackerel	41.7	1.6	6
2001	7	1	June	10	0	0	Krill	20.0	14.0	9
(100)	(50)						Japanese anchovy	50.0	25.3	4
							Walleye pollock	90.0	60.6	1
							Common squid	20.0	0.1	12
		2	May	24	0	5	Japanese anchovy	100.0	97.5	1
							Japanese pilchard	5.3	2.5	4
		3	May	4	0	0	Krill	75.0	74.8	1
							Japanese anchovy	50.0	25.2	4
		3-4	June	10	0	1	Krill	66.7	66.5	1
							Japanese anchovy	33.3	33.5	4
		4-5	June	2	0	0	Japanese anchovy	100.0	100.0	1
	8		July	21	0	3	Krill	16.7	8.9	4
	(21)						Japanese anchovy	5.6	5.6	9
							Pacific saury	94.4	85.2	1
							Common squid	5.6	0.3	16
							Other	5.6	0.0	20
	9		July	24	0	1	Krill	13.0	1.9	4
	(29)						Pacific saury	100.0	96.3	1
							Walleye pollock	4.3	1.9	15
							Other	4.3	0.0	20
			Aug.	5	1	0	Pacific saury	100.0	100.0	1

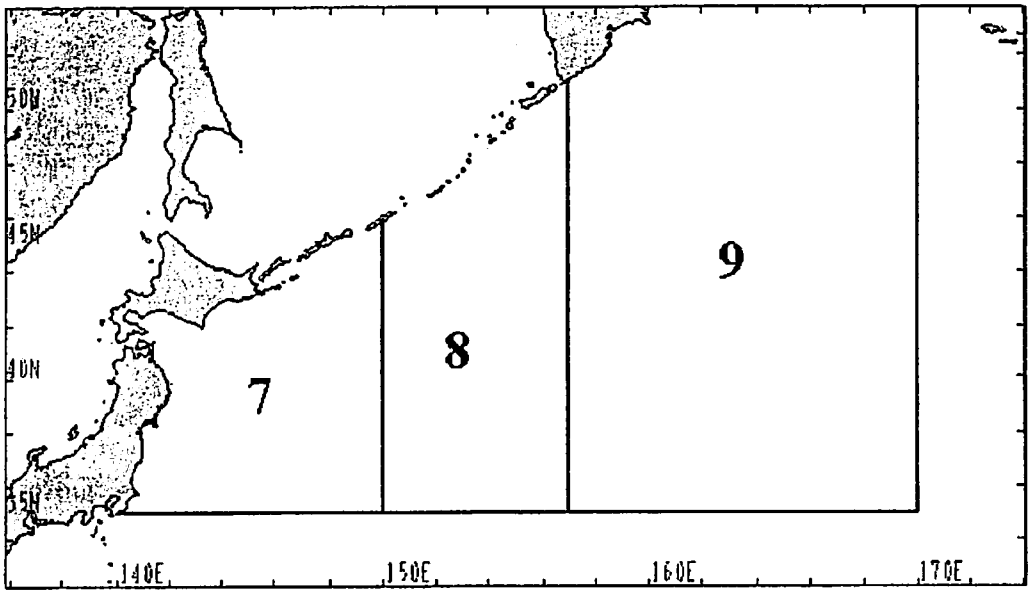


Fig. 1. Sub-areas surveyed by the JARPNII in 2000 and 2001. Sub-areas were based on IWC (1994), excluding the EEZ of foreign countries.

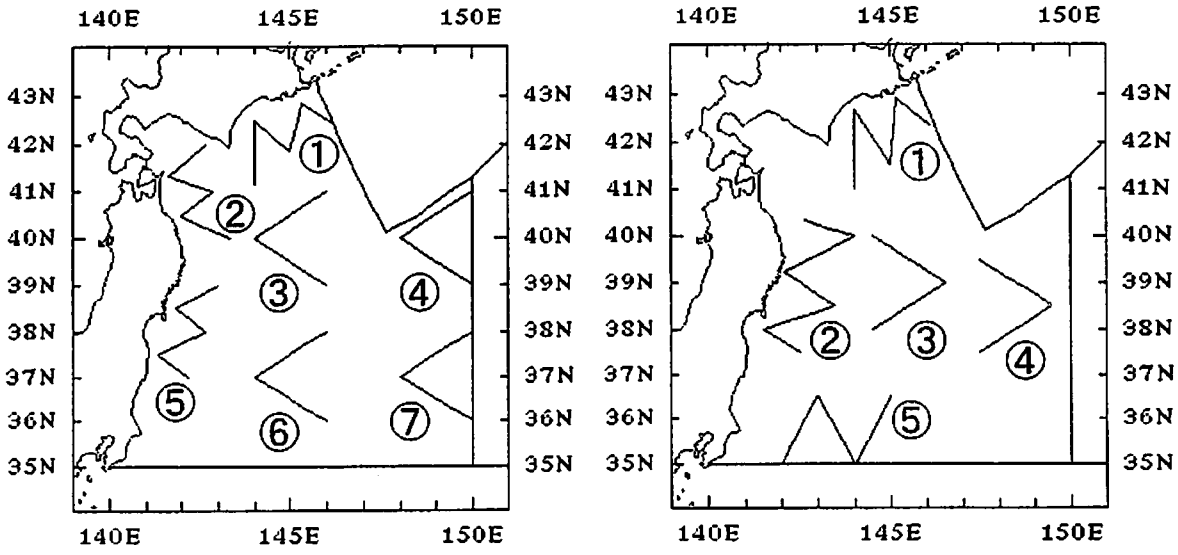


Fig. 2. Small blocks surveyed by the JARPNII in 2000 and 2001.

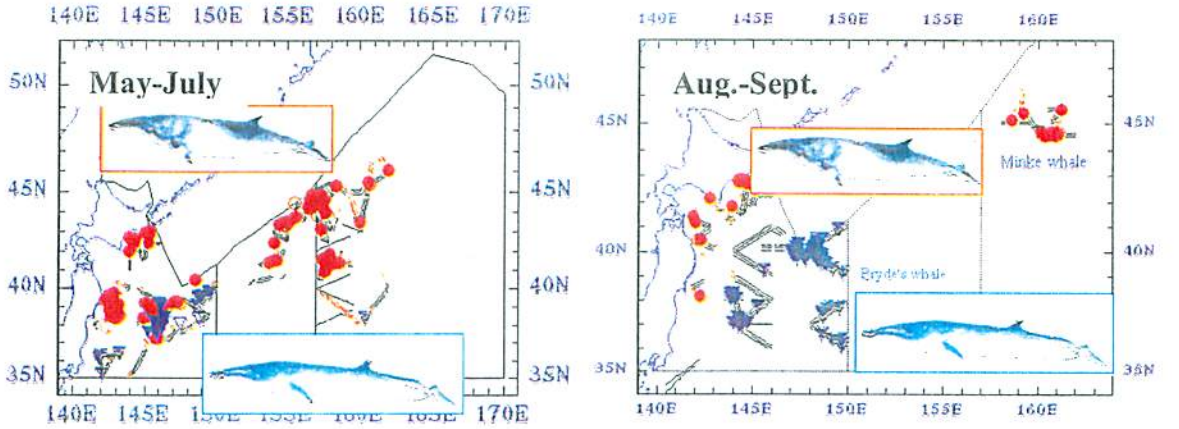
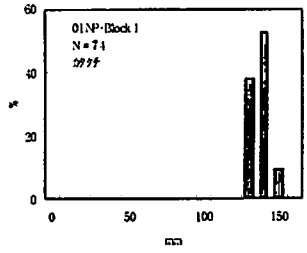


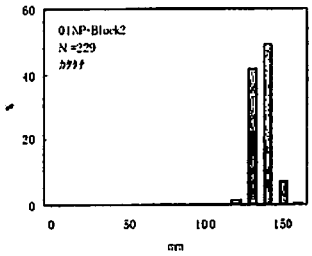
Fig. 3. Sighting position of minke whales (●) and Bryde's whales (▼) sampled by the JARPNII in 2000 and 2001.

Early period (2001)

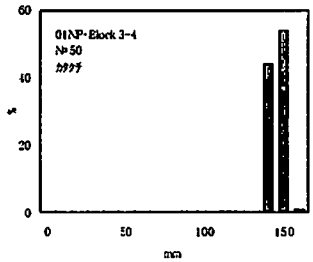
Sub-area 7 • Small block 1



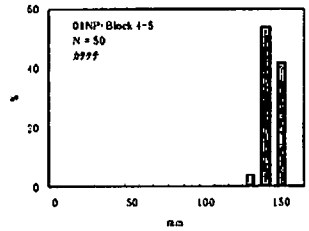
Small block 2



Small block 3-4

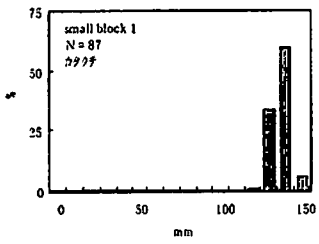


Small block 4-5

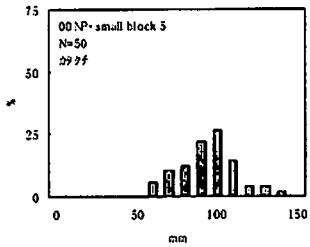


Late period (2000)

Sub-area 7 • Small block 1



Small block 5



Sub-area 9

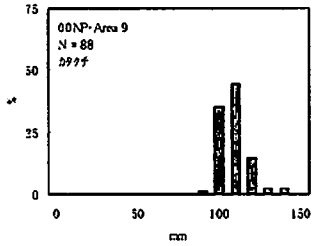


Fig. 4-1. Standard length frequency of Japanese anchovy consumed by minke whales in 2000 and 2001.

Late period (2001)
Sub-area 9

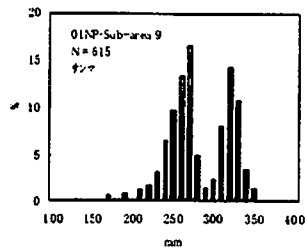
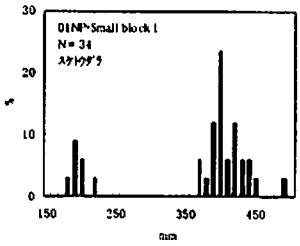


Fig. 4-2. Standard length frequency of Pacific saury consumed by minke whales in 2001.

Early period (2001)
Sub-area 7 • Small block 1



Late period (2000)
Sub-area 7 • Small block 1

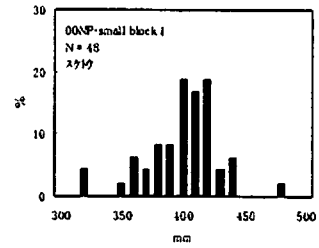


Fig. 4-3. Standard length frequency of walleye pollock consumed by minke whales in 2000 and 2001.

Late period (2001)
Sub-area 7 • Small block 1

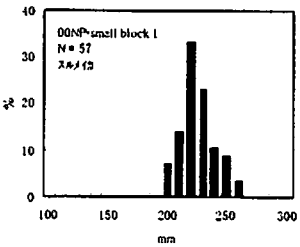
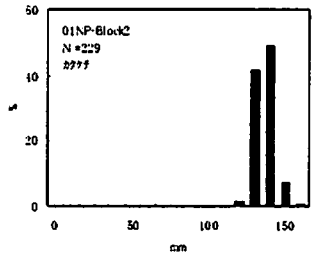


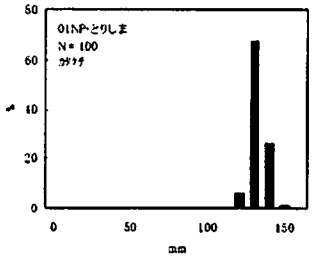
Fig. 4-4. Standard length frequency of Japanese common squid consumed by minke whales in 2000 and 2001.

Early period (2001)
Sub-area 7 • Small block 2

Stomach contents

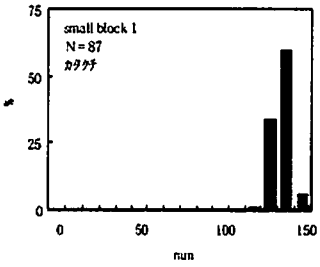


Sample by trawl net



Late period (2000)
Sub-area 7 • Small block 1

Stomach contents



Sample by trawl net

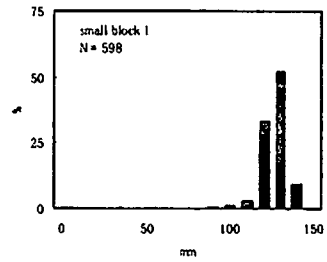


Fig. 5. Standard length frequency of Japanese anchovy consumed by minke whales and sampled by trawl in 2000 and 2001.

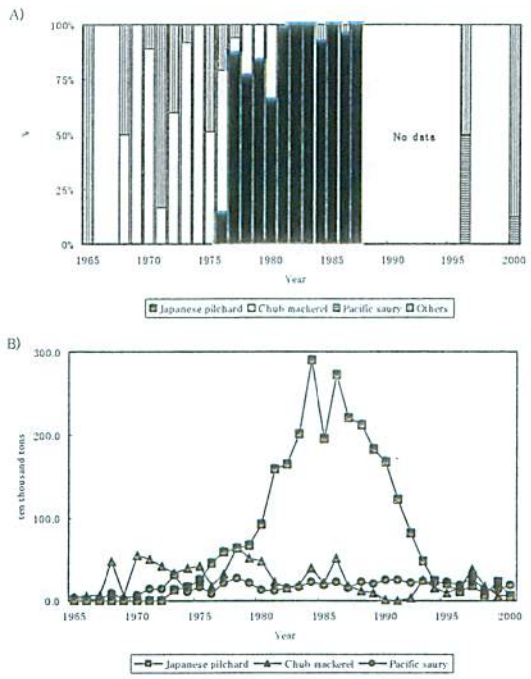


Fig. 6. The annual change of relative frequency of occurrence of each dominant prey species consumed by minke whale in sub-area 7W (A) during summer and commercial catch in Pacific side (B). (The ministry of Agriculture, Forestry and Fisheries of Japan, 1967-2000; Kasamatsu and Tanaka, 1992; this study).

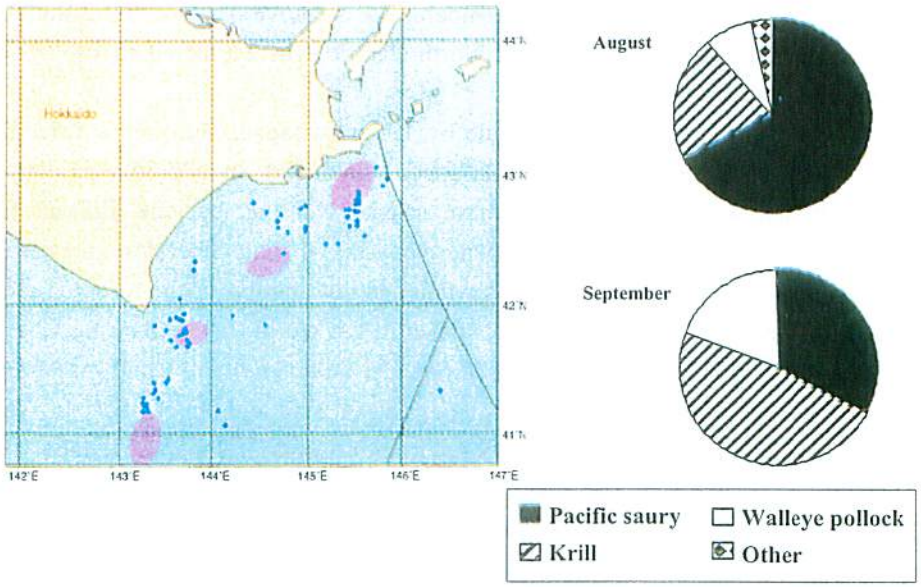


Fig. 7. Relationship between minke whale sightings and the fishing ground of Pacific saury in the sub-area 7W during 22 July and 8 September 1996. The information of the fishing grounds was obtained from the telex Nos. 27 - 33 on fishing grounds off the Pacific coast of eastern Hokkaido by the Fishing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

Appendix 2

Food habit of Bryde's whales based on JARPN II

Tsutomu Tamura and Yoshihiro Fujise

The Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

The forestomach contents of 93 Bryde's whale (*Balaenoptera edeni*) sampled in the western North Pacific from May to September through 2000 - 2001 JARPN II feasibility surveys, were analyzed. Nine prey species consisting of 3 euphausiids and 6 fishes were identified. Results showed seasonal changes of prey species of Bryde's whales. The dominant prey species was krill during May and June, Japanese anchovy (*Engraulis japonicus*) during July and August. These changes in the prey species of Bryde's whales probably reflect changes in the availability of prey species in these areas. In the sub-area 7, remarkable spatial segregation was observed between common minke (*B. acutorostrata*) and Bryde's whales. They feed mainly on Japanese anchovy and/or krill. But the standard lengths of Japanese anchovy consumed by two whales are deferent. This deference is caused by the deference of the size of prey species distributed in each area.

INTRODUCTION

The Bryde's whale (*Balaenoptera edeni*) is distributed in tropical and warm temperate waters throughtout the year, in which the surface temperature is above 16.4 °C (Ohsumi, 1977). The abundance of Bryde's whales in the western North Pacific was estimated to be 25,640 animals (CV=0.20)(Shimada and Miyashita, 1996).

This species was classified into the sei whale by 1950s in Japan, and prey species reported by Nemoto (1959) were described on both whale species included. In addition, feeding studies of Bryde's whales, which were caught by Japanese coastal whaling, became difficult from 1960s because of cutting belly of whale carcass in Japanese coastal whaling. Therefore, present knowledge on the prey species and feeding of the Bryde's whales is not enough in the research area. Nemoto (1959) reported the reviews of prey of baleen whales in the world. In the Sanriku Coast of Japan, Bryde's whales fed on krill, Japanese anchovy (*Engraulis japonicus*) and Chub mackerel (*Scomber japonicus*). In the waters around Bonin Islands, They fed on krill and lantern fish. In West Kyushu, they fed mainly on Japanese pilchard (*Sardinops melanostictus*), Japanese anchovy and horse mackerel (*Trachurus japonicus*). Nemoto and Kawamura (1977) reported the characteristics of food habits and distribution of baleen whales. In Japanese pelagic operations from 1952 to 1971, Bryde's whales fed on euphausiids (89 %) and fishes (11 %). The feeding type of Bryde's whale was considered the euphausiids feeder and fish feeder. However, the recent information of prey species of Bryde's whales was none in the North Pacific.

Japanese government planned to develop the existing research plan (JARPN) as a two-year feasibility study plan for cetacean studies in the western North Pacific under special permit, so called JARPN II (The Government of Japan, 2000). The overall goal of the JARPNII was to contribute to the conservation and sustainable use of marine living resources including whales in the western North Pacific, especially within Japan's EEZ. For the overall goal, it was important to gather the

information on resources and to merge it as a whole ecosystem. In this research special attention was paid to the ecosystem surrounding cetaceans, and the data and materials related to cetaceans, prey species and oceanographic conditions were collected.

One of the purposes of JARPNII research was to estimate the daily and/or yearly prey consumptions in each prey species with good precision. Furthermore, the data from this research will be used for ecosystem model such as Ecopath-type and Multspec-type models.

In this study, prey species and prey size based on the stomach contents of Bryde's whales sampled by JARPN II in the western North Pacific in 2000 and 2001 were examined. Furthermore, the interactions between Bryde's whale and fisheries of skipjack tuna (*Katsuwonus pelamis*) or minke whales were discussed.

MATERIALS AND METHODS

Research area, periods, sample size and sighting position of whales sampled

The research area of the JARPN II in 2000 and 2001 was sub-areas 7, 8 and 9 excluding the EEZ of foreign countries, which were established by the IWC (IWC, 1994). Furthermore, sub-area 7 was divided into 7 small blocks in 2000 and 5 small blocks in 2001 (Fig. 1, 2). To obtain the random samples of whales, a searching procedure for whales along randomly predetermined transects within each sub area was used. When a whale was observed during the survey, every effort was made to catch that particular whale. These transects were designed in saw-tooth patterns. However, to improve the efficiency of the search operations, a certain degree of modification of transect lines during the course of operations, depending on factors such as bad weather conditions and occurrences of whales.

The whales were sampled using one research base vessel (*Nisshin Maru*) and three sighting/sampling vessels (*Kyo Maru No.1*, *Toshi Maru No.25* and *Yushin Maru*). The whales were sampled according to sampling procedures described by Kato *et al* (1989). Sampled whales were immediately transported to a research base vessel, where biological measurements and sampling were carried out. A summary of the survey months, years and sample size in each sub-area is shown in Table 1. The sighting position of sampled minke and Bryde's whales is shown in Fig. 3.

Sampling of stomach contents

Bryde's whales have a 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). The prey composition of prey species between forestomach and fundus were very similar in this study. Therefore, this study was based on contents from forestomach.

In the 2000 and 2001 JARPN II surveys, we examined 93 stomach contents of Bryde's whales. Of them, 3 stomachs had been destroyed by the harpoon, and their contents were lost. Also, in the case of 32 of the 93 Bryde's whales sampled, the stomachs were empty. Then an analysis was based on 93 forestomach contents. Each stomach contents (both cases of including and excluding liquid) were weighed to the nearest 0.1 kg. Then, a sub-sample (3-4 kg) of forestomach contents was removed and frozen for later analyses. The stomach contents were transferred to a system consisting of three sieves (20 mm, 5 mm and 1 mm), which were applied in the Norwegian scientific research to filter off liquid from the rest of the material (Haug *et al.* 1995).

Data analyses

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, euphausiacea (Baker *et al.*, 1990) and fish (Masuda *et al.*, 1988; Chihara *et al.*, 1997). The otoliths were used to identify the fish with advanced stage of digestion (Morrow, 1979; Ohe, 1984; Arai, 1993).

When undigested fish or squid were found, standard length or the weights were measured to the nearest 1 mm and 1 g, respectively.

The total number of each fish species in the sub-sample was calculated by adding to the number of undigested fish, 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 forestomach were estimated by using the figures obtained from the sub-sample and the total weight of forestomach contents. The total weight of each zooplankton was estimated by using an assimilation efficiency of 84 % (Lockyer, 1981).

Feeding Indices

The importance of each dominant prey species was evaluated by using the Combined Rank Index (*CRI*: Pitcher 1981).

In order to simplify the comparison of feeding indices, prey species were divided into the following prey groups: krill (*Euphausia pacifica*, *E. similes* and *Thysanoessa inspinata*), Japanese anchovy, Chub mackerel and other fishes. The *CRI* was calculated for each month, sub area and year.

First, we calculated the relative frequency of occurrence of each prey species (*RF*) as follows:

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

Ni = the number of stomachs containing prey group i

N_{all} = the total number of stomachs analyzed.

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

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

W_i = the weight of contents containing prey group i

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

The *CRI* was then calculated as follows:

CRI = rank of RF $\times$ rank of RW (3)

RESULTS

Diversity of prey species

A total of nine prey species, including 3 euphausiids and 6 fishes were identified in the 93 stomachs of Bryde's whales based on JARPN II surveys. Major prey species were krill, Japanese anchovy and young of Chub mackerel. Minor prey species were Russell's scad (*Decapterus russelli*) and some lantern fishes (Table 2).

Geographical and seasonal changes in dominant prey species in the forestomach

In the JARPN II, krill was most important prey species in May and June (Early period), while Japanese anchovy was most important prey species in July and August (Late period) (Table 3).

Standard length frequency of dominant prey species ingested by Bryde's whales and trawled

Japanese anchovy

In late period, the standard length of Japanese anchovy ingested ranged from 43 to 131 mm with average length at 71-72 mm in small block 3, 3-4 (Fig. 4). On the other hand, the standard length of Japanese anchovy sampled by trawl in small block 3 ranged from 47 to 120 mm with average length at 93 mm, and that in small block 4 ranged from 24 to 130 mm with average length at 53 mm (Fig. 5).

The deference between the prey species of the mother and the calf

The biological and stomach contents data of the mother and calf of Bryde's whales sampled by JARPN II surveys in 2000 and 2001 is shown in Table 4. The 8 pair of parent and calf were targeted, 8 calves and 7 mother whales were sampled in 2000 and 2001 JARPNII. It was confirmed that the 3 individuals which are under 8.0 m of body length did not feed on prey other than milk excluding 1 individual (Mixture milk and krill). However, the 3 individuals who were over 8.0 m of body length feed on only krill as their prey.

Interaction between Bryde's whale and minke whale

In the sub-area 7, remarkable spatial segregation was observed between minke and Bryde's whales. In minke whales, the sightings are limited along coastal region of Japan. In contrast, sightings of Bryde's whales are made in offshore region of the sub-area 7 (Fig. 3).

Interaction between Bryde's whale and skipjack tuna

Fig. 6 shows the fishing grounds of skipjack tuna and the positions of Bryde's whales sightings in sub-area 7 in the survey. Most of the Bryde's whales sightings occurred close to these fishing grounds, they feed mainly on Japanese anchovy.

DISCUSSIONS

Prey species

In this study the major prey species were krill, Japanese anchovy and young of chub mackerel. Nemoto (1959) reported Bryde's whales fed on krill, Japanese anchovy and Chub mackerel in the Sanriku Coast of Japan. It was confirmed that there was no change qualitatively about prey species of Bryde's whale between previous report and this research.

Geographical and seasonal changes of prey species

In the Pacific side of Japan, the dominant prey species was krill during May and June, Japanese anchovy during July and August. Differences in the *CRI* between krill and Japanese anchovy might reflect to local changes in the relative abundance of these species in the area. Prey species of Bryde's whales varied both geographically and temporally. However, the more data was needed to clear their seasonal change of prey species in this research area.

The deference between the prey species of the mother and the calf

The deference between the prey species of the mother and the calf was observed. Almost of the individuals which are under 8.0 m of body length did not feed on prey. They feed mainly on mother's milk. However, the individuals who are over 8.0 m of body length feed on only krill as their prey. The examination of these individuals for feeding ecology showed that the stomach contents of cows were not different from other animals and calves only had milk in the stomach. Consequently, calf samples are of less value for the studies of feeding ecology.

Interaction between Bryde's whale and minke whale

In the sub-area 7, remarkable spatial segregation was observed between minke and Bryde's whales. In minke whales, the sightings are limited along coastal region of Japan. In contrast, sightings of Bryde's whales are made in offshore region of the sub-area 7. They feed mainly on Japanese anchovy and/or krill. But the standard lengths of Japanese anchovy consumed by two whales are deferent. This deference is caused the deference of the size of prey species distributed in each area. However, there is deference of the standard length of Japanese anchovy between stomach contents sampled and samples by trawled net, but their cause was not clear whether it is to dependent on size preference of Bryde's whales. Therefore, further research might be necessary to clear their interaction in the future.

Interaction between Bryde's whales and skipjack tuna

Most of the Bryde's whale sightings occurred close to these fishing grounds of skipjack tuna in 2000 JARPNII feasibility survey, they feed mainly on Japanese anchovy. There seems a suggestion of a direct competition between Bryde's whales and skipjack tuna in summer in the western North Pacific. Therefore, further research might be necessary to clear their interaction in the future.

ACKNOWLEDGEMENTS

We are indebted to T. Bando, T. Mogoe, S. Otani, N. Kanda and G. Yasunaga of the Institute of Cetacean Research (ICR) who collected and weighed the stomach contents in JARPNII surveys. We would like to thank all captains, crews and researchers, who were involved in JARPNII surveys in 2000 and 2001. Our sincere thank to Dr. H. Hatanaka of the Fisheries Research Agency and 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 shyuuhennkaiiki ni seisokusuru gyorui no jiseki no hikakukeitaigakuteki kenkyuu [Preliminary keys to otoliths of fishes of Usujiri and adjacent waters in Southern Hokkaido, Japan]. Graduation Thesis, Hokkaido University. 98pp. [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. 96pp.

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

Haug, T., Gjøsæter, H., Lindstrøm, U. and Nilssen, K. T. 1995. Diets and food availability for

northeast Atlantic common minke whale *Balaenoptera acutorostrata* during summer 1992. *ICES J. mar. Sci.* 52:77-86.

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 habit 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 common minke whale management trials. *Rep. int. Whal. Commn.* 44:120-44.

Kato, H., Hiroyama, H., Fujise, Y. and Ono, K. 1989. Preliminary report of the 1987/88 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. Report of the International Whaling Commission, 39: 235-248.

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

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

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. 378pp.

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

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

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

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

Ohsumi, S. 1977. Bryde's whales in the pelagic whaling ground of the North Pacific. *Rep. int. Whal. Commn* (Special Issue 1):140-50.

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

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. *Fishery Bulletin*. 79:467-72.

Shimada, H. and Miyashita, T. 1996. Further estimation of Bryde's whale abundance in the western North Pacific incorporating sighting data in 1995 survey. SC/48/NP17. Paper submitted at 47th meeting of the IWC/SC. 9pp.

The Government of Japan. 2000. Research plan for cetacean studies in the western North Pacific under special permit (JARPNII) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC IWC Scientific meeting (unpublished). 68pp.

Table 1. Years, sub areas, small blocks, months of surveys and sample size used in this study.

Year (Numbers)	Sub area (Numbers)	Small block	Month	Sample size	Empty stomachs	Broken stomachs
2000	7	3-4	September	19	10	1
(43)		4	August	14	3	0
		6	August	4	1	0
		7	August	6	5	0
2001	7	3	May	2	1	0
(50)		3-4	June	19	5	0
		4	June	4	1	0
		4-5	June	10	3	0
		5	May	4	1	0
		-	July	11	2	2

Table 2. Prey species found in stomach of Bryde's whales sampled in this study.

Major prey species		
Krill		*Euphausia pacifica*
		E. similis
		Thysanoessa inspinata
Pisces	Japanese anchovy	*Engraulis japonicus*
	Chub mackerel	*Scomber japonicus*
Miner prey species		
Pisces	Russell's scad	*Decapterus russelli*
	Lantern fish	*Diaphus theta*
	Lantern fish	*Tarletonbeania taylori*
	Lantern fish	*Vinciguerria nimbaria*

Table 3. Geographical and temporal changes in stomach contents of 93 Bryde's whales sampled by JARPN II surveys in 2000 and 2001.

Year (Numbers)	Sub area (Numbers)	Small block	Month	Sample size	Empty stomachs	Broken stomachs	Prey species	Occurrence %	weight ingested %	CRI
2000	7	3-4	Sept.	19	10	1	Krill	25.0	17.9	4
(43)							Japanese anchovy	87.5	82.1	1
		4	Aug.	14	3	0	Krill	36.4	27.9	4
							Japanese anchovy	72.7	72.1	1
							Russell's scad	27.3	0.0	9
							Chub mackerel	18.2	0.0	12
		6	Aug.	4	1	0	Krill	50.0	66.7	1
							Japanese anchovy	25.0	33.0	4
							Russell's scad	25.0	0.3	6
		7	Aug.	6	5	0	Japanese anchovy	100.0	100.0	1
2001	7	3	May	2	1	0	Krill	100.0	100.0	1
(50)		3-4	June	19	5	0	Krill	100.0	100.0	1
							Lantern fish	14.3	0.0	4
		4	June	4	1	0	Krill	100.0	100.0	1
		4-5	June	10	3	0	Krill	85.7	85.7	1
							Chub mackerel	14.3	14.3	4
		5	May	4	1	0	Krill	100.0	100.0	1
							Lantern fish	33.3	0.0	4
		-	July	11	2	2	Krill	71.4	69.1	1
							Japanese anchovy	42.9	30.9	4

Table 4. The biological and stomach contents data of the mother and calf of Bryde's whales sampled by JARPN II surveys in 2000 and 2001.

	Year	Sample No.	Sample Date	Body Length (m)	Body weight (t)	Sex	Lactating	Forestomach Food type	Forestomach Content's weight (kg)	Comments
Mother										
	2000	B040	9.10	13.51	19.96	F	Y	Empty		
Calf										
	2000	B039	9.10	8.54	6.35	F		Empty		
Mother										
	2001	B002	5.27	12.39	14.30	F	Y	Krill	12.39	
	2001	B011	6.03	13.77	16.45	F	Y	Empty		
	2001	B016	6.06	13.11	16.40	F	Y	Krill	8.16	
	2001	B026	6.15	13.14	17.30	F	Y	Krill	Trace	
	2001	B030	6.16	12.55	14.25	F	Y	Krill	8.94	
	2001	B032	6.16	13.71	18.60	F	Y	Empty		
Calf	2001	B001	5.27	6.70	2.80	F		Empty		Like milk liquid in fundus, Krill in third stomach
	2001	B028	6.15	7.47	4.25	F		Empty		Like milk liquid and krill in third and fourth stomachs
	2001	B031	6.16	7.57	4.50	M		Empty		Like milk liquid in all stomachs
	2001	B010	6.03	7.80	4.00	M		Empty		Like milk liquid in third stomach
	2001	B015	6.06	8.07	4.44	F		Krill	Trace	
	2001	B025	6.15	8.20	5.39	M		Krill	0.15	
	2001	B029	6.16	8.57	6.00	F		Krill	2.51	

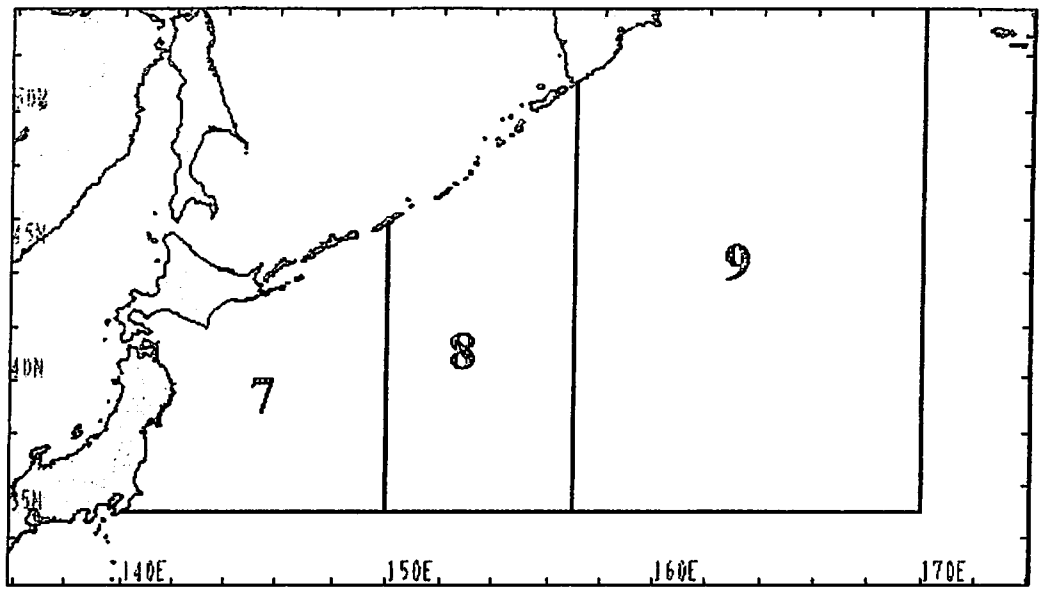


Fig. 1. Sub-areas surveyed by the JARPNII in 2000 and 2001. Sub-areas were based on IWC (1994), excluding the EEZ of foreign countries.

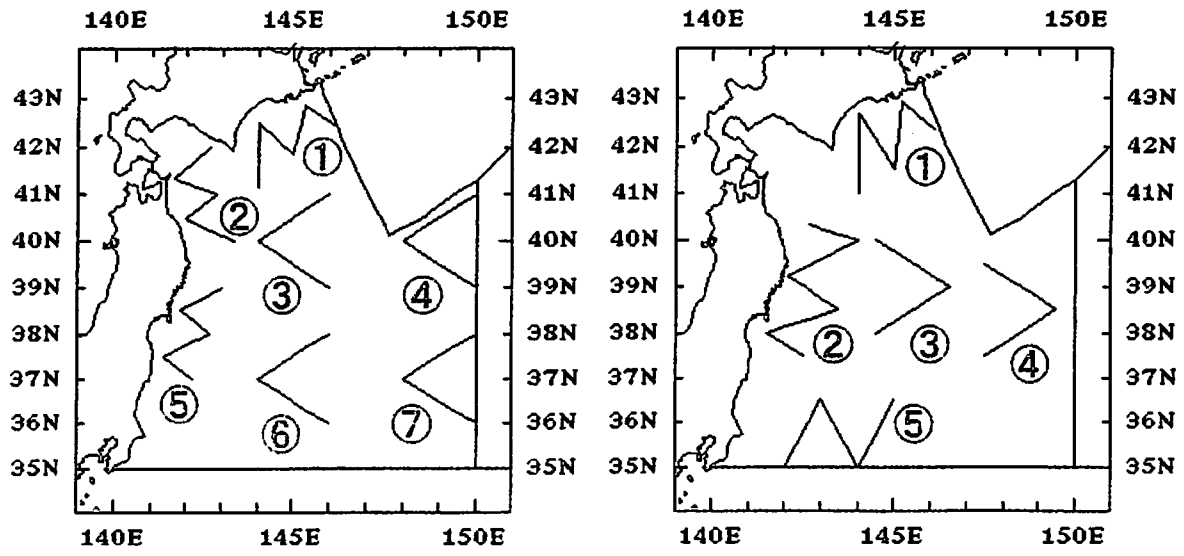


Fig. 2. Small blocks surveyed by the JARPNII in 2000 and 2001.

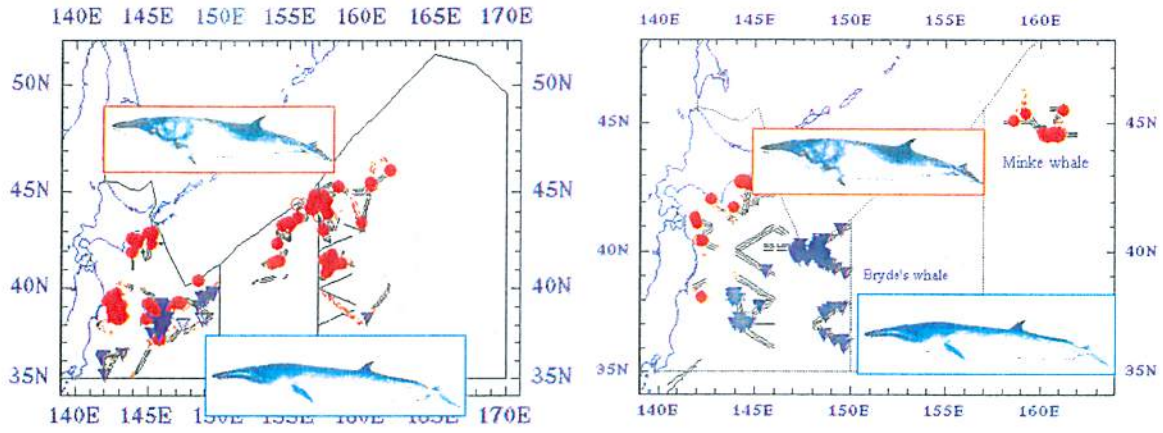
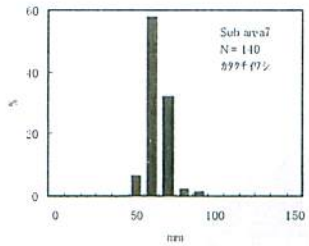
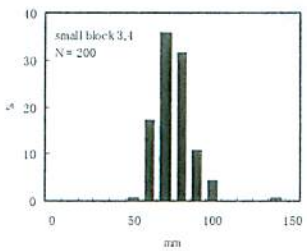


Fig. 3. Sighting position of minke whales (●) and Bryde's whales (▼) sampled by the JARPNII in 2000 and 2001.

Early period (2001)
Sub-area 7



Late period (2000)
Sub-area 7 · Small block 3-4



Small block 4

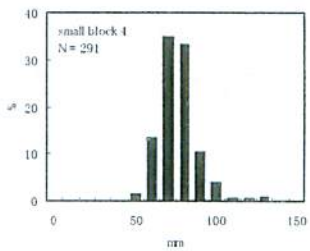
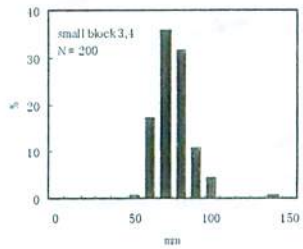


Fig. 4. Standard length frequency of Japanese anchovy consumed by Bryde's whales in 2000 and 2001.

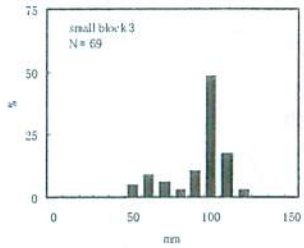
Late period (2000)

Sub-area 7 · Small block 3

Stomach contents

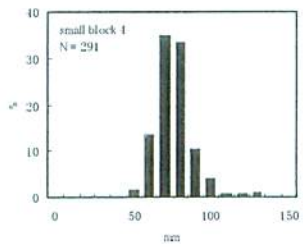


Sample by trawl net



Sub-area 7 · Small block 3-4

Stomach contents



Sample by trawl net

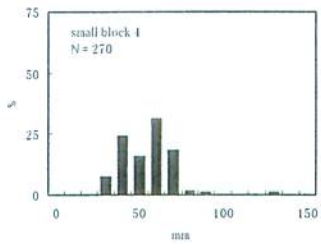


Fig. 5. Standard length frequency of Japanese anchovy consumed by Bryde's whales and sampled by trawl in 2000.

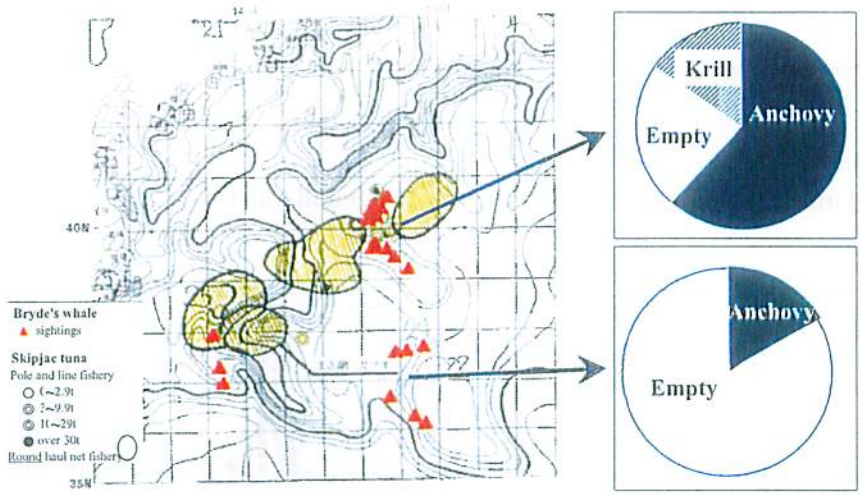


Fig. 6. Relationship between Bryde's whale sightings and the fishing grounds of skipjack tuna in the Northwest Pacific during summer 2000. The position of the sightings of Bryde's whales and the locations of the commercial fishing grounds for skipjack tuna in August (2 - 29) based on the thermal distribution during 23 to 29 August (Telex No. 1697 on fishing grounds in the North Pacific from off the the Japanese fisheries Information Center (JAFIC)). The later information was also obtained from the telex series Nos. 1697 – 1699 of the JAFIC.

Appendix 3

Food habit of sperm whales based on JARPN II

Tsutomu Tamura*, Tsunemi Kubodera**, Hiroshi Ohizumi*** and Yoshihiro Fujise*

*: *The Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan*

**: *National Science Museum, 3-23-1, Hyakunin-cho, Shinjuku-ku, Tokyo, 169-0026, Japan*

***: *National Research Institute of Far Seas Fisheries, 5-7-1, Orido, Shimizu, Shizuoka 424-0902, Japan*

ABSTRACT

The forestomach contents of 13 sperm whale (*Physeter macrocephalus*) sampled in the western North Pacific from May to September through 2000 - 2001 JARPN II feasibility surveys, were analyzed. Thirty-three prey species consisting of 29 squid, 1 octopus and 3 fish were identified. Results showed seasonal changes of prey species of sperm whales. They fed mainly on 1 fish (*Trachipterus ishikawae*) and 3 squids species (*Ancistrocheirus lesueuri, Histioteuthis dofleini* and *Ommastrephes bartrami*) in May and June. However, they fed mainly on 4 squids species (*Moroteuthis robusta, Gonatopsis borealis, Histioteuthis dofleini* and *Taonius pacifica borealis*) in July and August. The estimated contributtion rates (*CR*) for surface layer were ranged from 0 to 96 % (average: 17 %). the stomach contents weight ranged from 9.0 kg to 236.7 kg. These weights were equivalent to under 1.0% of body weigh of sperm whale.

INTRODUCTION

The sperm whale (*Physeter macrocephalus*) is distributed in the world from the equator to the edge of the polar pack ice area. The abundance of sperm whales in the western North Pacific was estimated to be 102,112 animals (CV=0.155)(Kato and Miyashita, 1998).

Many papers 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. According to this, the ratios of fishes in the stomach contents of sperm whales caught varies largely by different waters, and they occupy 1-68 %, and he listed the species. In the northern part of the west of 180 longitude fishes occupy 7-29 %. Squids were most dominant prey, and he listed the species. The most important prey species in Sanriku-Hokkaido area are neon flying squid *Ommastrephes bartrami*, Kurage ika *Histioteuthis dolfleini*, *Octopoteuthis* sp. and giant squid *Moroteuthis robusta*. Among the stomach contents data, the contents were 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 North Pacific.

Sperm whales seem to play an important role in the food web, especially, in the mesopelagic and deep sea from spring to autumn, because their abundance and biomass is huge. To understand their role in the marine ecosystem in Northwest Pacific, it is necessary to obtain more information of sperm whale food habit both qualitative and quantitative. However, since 1978, there have been few

published reports of their feeding habits in the North Pacific. Furthermore, the quantitative data of stomach contents were few until now.

In this study, prey species and prey size based on the stomach contents of 13 sperm whales sampled by JARPN II in the western North Pacific are examined. This result improves our knowledge of the feeding habits of sperm whales in this region.

MATERIALS AND METHODS

Research area and period

The sperm whales were sampled in sub-areas 7 excluding the EEZ of foreign countries. Fig. 1 shows the sighting positions of sperm whales sampled in 2000 and 2001. Table 1 shows the date, position, body length, body weight, sex and stomach contents weight of samples. The JARPNII surveys were conducted from August to September in 2000, from May to August in 2001. Sampled whales were immediately transported to a research base vessel, where biological measurements and sampling was carried out.

Sampling of stomach contents

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.

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, Okutani, 1995). The otoliths and jaw plate were used to identify the fish, squid and octopus with advanced stage of digestion (Kubodera and Furuhashi, 1987).

When undigested squid were found, mantle length and the weights were measured to the nearest 1 mm and 1 g, respectively.

The total number of each prey species in the sample was calculated by adding to the number of undigested prey, digested prey and buccal masses of squid and octopus and half the total number of free otoliths in forestomach and fundus. The total weight of each prey species in the sub-sample was added, apparently.

Feeding Indices

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.

Estimated contribution rates for surface layer

The estimated contribution rates for surface layer (*CR*) in each whale was calculated as follows:

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

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

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

RESULTS

Diversity of prey species

Thirty-three prey species consisting of 29 squid, 1 octopus and 3 fish, were identified (Table 2).

Composition of prey species in each sperm whale

Early period (May – June)

The occurrence (%) and apparent wet weight composition (%) of prey species consumed by sperm whales were shown on Table 3. They feed mainly on 1 fish (*Trachipterus ishikawae*) and 3 squids species (*Ancistrocheirus lesueuri*, *Histioteuthis dofleini* and *Ommastrephes bartrami*). The apparent wet weight composition (%) of fish were 0-39 %. The estimated contributtion rates for surface layer were ranged from 0 to 96 % (average: 18 %).

Late period (August – September)

The occurrence (%) and apparent wet weight composition (%) of prey species consumed by sperm whales were shown on Table 4. They feed mainly on 4 squids species (*Moroteuthis robusta, Gonatopsis borealis, Histioteuthis dofleini* and *Taonius pacifica borealis*). The apparent wet weight composition (%) of fish were 0-8 %. The estimated contributtion rates for surface layer were ranged from 0 to 48 % (average: 17 %).

Size frequency of prey species in each sperm whale

Late period (August – September)

The size frequency of *Taonius pacifica borealis*, *Histioteuthis dofleini* and *Gonatopsis borealis* is shown in Fig. 2.

Taonius pacifica borealis

The dorsal mantle length of *Taonius pacifica borealis* ingested by sperm whales ranged from 360 to 612 mm with a single mode at 495 mm (Fig. 2A).

Histioteuthis dofleini

The dorsal mantle length of *Histioteuthis dofleini* ingested by sperm whales ranged from 107 to 210 mm with a single mode at 154 mm (Fig. 2B).

Gonatopsis borealis

The dorsal mantle length of *Gonatopsis borealis* ingested by sperm whales ranged from 261 to 298 mm with a single mode at 284 mm (Fig. 2C).

Weight and freshness of stomach contents and freshness in each sperm whale

Early period (May – June)

In 2001 JARPNII, the stomach contents weight ranged from 9.0 kg to 82.6 kg. These weights were equivalent to under 1.0% of body weigh of sperm whale. The freshness of stomach contents showed fff (2 inds.), ff (1 inds.) and f (4 inds.). 1 individual was empty (Table 1).

Late period (August – September)

In 2000 JARPNII, the stomach contents weight ranged from 47.0 kg to 236.7 kg. These weights were equivalent to under 1.0% of body weigh of sperm whale. The freshness of stomach contents showed fff (3 inds.) or ff (2 inds.) (Table 1).

DISCUSSIONS

Diversity of prey species

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.

Squids were most dominant in the stomach contents of sperm whales, and he listed the species. The most important prey species in Sanriku-Hokkaido area are *Histioteuthis dolfleini*, *Octopoteuthis* sp., *Moroteuthis robusta* and *Ommastrephes bartrami*.

According to this report, the ratios of fishes in the stomach contents of sperm whales caught varies largely by different waters, and they occupy 1-68 %. In Sanriku-Hokkaido area rockfishes occupy 14%, cods 30% and Pacific saury, Japanese pilchard and sharks 14 %, respectively. In the northern part of the west of 180° fishes occupy 7-29 %, and he listed these fish species.

In 2000 and 2001 JARPNII surveys, deep-sea squids and fish were most dominant prey in the stomach contents of sperm whales. The most important prey species in JARPNII surveys are 1 fish (*Trachipterus ishikawae*) and 3 squids (*Ancistrocheirus lesueuri*, *Histioteuthis dofleini* and *Ommastrephes bartrami*).

There seems to be the seasonal and geographical change of prey species. It need the additional samples to clear these change in the future.

Daily prey consumption and feeding activity

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 not exceed 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 2 – 4 % of their body weight and calculated as 300 kg and 200 kg for males and females, respectively. According to this calculation, the sperm whale might feed on prey for several times. The sperm whale generally feed on prey near the surface during night. However, they also feed on prey during day in the mesopelagic and/or bottom.

The application of this result for ecopath & ecosym model

The sperm whales are considered to be the deep sea squid feeder. In this research, they fed mainly on deep-sea squids. However, it was reported that they fed mainly on mesopelagic and/or bottom fishes in other region (Iceland, Bering Sea, West of Canada and New Zealand) (Pike, 1950; Okutani and Nemoto, 1964; Gaskin and Cawthorn, 1967; Roe, 1969). The neon-flying squid (*O. bartrami*) which was found in the stomach contents is one of the important commercial squids, and therefore

there is a possibility of direct competition with fishery.

To clear the food habit of sperm whales, and the relation to surface ecosystem, more seasonal and yearly data is needed.

ACKNOWLEDGEMENT

We are indebted to T. Bando, T. Mogoe, S. Otani, N. Kanda and G. Yasunaga of the Institute of Cetacean Research (ICR) who collected and weighed the stomach contents in JARPNII surveys. We would like to thank all captains, crews and researchers, who were involved in JARPNII surveys in 2000 and 2001. We appreciate very much the helpful sorting and analyzing to Mr. T. Isoda and Ms. I. Kouda. Our sincere thank to Dr. H. Hatanaka of the Fisheries Research Agency and Dr. Luis A. Pastene of the Institute of Cetacean Research (ICR) for their valuable suggestions and useful comments on this paper.

REFERENCES

Betesheva, F. I. And I. I. Akimushkin, 1955. Food of the sperm whale (*Physeter catodon* L.) in the Kurile Island region. *Trudy Inst. Okeamol.* 18: 86-94. (in Russian).

Berzin, A. 1971. The sperm whale (translated into English in 1972). Israel Program for Scientific translation. 394pp.

Clarke, M. R. 1977. Beaks, nets and numbers. *Sym. Zool. Soc. London*, 38: 89-126.

Gaskin, D. E. and Cawthorn, N. W. 1967. Diet and feeding habits of the sperm whales (*Physeter catodon* L.) in the Cook Strait region of New Zealand. N. Z. J. mar. Freswat. Res. 1 (2) 159-79.

Kato, H. and Miyashita, T. 1998. Current status of the North Pacific sperm whales and its preliminary abundance estimates. Paper SC/50/CAWS2 presented to the IWC Scientific Committee, May 1998 (unpublished). 13pp. [Available from the author].

Kawakami, T. 1980. A review of food of sperm whale food. *Sci. Rep. Whales Res. Inst.* 32:199-218.

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. 65pp. [In Japanese].

Okutani, T. and Nemoto, T. 1964. Squids as thefood of sperm whale in the Bering Sea and Alaskan Gulf. *Sci. Rep. Whales Res. Inst.* 18: 111-121.

Okutani, T. (1980) Biology of cephalopoda-9 Systematics and life history of enoploteuthidae (2). Aquabiology, Vol2, No. 4, 278-282.

Okutani, T. 1995. Cuttlefish and squids of the world in color. *National Cooperative Association of Squid Processors*. 185pp.

Pike, G. C. 1950. Stomach contents of whales caught off the coast of British Columbia. *Prog. Rep. Pacif. Cst. Stns*, 83: 27-8.

Roe, H. S. J. 1969. The food and feeding habits of sperm whales (*Physeter catodon* L.) taken off the west coast of Iceland. J. Cons. Int. Explor. Mer., 33 (1): 93-102.

Table 1. The biological and stomach contents data of sperm whales sampled by JARPN II surveys in 2000 and 2001.

2000NP

No.	Small block	Sampling date	Sighting time	Sighting position N. Lat.	Sighting position E. Long.	Length (m)	Weight (t)	Sex	Weight of s. c. (kg)*	Ratio of body weight (%)	Freshness of s. c.
1	1	2000.8.06	12.03	41 10.0	144 7.7	11.3	19.7	M	196.6	1.0	fff
2	4	2000.8.22	12.03	40 45.4	149 26	12.8	30.4	M	236.7	0.8	fff
3	7	2000.8.28	11.36	37 0.0	148 14	11.6	21.4	F	170.0	0.8	ff
4	6	2000.8.31	11.11	37 30.3	144 46	8.8	10.2	M	46.8+	0.5+	fff
5	3	2000.9.05	9.03	39 59.4	144 2.6	8.2	7.5	F	77.4	1.0	ff

2001NP

No.	Small block	Sampling date	Sighting time	Sighting position N. Lat.	Sighting position E. Long.	Length (m)	Weight (t)	Sex	Weight of s. c. (kg)*	Ratio of body weight (%)	Freshness of s. c.
1		2001.5.14	13.01	37 37.0	142 30.1	9.2	10.9	F	82.6	0.8	f
2		2001.5.28	9.15	36 28.0	142 58.4	10.2	14.4	M	10.0	0.1	f
3		2001.5.28	16.31	35 32.4	142 29.9	10.2	16.2	F	31.5	0.2	fff
4		2001.6.01	11.04	35 9.4	144 14.6	9.7	11.8	F	76.0	0.6	fff
5		2001.6.02	12.23	36 51.4	145 30.7	9.0	10.8	M	74.2	0.7	ff
6		2001.6.09	6.43	37 36.9	146 27.3	10.2	15.5	F	9.0	0.1	
7		2001.6.09	17.5	37 16.0	146 50.0	9.1	11.8	F	11.9	0.1	f
8		2001.6.14	7.39	38 43.6	146 43.4	11.0	21.9	F	35.3	0.2	f

* : Including forestomach, fundas and third stomach contents

s. c. : stomach contents

Table 2. The prey species of sperm whales in 2000 and 2001.

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

	Scientific name	Japanese name or English name	Occurences in past
Cephalopoda			
	Enoploteuthis chuni	ホタルイカモドキ(Hotaruikamodoki)	
	Ancistrocheirus lesueuri	ダイオウホタルイカモドキ(Daiouhotaruikamod(	○
	Taningia danae	ヒロビレイカ(Hirobire-ika)	○
	Octopoteuthis sicula	ヤツデイカ(Yatude-ika)	○
	Octopoteuthis deletron	キタノヤツデイカ(Kitanoyatsude-ika)	
	O. megaptera	タイセイヨウヤツデイカ(Taiseiyouyatsude-ika)	
	O. sp.	ヤツデイカの仲間(M)(Yatude-ika sp. M size)	
	O. sp.	ヤツデイカの仲間(L)(Yatude-ika sp. L size)	
	Onychoteuthis borealijaponica	ツメイカ(Clubhook squid)	
	O. banksi	ホンツメイカ(Hontsume-ika)	
	Moroteuthis loennbergi	カギイカ(Kagi-ika)	○
	M. robusta	ニュウドウイカ(Giant squid)	○
	Gonatus berryi	ベリィテカギイカ(Berryi tekagi-ika)	
	G. pyros	ヒカリテカギイカ(Hikaritekagi-ika)	
	G. middendorffi	カムチャッカテカギイカ(Kamutyakatekagi-ika)	
	Eogonatus tinro	ニセテカギイカ(Nisetekagi-ika)	
	G. spp.	テカギイカの仲間 (Tekagi-ika sp.)	
	Gonatopsis borealis	タコイカ(Eight-armed squid)	○
	Histioteuthis dofleini	クラゲイカ(Kurage-ika)	○
	H. corona inermis	ゴマフイカ(Gomafu-ika)	
	H. meleagroteuthis	シラタマイカ(Shiratama-ika)	
	Architeuthis martensi	ダイオウイカ(Daiou-ika)	
	Ommastrephes bartrami	アカイカ(Neon flying squid)	○
	Pholidoteuthis sp.	ヤワライカの仲間 (Yawara-ika sp.)	
	Discoteuthis discus	ウチワイカ (Utiwa-ika)	
	Cycloteuthis akimushkini	オオウチワイカ (Ohutiwa-ika)	
	Chiroteuthis imperator	ユウレイイカ (Yuurei-ika)	
	C. calyx	ツクシユウレイイカ (Tsukushiyuurei-ika)	○
	Asperoteuthis acanthoderma	シチクイカ (Shitiku-ika)	
	Galiteuthis pacifica	スカシイカ (Sukashi-ika)	
	Galiteuthis sp.	スカシイカの仲間 (Sukashi-ika sp.)	
	Taonius pacifica borealis	クジャクイカ (Kujyaku-ika)	○
	Megalocranchia maxima	オオホウズキイカ (Ohhouzuki-ika)	
	Megalocranchia sp.	オオホウズキイカの一種 (Ohhouzuki-ika sp.)	
	Cranchidae sp.		
	Unidentified squids	不明イカ類	
	Alloposus mollis	カンテンダコ (Kanten-tako)	
Pisces	*Trachipterus ishikawae*	サケガシラ (King of salmon)	
	Laemonema longipes	イトヒキダラ (Threadfin hakeling)	○
	Theragra chalcogramma	スケトウダラ (Walleye pollock)	○

Table 3. 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		Ref.	Remarks
	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %		
Cephalopoda														
Enoploteuthis chuni													3	Day time: 300-900 m; Nigh time: Upper 200m
Ancistrocheirus lesueuri	34.5	55.6			25.0	14.3	7.6	2.2	21.3	25.9			1	Night time: Upper 100m (DML is under 35mm)
Taningia danae							9.1	1.7					1	Night time: Upper 180m (Sub-adult); Upper 1,200m (Adult)
Octopoteuthis sicula													1	Day time: Lower 200m, especially 300-500m. Night time: Lower 500m (DML is under 15mm)
Octopoteuthis deletron					12.5	0.7			7.9	5.7			1	Day time: Lower 200m, especially 300-400m. Night time: Lower 500m (DML is under 15mm)
* *O. megaptera*							3.0	2.2					2	Day time: Mid-bottom water; Night time: Surface layer
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*													2	Surface layer
** *O. banksi*													1	Upper 150 m
* *Moroteuthis loennbergi*	24.1	5.6							1.1	1.4			2	From surface layer to bottom layer
M. robusta													1	Under 100m of bottom layer
Gonatus berryi													1	Day time: 500-800 m; Nigh time: 400-800m (Sub-adult)
G. pyros	3.4	ND	16.7	ND			10.6	ND					1	Day time: 400-700m, Night time: 150-500m especially 300-400m (DML is under 20mm)
G. middendorffi													1	Day time: 400-500m, Night time: Upper 300m (DML is under 21mm)
Eogunatus tinro													2	From surface layer to bottom layer
G. spp.			16.7	1.9			9.1	3.3	1.1	ND	25.0	ND		
* *Gonatopsis borealis*													1	Day time: 400-800m (DML is 16-47mm), Night time: 0-400m
Histioteuthis dofleini	34.5	35.5			18.8	5.4	4.5	9.5	38.2	27.6			1	Day time: 500m, Night time: 50m (DML is 12-14mm)
H. corona inermis									2.2	0.4			1	Day time: 600m (DML is 25-27mm)
H. meleagroteuthis													1	Day time: 700m, Night time: 400m (DML is 16-32mm)
Architeuthis martensi													1	From 200-1200 m
* *Ommastrephes bartrami*			33.3	95.8									4	Day time: 300-400m, Night time: Surface layer
Pholidoteuthis sp.					6.3	14.6							1,2	Day time: Bottom layer (400-2,000m), Night time: Mid layer
Discoteuthis discus							1.5	ND					1	Day time: upper 750m, Night time: upper 400m (DML is under 53mm)
Cycloteuthis akimushkini							1.5	4.4					1	Day time: Upper 650m, Night time: Upper 200m
Chiroteuthis imperator									1.1	ND			2	From mid layer to bottom layer
C. calyx							1.5	1.7	1.1	1.1			1	Day time: 500-800m, Night time: 0-500m (Sub-adult)
Asperoteuthis acanthoderma							1.5	3.2					2	From mid layer to bottom layer
Galiteuthis pacifica							7.6	2.1	20.2	3.2	75.0	ND	1	Day time: lower 900m, Night time: 0-1200m (Sub-adult)
Galiteuthis sp.														
Taonius pacifica borealis			16.7	2.3	12.5	0.5	7.6	1.0	4.5	0.5			1	Day time: 600-800m (DML is under 60mm)
Megalocranchia maxima													2	Mid layer
Megalocranchia sp.							1.5	0.5						
Cranchidae sp.														
Unidentified squids			16.7	ND	3.1	ND	4.5							
Alloposus mollis													1	0-3,200 m, especially 0-200m, 450-1,000m
Pisces														
Trachipterus ishikawae							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	3.0	2.2	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	3.0	2.2	1.1	1.4	0.0	0.0		
Estimated contribution rate of surface *											10.3	17.5		
Estimated contribution rate of surface *+**											10.3	17.5		

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

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 Number %	S001 Weight %	S002 Number %	S002 Weight %	S003 Number %	S003 Weight %	S004 Number %	S004 Weight %	S005 Number %	S005 Weight %	Ref.	Remarks
Cephalopoda												
Enoploteuthis chuni											3	Day time: 300-900 m; Nigh time: Upper 200m
Ancistrocheirus lesueuri	1.6	ND			1.6	3.1					1	Night time: Upper 100m (DML is under 35mm)
Taningia danae					1.6	2.4					1	Night time: Upper 180m (Sub-adult); Upper 1,200m (Adult)
Octopoteuthis sicula			0.8	0.2					1.2	0.1	1	Day time: Lower 200m, especially 300-400m, Night time: Lower 500m (DML is under 15mm)
Octopoteuthis deletron											1	Day time: Lower 200m, especially 300-400m, Night time: Lower 500m (DML is under 15mm)
* *O. megaptera*											2	Day time: Mid-bottom water; Night time: Surface layer
O. sp. (Type M)												
O. sp. (Type L)												
** *Onychoteuthis borealijaponica*			0.8	2.8					1.2	ND	2	Surface layer
** *O. banksi*											1	Upper 150 m
* *Moroteuthis loennbergi*							3.3	2.0			2	From surface layer to bottom layer
M. robusta	2.1	40.2			3.2	16.1					1	Under 100m of bottom layer
Gonatus berryi					1.6	0.2					1	Day time: 500-800 m; Nigh time: 400-800m (Sub-adult)
G. pyros											1	Day time: 400-700m, Night time: 100-500m especially 300-400m (DML is under 20mm)
G. middendorffi	0.5	0.2					1.7	0.1	2.3	0.3	1	Day time: 400-800m, Night time: Upper 500m (DML is under 21mm)
Eogonatus tinro									1.2	0.1	2	From surface layer to bottom layer
G. spp.	0.5	0.2							8.1	0.1		
* *Gonatopsis borealis*			0.8	2.9			15.0	30.2	36.0	48.4	1	Day time: 400-800m (DML is 16-47mm), Night time: 0-400m
Histioteuthis dofleini	34.7	29.2	11.9	25.5	79.0	77.3	28.3	44.5	4.7	19.0	1	Day time: 500m, Night time: 50m (DML is 12-14mm)
H. corona inermis											1	Day time: 600m (DML is 25-27mm)
H. meleagroteuthis											1	Day time: 700m, Night time: 400m (DML is 16-32mm)
Architeuthis martensi	0.5	8.5									1	From 200-1200 m
* *Ommastrephes bartrami*											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							3.3	1.8			1	Day time: upper 750m, Night time: upper 400m (DML is under 53mm)
Cycloteuthis akimushkini											1	Day time: Upper 650m, Night time: Upper 200m
Chiroteuthis imperator									1.2	0.1	2	From mid layer to bottom layer
C. calyx			1.6	1.6							1	Day time: 500-800m, Night time: 0-500m (Sub-adult)
Asperoteuthis acanthoderma											2	From mid layer to bottom layer
Galiteuthis pacifica	4.7	0.5	1.6	0.5			18.3	6.6	7.0	2.3	1	Day time: lower 900m, Night time: 0-1200m (Sub-adult)
Galiteuthis sp.	1.1	0.2			1.6	0.0						
Taonius pacifica borealis	48.9	13.0	82.5	66.6	6.5	0.2	13.3	5.2	34.9	29.2	1	Day time: 600-800m (DML is under 60mm)
Megalocranchia maxima							15.0	6.3			2	Mid layer
Megalocranchia sp.												
Cranchidae sp.					4.8	0.7						
Unidentified squids	2.1	ND							2.3	0.4		
Alloposus mollis							1.7	3.4			1	0-3,200 m, especially 0-200m, 450-1,000m
Pisces												
Trachipterus ishikawae	0.5	3.6										
Laemonema longipes	0.5	ND										
Theragra chalcogramma	0.5	ND										
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		

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

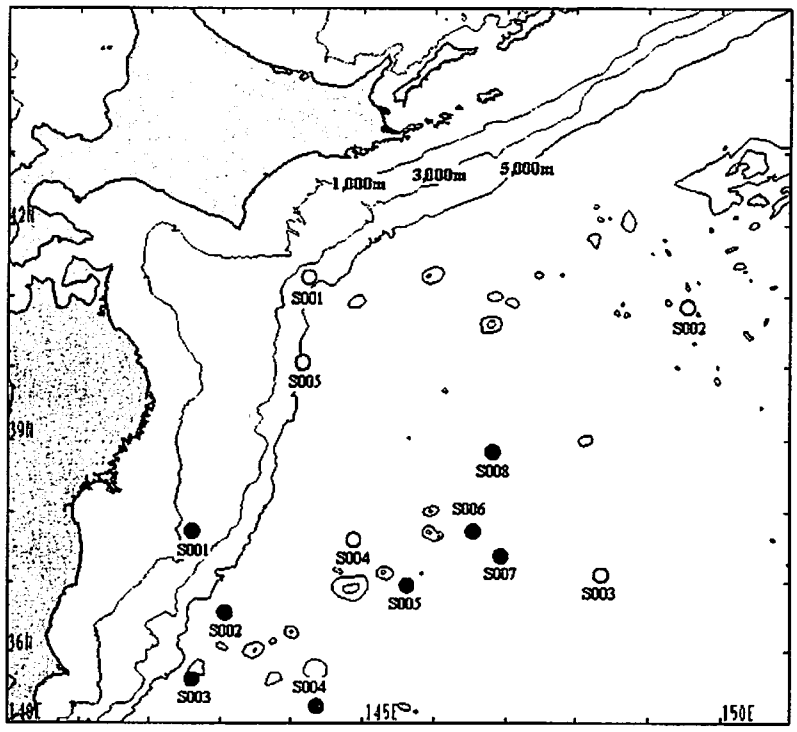
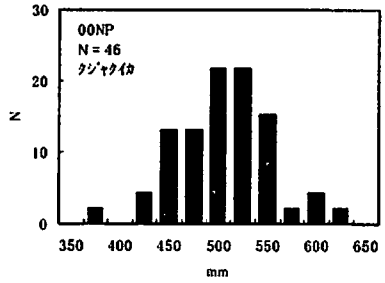
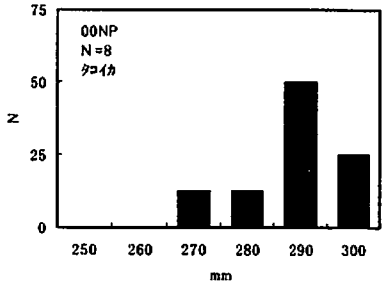


Fig. 1. The sighting positions of sperm whale sampled in 2000 JARPNII (○) and 2001 JARPNII (●).

(A) *Taonius pacifica borealis,*



(B) *Histioteuthis dofleini*



(C) *Gonatopsis borealis*

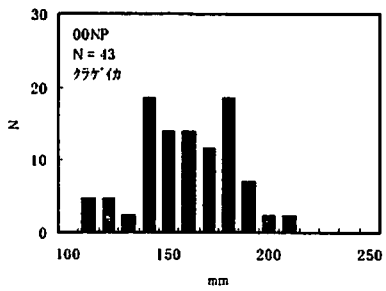


Fig. 2. The body length of dominant prey species consumed by sperm whale in 2000 JARPNII.

Appendix 4

Daily and seasonal prey consumption by common minke whale and Bryde's whale in the western North Pacific

Tsutomu Tamura and Yoshihiro Fujise

The Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

Daily prey consumption of common minke whale (*Balaenoptera acutorostrata*) and Bryde's whale (*B. edeni*) in the western North Pacific was estimated using two methods: 1) diurnal change in the forestomach and fundus content weight and 2) field metabolism. A total of 116 forestomach and fundus of minke whales and 90 forestomach and fundus of Bryde's whales sampled by JARPNII surveys from 2000 to 2001 were examined. Estimations were made by sexual maturity stage. Estimates of the daily prey consumption rate obtained by the method–1 were 4.6 and 4.0 % of body weight of minke whale and Bryde's whale if the proportion of the rest of prey after 8 hours was 20 %, respectively. Estimates of the daily prey consumption rate obtained by the method–2, ranged from 1.4 to 8.2 % and 3.3 to 8.2 % of body weight of minke whale and Bryde's whale, respectively.

INTRODUCTION

At the present, the study of prey consumption of baleen whales was few, because the weight of stomach contents was difficult to measure on the deck. There are some information of full stomach contents weight and/or richness.

Sergeant (1969) indicated that there is reverse correlation relation between the prey consumption weight per day and their body weight based on eight species of dolphins. The daily prey consumption rate of all cetaceans was calculated to be 4-13% of their body weight and 4% of body weight of mature baleen whales.

Also, Lockyer (1981a) made the reassessment of the growth and energy requirement of the large baleen whale in the Southern Hemisphere based on the basal metabolism and it was calculated 4% of body weight of mature baleen whales for daily prey consumption. The feeding activity was estimated to be twice or three times per day based on diurnal change of stomach contents fullness. Their activity were conducted especially in the morning and evening. Full stomach contents were 1-2 % of their body weight, so the daily prey consumption of baleen whales were estimated 4% (Bushuev, 1986). Tamura *et al.* (1997) estimated that the daily prey consumption of Antarctic minke whale (*Balaenoptera bonaerensis*) was 4% based on diurnal change of stomach contents and their energy requirement from JARPA surveys. In the North Pacific, Tamura and Fujise (2000a) estimated to be the daily prey consumption of common minke whale (*B. acutorostrata*) were estimated 4% based on diurnal change of stomach contents and their energy requirement from JARPN surveys between 1994 and 1999.

One of the purposes of JARPNII research was to obtain the information about their food habit and to estimate the daily and/or yearly prey consumptions in each prey species with good precision. Furthermore, the data from this research will be used for ecosystem model such as Ecopath-type

model and Multspec-type models.

In this paper, the daily and feeding period's prey consumption of minke whale and Bryde's whale (*B. edeni*) were tried to calculate using two different methods. In these two methods, several biological parameters were obtained directly from minke whale and Bryde's whale in the western North Pacific through 2000 and 2001 JARPNII surveys.

MATERIALS AND METHODS

Research area, year and sample size

The research area of the JARPNII was sub-areas 7, 8 and 9 which were established by the IWC/SC (IWC, 1994), excluding the EEZ of Russia (Fig. 1). The survey months, years and sample size in each sub-area are shown in Table 1. A total of 116 forestomach and fundus of minke whales and 90 forestomach and fundus of Bryde's whales sampled by JARPNII surveys from 2000 to 2001 were examined.

Sampling of stomach contents of minke and Bryde's whales

Minke and Bryde's 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. The total number and weight of each prey species in the forestomach were estimated by using the figures obtained from the sub-sample and the total weight of forestomach contents.

Estimation of daily prey consumption

Estimation of daily prey consumption from diurnal change in stomach content weight (Method-1)

Miura (1969) proposed a method for estimating daily prey consumption from diurnal changes in stomach content weight (Vi) with the time of passage based on a known digestion rate in the stomach. If the proportion of prey digested during an interval is d and the proportion of rest of prey (S) is $1-d$, the amount of prey consumed (Ci) is given by the following equations:

$$t_1: C_1 = V_1$$
$$t_2: C_2 = V_2 - SV_1$$
$$t_3: C_3 = V_3 - SV_2 - S^2V_1$$
$$t_i: C_i = V_i - SV_{i-1} - S^2V_{i-2} \cdots - S^{i-1}V_1$$

The daily prey consumption ($\sum_{i=1}^{k} C_i$) is given by:

$$\sum_{i=1}^{k} C_i = V_1 \frac{(1-2S+S^k)}{1-S} + V_2 \frac{(1-2S+S^{k-1})}{1-S} + \cdots + V_{k-1}(1-S) + \cdots + V_k \qquad (1)$$

In this analysis the mean forestomach and fundus content weight as percentage of body weight (V_i) at 1 hour intervals were expressed. Assuming that prey takes 8 hours to digest the stomach contents and that d is exponential (Elliott and Persson, 1978), S was estimated to be 0.69 if the proportion of the rest of prey after 8 hours is 20 % (Tobayama, 1974; Bushuev, 1986; Sekiguchi, 1994).

In this method, it was assumed that minke whales and Bryde's whales did not feed during night (Folkow and Blix, 1993; Zhongxue *et al.*, 1983, Haug *et al.*, 1997, Tamura and Fujise, 2000B and this 2000 and 2001 JARPNII surveys). Estimations were made by sex and sexual maturity stages.

Estimation of daily prey consumption from the field metabolism (Method-2)

The daily consumption of each prey species (F) by different maturity stages of minke whale and Bryde's whale were calculated from the standard metabolic rate (SMR), pregnancy energy contents and growth energy contents according to the following equations (Blix and Folkow, 1995):

Immature male and female, mature male: F (kg day^{-1}) = $SMR \times 365/D\ /E\ /A$

Mature female: F (kg day^{-1}) = $(SMR \times 365/D\ /E+R)/A$

SMR	: Standard metabolic rate (kJ day^{-1})
D	: Residence time (days)
E	: Caloric value of prey species (kJ kg^{-1})
G	: Growth cost (kg day^{-1})
R	: Reproduction cost (kJ day^{-1})
A	: Assimilation efficiency

The following assumptions were made for both methods.

A: Mean body weight (W)

The mean body weight of 2,500 kg and 2,600 kg for immature male and female of minke whale were calculated, respectively. For mature male and female of minke whale were 4,800 kg and 5,900 kg, respectively. The mean body weight of 8,400 kg and 7,500 kg for immature male and female of Bryde's whale were calculated, respectively. For mature male and female of Bryde's whale were 15,600 kg and 17,500 kg, respectively. These weights were obtained during JARPNII survey data.

B: Residence time in the western North Pacific (D)

It was assumed that the minke whales and Bryde's whale spend about 180 days in the feeding areas in the western North Pacific (Ohsumi, 1980, 1982). Lockyer (1981b) reported that the daily prey consumption of minke whale in winter was equivalent to 10 % of that in the summer. These assumptions for estimating the feeding days were used.

The following assumptions were made for method-2.

C: Standard metabolic rate (*SMR*)
We calculated the *SMR* according to Blix and Folkow (1995):

Immature male or female: $SMR = 1.58 \times 80W$ (kJ day^{-1})
Mature male or female: $SMR = 80W$ (kJ day^{-1})

The average *SMR* used in these calculations was obtained from Blix and Folkow (1995). The value used of 80 kJ/kg per day is based on indirect determination of oxygen consumption from studies of the respiratory rates of a number of similar sized free swimming minke whales performing different activities, such as feeding, cruising and sleeping. Additional data on lung volumes, oxygen extraction and tidal volume were also used in these calculations.

D: Caloric value of prey species (*E*)
Stomach contents analyses show large variations in the diet of minke whales in the western North Pacific (Kasamatsu and Tanaka, 1992; Tamura *et al.*, 1998). In the North Atlantic, the energy contents of the prey species varies from 900 kcal kg^{-1} when feeding on *Parathemisto* spp. to as high as 3,000 kcal kg^{-1} when feeding on herring (Markussen *et al.*, 1992). In this study, the mean caloric value of krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese common squid (*Todarodes pacificus*) were calculated using bomb caloric meter (Table 2).

E: Reproduction cost (*R*)
The total reproductive cost for female minke whales and female Bryde's whales were re-calculated to be 1.9×10^7 kJ, 3.4×10^7 kJ (Lockyer, 1981a), assuming a length at birth fetus of 280 kg (Christensen, 1981), 390kg, respectively (Ohsumi, 1977; Doi, 1978). The pregnancy rate is 95 % for mature. All energy related to reproduction costs as obtained during the residence (feeding) time in the western North Pacific (*D*) were assumed.

G: Assimilation efficiency (*A*)
That minke whales and Bryde's whale have an assimilation efficiency of 80 % were assumed (Markussen *et al.*, 1992).

The total prey consumption during feeding period
The feeding period were divided up early period (May-June; 60days) and late period (July-October; 120days). The total prey consumption during feeding period per individual was estimated in each sub-area using the composition of prey species in JARPN and JARPNII results.

RESULTS

Minke whale
The average and maximum stomach contents weight of five dominant prey species (krill, Japanese anchovy, Pacific saury, walleye Pollock and Japanese common squid), *S.D.* of average stomach contents weight, the average and maximum stomach contents weight as percentage of body weight were shown in Table 3. Estimated the average stomach contents are ranged from 25.0 kg (Pacific saury) to 146.2 kg (Japanese common squid). The maximum stomach contents are ranged from 76.1

kg (Pacific saury) to 306.8 kg (Japanese anchovy). The maximum stomach contents weight as percentage of body weight are ranged from 1.9 % (Pacific saury) to 6.1 % (Japanese anchovy).

Fig. 1 shows the diurnal change with time (hourly) of the mean forestomach and fundus content weight as percentage of body weight. The daily prey consumption rates based on method-1 were calculated to be 4.6 % of body weight (114.8 – 270.8 kg) for both sexes if the proportion of undigested prey after 8 hours was 20 %. The daily prey consumption rates based on method-2 were calculated to be 1.4-8.2 % of body weight (55.3 – 338.1 kg) for both sexes.

Table 5 shows the component of stomach contents of minke whales in each period (early and late) and sub-area (7, 8 and 9) based on JARPN and JARPNII. Using these values, the total prey consumption were calculated per individual during feeding period (May-October). Based on the average of two methods, the estimated total prey consumption weights during feeding period in sub area 7 were 22 t for immature male and female, and 33 t and 43 t for mature male and female, respectively (Table 6).

Bryde's whale

The estimated average and maximum stomach contents weight of two dominant prey species (krill, Japanese anchovy), *S.D.* of average stomach contents weight, the average and maximum stomach contents weight as percentage of body weight were shown in Table 3. Estimated the average stomach contents are ranged from 71.1 kg (krill) to 354.3 kg (Japanese anchovy). The maximum stomach contents are ranged from 369.5 kg (krill) to 1,184.3 kg (Japanese anchovy). The maximum stomach contents weight as percentage of body weight are ranged from 3.6 % (krill) to 6.6 % (Japanese anchovy).

Fig. 2 shows the diurnal change with time (hourly) of the mean forestomach and fundus content weight as percentage of body weight. The daily prey consumption rates based on method-1 were calculated to be 4.0 % of body weight (300.0 – 700.0 kg) for both sexes if the proportion of undigested prey after 8 hours was 20 %. The daily prey consumption rates based on method-2 were calculated to be 3.3-8.2 % of body weight (394.5 – 937.9 kg) for both sexes.

Table 5 shows the component of stomach contents of minke whales in each period (early and late) and sub-area (7, 8 and 9) based on JARPN and JARPNII. Using these values, the total prey consumption were calculated per individual during feeding period (May-October). Based on the average of two methods, the estimated total prey consumption weights during feeding period in sub area 7 were 68 t and 61 t for immature male and female, respectively and 101 t and 115 t for mature male and female, respectively (Table 6).

DISCUSSIONS

There are large differences of average and maximum of stomach contents of minke whale and Bryde's whale among prey species. It is necessary to obtain more information of each prey species in the future.

The estimates of the daily food consumption rate obtained by the two methods, were not substantially different. However, there are same aspects of these methods, which should be considered. Firstly under method-1, we considered that minke whales and Bryde's whale do not feed during night (Folkow and Blix, 1993; Zhongxue *et al.*, 1983, Tamura and Fujise, 2000b and this research). If feeding activity also occurred at night, the daily food consumption rates using method-1

would underestimate the actual food consumption rates. Furthermore, we made assumptions on the digestion rate in the stomach, which was the same for all prey species. These rates might be different by prey species. It might be necessary to collect more information on the digestion rate of each prey species in the future.

Regarding to method-2, data was lacked on the information of caloric value of prey species for each sub-area and month. The caloric value of prey species might change among areas and months. For example the caloric value of Pacific saury was known to change during northward migration (spring) and during southward-migration (autumn) (Odate, 1977). It might be necessary to obtain more information on the caloric value of prey species on seasonal, areal and annual basis in the future.

Any estimate of the daily prey consumption rate of minke whales and Bryde's whales obtained by the two methods in this study was similar to the estimates by Markussen *et al.* (1992), which investigated the eastern North Atlantic minke whales and these obtained by Lockyer (1981b), which investigated the large baleen whales.

In addition, more data are needed on seasonal, local and annual variations in the prey of minke whales and Bryde's whales before conclusions can be drawn with regard to their food consumption in western North Pacific from spring to autumn.

REFERENCES

Blix, A. S. and Folkow, L. P. 1995. Daily energy expenditure in free living minke whales. *Acta Physiol. Scand.*, 153:61-6.

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

Christensen, I. 1981. Age, determination of minke whale, *Balaenoptera acutorostrata,* from laminated structures in the tympanic bullae. *Rep. int. Whal. Commn.* 31:245-53.

Doi, N. 1978. The theory of body weight of whales. *Geiken tsuushin* 318. 57-64. [in Japanese].

Elliott, J. M. and Persson, L. 1978. The estimation of daily rates of food consumption for fish. *J. Animal Ecol.* 47:977-91.

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.

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

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.

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.

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

Whal. Commn 31:337-43.

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

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

Miura, T. 1969. *Research methods of the productivity of limnological life*. Koudansya. Tokyo. 168-71. [in Japanese].

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:3. 53-61.

Ohsumi, S. 1977. Bryde's whales in the pelagic whaling ground of the North Pacific. *Rep. int. Whal. Commn* (Special Issue 1):140-50.

Ohsumi, S. 1980. Minke whales in the coastal waters of Japan, 1978. *Rep. int. Whal. Commn* 30: 307-11.

Ohsumi, S. 1982. Minke whales in the coastal waters of Japan in 1980 and a population assessment of the

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.

Sekiguchi, K.1994. Studies on feeding habits and dietary analytical methods for smaller odontocete species along the Southern African coast. Ph. D. thesis, University of Pretoria. 259pp.

Sergeant, D.E. 1969. *Feeding rates of cetacea*. Fisk Dir Skr Ser HavUnders 15:246-58.

Tamura, T., Ichii, T, and Fujise, Y. 1997. Consumption of krill by minke whales in Area IV and V of the Antarctic. Paper SC/M97/17 presented to the JARPA review meeting, May 1997 (unpublished). 9pp.

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. *Fisheries Science* 64(1): 71-6

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.

Tobayama, T. 1974. Studies on the feeding habits of the little toothed whales. Ph. D. thesis, University of Tokyo. 231pp. [In Japanese].

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].

Table 1. Sample size used in this study.

Minke whale

Year (Number)	Sub-area	Month	Sample size	Empty stomach	Broken stomach
2000	7	8	6	0	0
(40)		9	18	1	1
	9	8	16	0	4
2001	7	5	28	0	5
(100)		6	22	0	1
	8	7	21	0	3
	9	7	24	0	1
		8	5	1	0

Bryde's whale

Year (Number)	Sub-area (Number)	Month	Sample size	Empty stomach	Broken stomach
2000	7	8	24	9	0
(43)		9	19	10	1
2001	7	5	6	2	0
(50)		6	33	9	0
		7	11	2	2

Table 2. Results of caloric value of dominant prey species of minke and Bryde's whales in western North Pacific.

Species	Size	Body length	Body weight	Caloric value KJ / kg
Krill				3,556
Japanese anchovy				
	Small	86 mm	7 g	5,523
	Large	125 mm	18 g	6,402
Pacific saury				
	Small	158 mm	16 g	5,272
	Large	300 mm	145 g	13,138
Walleye pollock		430 mm	624 g	6,192
Japanese common squid		206 mm	200 g	6,611

Table 3. Results of caloric value of dominant prey species of minke and Bryde's whales in western North Pacific.

Minke whale

Species	Mean (kg)	S.D. (kg)	Mean (%)	Max. (kg)	Max. (%)
Krill	43.7	47.7	0.9	163.8	3.1
Japanese anchovy	33.7	49.0	0.9	306.8	6.1
Pacific saury	25.0	22.2	0.5	76.1	1.9
Walleye pollock	53.3	67.5	1.2	221.6	4.3
Japanese common squid	146.2	0.8	2.5	146.8	2.5

Bryde's whale

Species	Mean (kg)	S.D. (kg)	Mean (%)	Max. (kg)	Max. (%)
Krill	71.1	82.2	0.6	369.5	3.6
Japanese anchovy	354.3	316.5	1.7	1,184.3	6.6

Table 4. Estimated daily prey consumption (kg and as % of body weight) during feeding period by minke whales and Bryde's whales (Method-1, Method-2).

Minke whale

1. Method-1

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	114.8	4.6
Immature female	2,600	119.3	4.6
Mature male	4,800	220.3	4.6
Mature female	5,900	270.8	4.6

2. Method-2

A. Krill

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	204.3	8.2
Immature female	2,600	212.4	8.2
Mature male	4,800	248.2	5.2
Mature female	5,900	338.1	5.7

B. Japanese anchovy

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	113.5	4.5
Immature female	2,600	118.0	4.5
Mature male	4,800	137.9	2.9
Mature female	5,900	187.8	3.2

C. Pacific saury (small)

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	137.8	5.5
Immature female	2,600	143.3	5.5
Mature male	4,800	167.4	3.5
Mature female	5,900	228.0	3.9

D. Pacific saury (large)

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	55.3	2.2
Immature female	2,600	57.5	2.2
Mature male	4,800	67.2	1.4
Mature female	5,900	96.6	1.6

E. Walleye pollock

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	117.3	4.7
Immature female	2,600	122.0	4.7
Mature male	4,800	142.5	3.0
Mature female	5,900	194.2	3.3

F. Japanese common squid

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	2,500	109.9	4.4
Immature female	2,600	114.3	4.4
Mature male	4,800	133.5	2.8
Mature female	5,900	181.9	3.1

Bryde's whale

1. Method-1

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	8,400	336.0	4.0
Immature female	7,500	300.0	4.0
Mature male	15,600	624.0	4.0
Mature female	17,500	700.0	4.0

2. Method-2

A. Krill

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	8,400	686.3	8.2
Immature female	7,500	612.8	8.2
Mature male	15,600	806.7	5.2
Mature female	17,500	937.9	5.4

B. Japanese anchovy

Sex maturity	Body weight	Consumption	
	kg	kg	%
Immature male	8,400	441.9	5.3
Immature female	7,500	394.5	5.3
Mature male	15,600	519.4	3.3
Mature female	17,500	603.9	3.5

Table 5. Stomach contents (% in weight) of minke and Bryde's whales in the western North Pacific.

Minke whale

Research periods		Area 7		Area 8		Area 9	
		Prey species	%	Prey species	%	Prey species	%
JARPN	May-June	Japanese anchovy	91.6	Japanese anchovy	92.2	Japanese anchovy	81.4
		Walleye pollock	5.2	Pacific saury	2.9	Pacific saury	12.9
		Krill	1.8	Krill	2.9	Krill	3.1
		Others	1.4	Others	2.0	Others	2.6
	July-Sept.	Pacific saury	53.2	Pacific saury	84.5	Pacific saury	76.6
		Krill	35.6	Japanese anchovy	10.2	Krill	8.7
		Walleye pollock	11.1	Krill	1.9	Japanese anchovy	8.2
		Others	0.1	Others	3.3	Others	6.6
JARPN II	May-June	Japanese anchovy	63.5				
		Krill	23.4				
		Walleye pollock	12.7				
		Others	0.3				
	July-Sept.	Walleye pollock	39.5	Pacific saury	88.3	Pacific saury	67.6
		Japanese anchovy	31.8	Japanese anchovy	5.6	Japanese anchovy	28.3
		Japanese common squid	15.0	Krill	5.2	Krill	3.1
		Krill	8.2	Others	0.8	Others	0.9
		Pacific saury	5.5				

Bryde's whale

Research periods		Area 7		Area 8		Area 9	
		Prey species	%	Prey species	%	Prey species	%
JARPN II	May-June	Krill	96.4				
		Other	3.6				
	July-Sept.	Japanese anchovy	62.2				
		Krill	37.8				

JARPN : Japanese Whale Research Program under Special Permit in the Western North Pacific (1994-1999)
JARPN II: Japanese Whale Research Program under Special Permit in the Western North Pacific : Phase II (2000-2001)

Table 6. Prey consumption during feeding period (tons) of minke and Bryde's whales based on JARPN II data in each sub-area in the western North Pacific.

Minke whale

I. Sub-area 7

Method-1					Method-2					Average				
May-June (90 days)	IM	IF	MM	MF	May-June (90 days)	IM	IF	MM	MF	May-June (90 days)	IM	IF	MM	MF
Krill	1.6	1.7	3.1	3.8	Krill	2.9	3.0	3.5	4.7	Krill	2.2	2.3	3.3	4.3
Japanese anchovy	4.4	4.5	8.4	10.3	Japanese anchovy	4.3	4.5	5.3	7.2	Japanese anchovy	4.3	4.5	6.8	8.7
Walleye pollock	0.9	0.9	1.7	2.1	Walleye pollock	0.9	0.9	1.1	1.5	Walleye pollock	0.9	0.9	1.4	1.8
Others	0.02	0.02	0.04	0.05	Others					Others	0.02	0.02	0.04	0.05
Total	6.9	7.2	13.2	16.2	Total	8.1	8.4	9.8	13.4	Total	7.5	7.8	11.5	14.8
July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF
Krill	1.1	1.2	2.2	2.7	Krill	2.0	2.1	2.4	3.3	Krill	1.6	1.6	2.3	3.0
Japanese anchovy	4.4	4.6	8.4	10.3	Japanese anchovy	4.3	4.5	5.3	7.2	Japanese anchovy	4.4	4.5	6.8	8.8
Walleye pollock	5.4	5.7	10.4	12.8	Walleye pollock	5.6	5.8	6.8	9.2	Walleye pollock	5.5	5.7	8.6	11.0
Pacific saury	0.8	0.8	1.5	1.8	Pacific saury	0.4	0.4	0.4	0.6	Pacific saury	0.6	0.6	0.9	1.2
Common squid	2.1	2.1	4.0	4.9	Common squid	2.0	2.1	2.4	3.3	Common squid	2.0	2.1	3.2	4.1
Total	13.8	14.3	26.4	32.5	Total	14.2	14.8	17.3	23.6	Total	14.0	14.6	21.9	28.1
Total	**20.7**	**21.5**	**39.6**	**48.7**	**Total**	**22.3**	**23.2**	**27.1**	**37.0**	**Total**	**21.5**	**22.4**	**33.4**	**42.9**

II. Sub-area 8

Method-1					Method-2					Average				
July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF
Krill	0.7	0.7	1.4	1.7	Krill	1.3	1.3	1.5	2.1	Krill	1.0	1.0	1.5	1.9
Japanese anchovy	0.8	0.8	1.5	1.8	Japanese anchovy	0.8	0.8	0.9	1.3	Japanese anchovy	0.8	0.8	1.2	1.5
Pacific saury	11.5	11.9	22.0	27.1	Pacific saury	5.5	5.7	6.7	9.7	Pacific saury	8.5	8.8	14.4	18.4
Others	0.1	0.1	0.2	0.3	Others					Others	0.1	0.1	0.2	0.3
Total	13.1	13.6	25.1	30.8	Total	7.6	7.9	9.2	13.0	Total	10.4	10.8	17.2	22.1

III. Sub-area 9

Method-1					Method-2					Average				
July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF
Krill	0.4	0.4	0.8	1.0	Krill	0.8	0.8	0.9	1.3	Krill	0.6	0.6	0.9	1.1
Japanese anchovy	3.9	4.1	7.5	9.2	Japanese anchovy	3.9	4.0	4.7	6.4	Japanese anchovy	3.9	4.0	6.1	7.8
Pacific saury	9.3	9.7	17.9	22.0	Pacific saury	4.5	4.7	5.5	7.8	Pacific saury	6.9	7.2	11.7	14.9
Others	0.1	0.1	0.2	0.3	Others					Others	0.1	0.1	0.1	0.1
Total	13.8	14.3	26.4	32.5	Total	9.1	9.5	11.1	15.5	Total	11.4	11.9	18.7	24.0

Bryde's whale

I. Sub-area 7

Method-1					Method-2					Average				
May-June (90 days)	IM	IF	MM	MF	May-June (90 days)	IM	IF	MM	MF	May-June (90 days)	IM	IF	MM	MF
Krill	19.4	17.4	36.1	40.5	Krill	26.1	23.3	30.7	35.7	Krill	22.8	20.3	33.4	38.1
Others	0.7	0.6	1.3	1.5	Others					Others	0.7	0.6	1.3	1.5
Total	20.2	18.0	37.4	42.0	Total	26.1	23.3	30.7	35.7	Total	23.5	21.0	34.8	39.6
July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF	July-Oct. (120 days)	IM	IF	MM	MF
Krill	15.2	13.6	28.3	31.8	Krill	15.6	13.9	18.3	21.3	Krill	15.4	13.8	23.3	26.5
Japanese anchovy	25.1	22.4	46.6	52.2	Japanese anchovy	33.0	29.4	38.8	45.1	Japanese anchovy	29.0	25.9	42.7	48.7
Total	40.3	36.0	74.9	84.0	Total	48.5	43.3	57.1	66.3	Total	44.4	39.7	66.0	75.2
Total	**60.5**	**54.0**	**112.3**	**126.0**	**Total**	**74.7**	**66.7**	**87.8**	**102.1**	**Total**	**68.0**	**60.7**	**100.7**	**114.8**

*: IM: Immature male, IF: Immature female, MM: Mature male, MF: Mature female

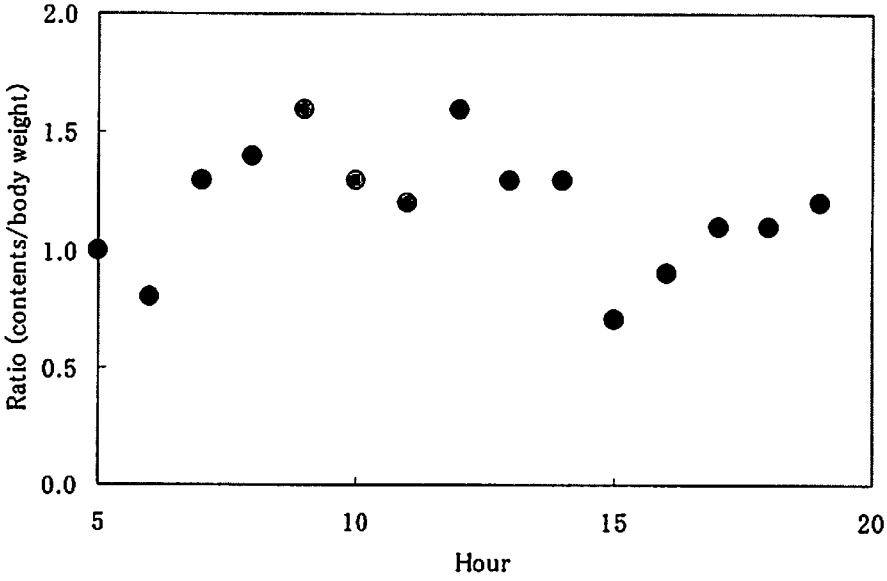


Fig. 1. Diurnal change inch the mean stomach contents as the percentage of body weight of minke whale.

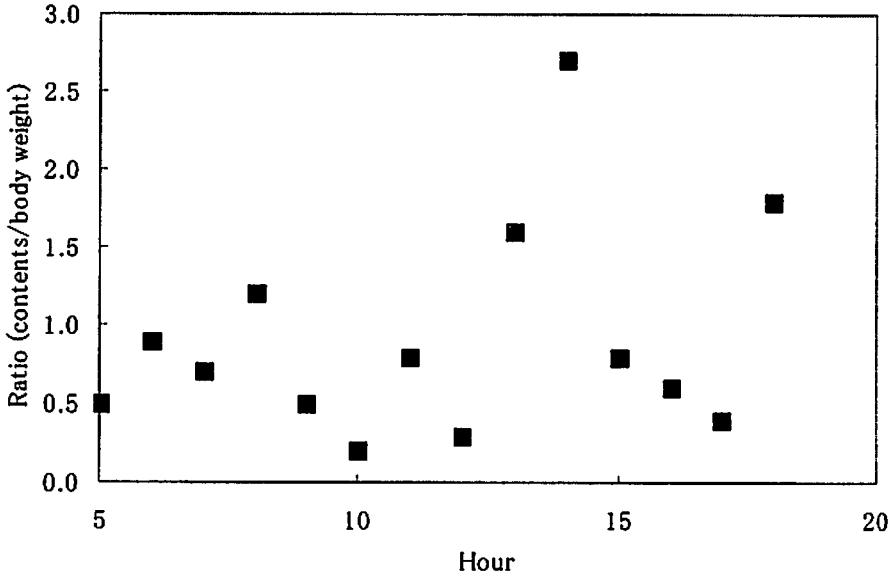


Fig. 2. Diurnal change inch the mean stomach contents as the percentage of body weight of Bryde' s whale.

Appendix 5

Preliminary estimation of prey preference of minke and Bryde's whales based on JARPN II

Hiroto Murase*, Tsutomu Tamura*, Kiwada Hiroshi*, Yoshihiro Fujise*, Hikaru Watanabe+, Hiroshi Ohizumi+, And Shigeyuki Kawahara+

* The Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku Tokyo, 104-0055, Japan
+ National Research Institute of Far Seas Fisheries, Fisheries Research, Agency, 5-7-1, Orido, Shimizu, 424-8633, Japan
Contact e-mail: murase@i-cetacean-r.or.jp

ABSTRACT

Preliminary analysis of prey preference of common minke and Bryde's whales in the western North Pacific was conducted using 2000 and 2001 JARPN II feasibility study data. Whale sighting and sampling survey and prey survey using quantitative echosounder and mid-water trawl were carried out concurrently in the study. The aim of this paper is to estimate prey preference of cetaceans that is important parameter in most ecosystem models. Biomasses of Japanese anchovy, walleye pollock and krill which were major prey species of minke and Bryde's whales were estimated using the echosounder. Cheeson's index was used to assess the prey preference of cetaceans. Preliminary results suggested that minke whale preferred to Japanese anchovy while they seemed to avoid krill. Preference to pelagic shoaling fish was similar to that in the eastern North Atlantic. Bryde's whale preferred to feed on Japanese anchovy in August in 2000, but such a preference could not be detected from May to July in 2001. In earlier season, Japanese anchovy was less abundant except the larva in Bryde's whale distribution area. Though results of prey preference study using feasibility study data is preliminary, it suggests that the concurrent whale and prey surveys adopted in the JARPN II feasibility survey can provide prey preference of cetaceans.

INTRODUCTION

Wide variety of prey species of common minke whales (*Balaenoptera acutorostrata*) in the western North Pacific was qualitatively described using commercial whaling data (Omura and Sakiura, 1956; Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992). Those were including Japanese anchovy (*Engraulis japonicus*), Japanese pilchard (*Sardinops melanostictus*), sand lane (*Ammodytes personatus*), chub mackerel (*Scomber japonicus*), walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), Pacific herring (*Clupea pallasi*), krill, copepods and squids. Quantitative feeding ecology study of minke whale was conducted from 1994 to 1999 in the Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN) (Tamura and Fujise, 2000). The study showed the large variation of main prey species with area, season and year. The most important prey species in May and June was Japanese anchovy, and it changed to Pacific saury in July and August. In 2000 when the commercial catch of Pacific saury decreased extremely, however, the main prey was Japanese anchovy even after July. Then, krill was the most important prey species in September. Walleye pollock was also one of the important prey species in June and September in coastal water region. Though Bryde's whale (*Balaenoptera edeni*) fed on Japanese anchovy, Japanese pilchard, horse mackerel

(*Trachurus japonicus*), chub mackerel, lantern fish and krill (Nemoto, 1959), those data came from commercial whaling data and no quantitative analysis has been conducted so far.

Because those two cetacean species fed on target species of commercial fisheries, development of multispecies model including cetacean in the western North Pacific is desirable from the marine living resources management and conservation perspectives. Prey preference of cetaceans is one of the important parameters in the most ecosystem models. In addition to the preference, biomass of each species is also important in the models. The whale and the prey surveys must be conduced concurrently to estimate the prey preference and the biomass. For that reason JARPN phase II was planed to conduct the concurrent whale and prey surveys (The Government of Japan, 2000). As the concurrent whale and prey surveys had never been conducted in the western North Pacific, a feasibility study was planned in 2000 and 2001.

This paper presents the preliminary result of the prey preference study of minke and Bryde's whales in the two-year feasibility study. Underlying questions are (1) whether minke and Bryde's whales show any prey preference and (2) whether the survey methods are appropriate to estimate the prey preference.

MATERIALS AND METHODS

Survey area, period and vessels

The research area of the concurrent whale and prey surveys was off the Pacific coast of the northern Japan (Fig. 1). The northern part of the research area was under the influence of Oyashio flow (cold low-salinity water) whereas southern part of the area was under the influence of Kuroshio (warm high-salinity water). Area between Oyashio flow and Kuroshio is called as Kuroshio-Oyashio inter-frontal zone or transitional zone. Seven small blocks (one of them was not surveyed) and five small blocks with additional three special blocks were set within the area in 2000 and 2001 respectively. The small blocks were predetermined mainly based on the information on the sea surface temperature just before the survey while the special blocks were set adoptively where target whale species were abundant. The concurrent survey was conducted in August 2000 and from mid-May to mid-July in 2001. Three vessels; *Yushin-Maru* (YS1: 720GT), *Kyo-Maru No. 1* (K01: 812GT) and *Toshi-Maru No. 25* (T25: 739GT) were engaged in the whale survey consisting of sighting and sampling of whales. Stomach contents of sampled minke and Bryde's whales were examined on the research base ship, *Nisshin-Maru* (NM: 7,575GT). Two vessels; *Kyoshin-Maru No. 2* (KS2: 368GT) and *Shunyo-Maru* (SYO: 396GT) were engaged in the prey survey in 2000. KS2 conducted the acoustic survey as well as XCTD castings and plankton net samplings. SYO conducted two types of mid-water trawlings and for CTD observations. During the daytime, KS2 steamed at 10-11 knots along the track line while conducting cetacean sightings. SYO followed KS2 at the distance of 1-2 nautical miles so that SYO could cast a mid-water trawl to identify the species of marks on the echosounder. *Torishima* (TOR: 426 GT) took over SYO in 2001.

Stomach content analysis

Each stomach content was weighted nearest 0.1 kg, then sub samples were taken and frozen for laboratory analysis on the research mother ship. In the laboratory, prey species were identified to the lowest taxonomic level as possible. The total weight of each prey species in the forestomach was estimated applying the weight ratio in the sub samples to the total weight of forestomach contents. Detail of stomach content analysis was described by Tamura and Fujise (2002a) and Tamura and Fujise (2002b). Animals with empty stomachs and destroyed stomachs by harpoon were not used in the analysis. Prey species less than 1% of total stomach content weights

were not included in this analysis. Proportion of occurrence of prey species in the stomachs was described by following three indices (Lindstrøm and Haug, 2001). First, frequency of occurrence of each prey species (F_j) in terms of number of stomachs is calculated as;

$$F_j = \frac{f_j}{f_t}$$

where f_j is number of stomach that contain prey species j whereas f_t is total number of stomach that have contents. Second, relative frequency of prey species by weight (B_i) is calculated as;

$$B_i = \frac{\sum b_{ij}}{\sum b_{tj}}$$

where b_{ij} is weight (kg) of prey species i in jth animal and b_{tj} is total amount of stomach contents of jth animal. Third, mean relative frequency by weight (MB_i) is calculated as;

$$MB_i = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{b_{ij}}{b_{tj}}\right)$$

where n is total number of stomachs that have contents and, b_{ij} and b_{tj} are same as mentioned above.

Acoustic data collection

A quantitative echo sounder (Simrad EK500 with software version 5.30) was operated during daytime on board KS2 to acquire acoustic data with operating frequency at 38, 120 and 200 kHz. The transducers were hull-mounted at the depth of 4.3 m from the sea surface. Each transducer was covered with a 40 mm polycarbonate acoustic and the hydraulic oil filled the space between the transducer surfaces and the acoustic windows. Calibrations were carried out off Kushiro, Hokkaido just before the survey (27 July) in 2000 and at Sendai Bay after the survey (17 July) in 2001 using the copper sphere technique described in EK 500 operation manual (Simrad, 1997). Data were stored with the aid of Simrad BI 500 post processing system in 2000 and SonarData Echoview version 2.10.51 in 2001.

Trawling

Two types of trawlings were made; targeting and predetermined trawlings. The targeting trawlings were made to identify the species when dense marks were detected by the echosounder. The mid-water trawl net was towed at the depth of the marks for 30 minutes to 1 hour. Another type of trawlings was made at predetermined stations in each small block during the daytime. The predetermined trawlings were made to estimate prey abundance independently from the acoustic survey. Acoustic abundance estimation is difficult for some prey species, as the back scattering from cephalopods is low and pacific saury mainly occurs in the surface layer. The predetermined trawls were towed for one hour; 20 minutes at each depth zone (0–30m, 30– 60m and 60–90m). Also nighttime trawlings were made at some of the daytime stations to sample meso-pelagic fishes and squids that showed diurnal migration. The nighttime trawlings were conducted about 1 hour after the sunset. For both types of trawlings, the same trawl net was used with the opening mouth of 30x30m and a liner (17.5mm mesh) attached to the cod end. Scammer Transducers were attached to near the mouth to monitor the net condition. Towing speed was 3-4 knots. Catches were sorted into species and weighed. For the major species, 100 animals were sampled at random and the length was measured. A part of samples were frozen at –30°C for further analysis in the laboratory.

Acoustic data analysis

Acoustic data were analyzed with the aid of SonarData Echoview (version 2.10.51) software at the laboratory. In principle, species were identified based on the trawl catches especially from targeting trawlings. For Japanese anchovy and walleye pollock, data collected at 38 kHz were used with the threshold set at -60dB and the depth range from 7m to 100m in 2000 and from 10 m to 250m in 2001 were analyzed. The integration was made at an interval of one nautical mile by 10 m depth interval in 2000 and by 50m depth interval in 2001. For krill, data collected at 120 kHz were used with the threshold set at –80 dB. The analyzed depth range was from 12m to 250m by 50 m depth intervals. Echoes were identified as krill if ΔSV (the difference of SV between 38 and 120) falls between 10 and 15 dB (Miyashita *et al.*, 1997).

Mean backscattering area pre square nautical mile of sea surface (s_A) by species for every 1 n. mile of survey transect over defined depth interval was calculated by following formula;

$$s_A = 4\pi r_0^2 1852^2 \int_{f_1}^{f_2} s_V dr \left(\frac{m^2}{n.mi^2}\right)$$

where r is depth from the sea surface, r_0 = 1m representing the reference range for backscattering strength. A length-target-strength (TS) relationship for Japanese anchovy (Anonymous, 1990) was used;

$$TS = 20LogTL - 72.5$$

where TL is total length in cm. A length-weight relationship for Japanese anchovy (Anonymous, 1990) was used;

$$W_t = 0.004TL^{3.09}$$

where W_t is weight in gram.

A length-target-strength (TS) relationship for walleye pollock (Foote and Traynor, 1988) was used;

$$TS = 20LogFL - 66$$

where FL is folk length.

A length-weight relationship for walleye pollock (Pereyra *et al.*, 1981) was used;

$$W_t = 0.0077FL^{2.906}$$

where W_t is weight in gram.

We assumed that all krill observed during two surveys was *Euphphausia pacifica* and length and TS were 16.4mm and –83.3 dB (Miyashita *et al.*, 1996), respectively because no length-TS relationship for krill was available in this area. The average weight was 30.6 mg calculated using formula described by Odate (1987).

Average area biomass density ($\bar{\rho}$) for each species was calculated as follows;

$$\bar{\rho} = \sum \frac{S_A}{\sigma} f_i W_{ti}$$

where f_i is frequency distribution of each length class. The acoustic cross section (σ) was converted from TS as followed;

$$\sigma = 4\pi 10^{0.1TS}$$

Frequency distribution of each class (fi) that is the acoustical contribution to the area back scattering for each length class (Ona, 1993);

$$f_i = \sum_{j=1}^{\infty} n_j L_j^2$$

where n_j is the number of individuals in size class j and the length is L.

Following procedures were adopted from Jolly and Hampton (1990). Weighted mean of S_A of each block was;

$$\overline{S_{Ak}} = \frac{\sum_{i=1}^{N_k} \overline{S_{Aki}}(n_{ki})}{\sum_{i=1}^{N_k} n_{ki}}$$

where $\overline{S_{Ak}}$ = mean S_A in kth block, N_k = number of transects in kth block, $\overline{S_{Aki}}$ = mean S_A on the *i*th transect in kth block and n_{ki} = number of 1 n. mile averaging intervals on the *i*th transect in kth block. In this formula, each transect was regarded as a single biomass density sample. Then variance of $\overline{S_{Ak}}$ was calculated with the formula (Jolly and Hampton, 1990);

$$Var(\overline{S_{Ak}}) = \frac{N_k}{N_k - 1} \frac{\sum_{i=1}^{N_k} (\overline{S_{Aki}} - \overline{S_{Ak}})^2 n_{ki}^2}{\left(\sum_{i=1}^{N_k} n_{ki}\right)^2}$$

$\overline{S_A}$ was converted to $\overline{\rho}$ using above motioned formula. Biomass was estimated as;

$$B_k = A_k \rho_k$$

where B_k is density biomass in kth block and A_k is area of kth block. Variance of B_k was calculated with following formula;

$$var(B_k) = A_k^2 \, var(\overline{\rho_k})$$

Coefficient of variation of B_k was calculated as;

$$CV(B_k) = \frac{\sqrt{var(B_k)}}{B_k}$$

Prey preference analysis

Though there are several preference indices, Chesson's index (Chesson, 1978) was successfully applied to the North Atlantic stock of minke whale to reveal prey selectivity (Lindstrøm and Haug, 2001). Chesson's index is also called as Manly's α (Krebs, 1999). In this analysis, Chesson's index was used. Chesson's index (α_i) for prey species i was calculated using following formula;

$$\alpha_i = \frac{r_i}{n_i} \left(\frac{1}{\sum_{j=1}^{m} r_j / n_j} \right)$$

where α_i is Chesson's index for prey species i, r_i is frequency of occurrence of species i in the stomach content, n_i is frequency of occurrence of prey species i in given survey block, r_j is frequency of occurrence of species j in the stomach content, n_j frequency of occurrence of prey species i in given survey block and m is number of prey species occurred in given survey block. The α values are normalized so that;

$$\sum_{i=1}^{m} \alpha_i = 1.0$$

If α_i is equal to 1/m, species i is randomly selected. If α_i greater than 1/m, species i is actively selected. If α_i less than 1/m, species i is avoided.

RESULTS

Stomach contents

A total of 49 minke and 34 Bryde's whales were used in the analysis. Sighting positions of sampled animals were shown in Fig. 2. Summary of stomach contents were shown in Table 1. Five animals of minke whales and fifteen animals of Bryde's whales could not used in the analysis because of either empty stomachs or damaged stomachs by harpoon.

Minke whale

Japanese anchovy was found in the stomachs of minke whales in all small blocks from late May to early August. Thirty five out of forty nine animals fed on Japanese anchovy. Walleye pollock was found only in small block 1 in 2001 which located off the coast of eastern Hokkaido. Eight animals fed on walleye pollock. Krill was found in three small blocks from May to June in 2001. Seasonal comparison can be made only in small block 2 in 2000 and 2001. Stomach contents were Japanese anchovy in May and August. The result suggested that Japanese anchovy was most important prey in small block 2 though coverage were slightly different from 2000 to 2001.

Six stomachs contained two prey species; one individual fed on both Japanese anchovy and krill in special block B in 2001 but proportion of Japanese anchovy was less than 0.01% of total stomach contents weights. One individual in small block 1 in 2001 fed on both walleye pollock and krill. The ratio was 3:7. Four individuals in small block 1 in 2001 fed on Japanese anchovy and walleye pollock. Ratios were varied from 8:2 to 2:8.

Bryde's whale

Japanese anchovy was found in the stomachs of Bryde's whales in small block 4 in August, 2000 and in special block C in July, 2001. Krill was found in all small blocks from May to August. Eleven stomach contained Japanese anchovy while twenty-five stomachs contained krill. Two stomachs contained both Japanese anchovy and krill. Proportion of Japanese anchovy to total stomach contents was less than 1% in one animal while it was 30% in another.

Prey species distribution and abundance

Horizontal distribution

Horizontal distributions of Japanese anchovy, walleye pollock and krill were shown in Fig.3. Distribution pattern of Japanese anchovy well reflected water temperature at 50m depth. Japanese anchovy was scarce in the southern part of survey area where influence of Kuroshio was strong. It was abundant in small area 2 in August 2000 and May 2001. Japanese anchovy in small block 1 was abundant in 2000 but scarce in 2001. The difference might be accounted for by the seasonal migration to the north in August. Walleye pollock was only found continental slope-shelf zone in small block 1 in 2001. Most of krill was observed in cold water area. Their distribution was well correlated with water temperature at 250m depth. Most of observed krill was considered as

Euphausia pacifica. Krill was sporadically observed in the southern part of survey area where krill consisted of several species other than *Euphausia pacifica*.

Vertical distribution

In 2000, all Japanese anchovy schools were found shallower than 40m depth (Table 2). In 2001, most of Japanese anchovy schools were observed shallower than 50m water depth but some schools were observed from 50m to 150m water depth especially in small block 2 and 4. Walleye pollocks were abundant at depths deeper than 50m and the peak was at depths between 100 and 150m (Table 3). They were scarce in depth range 7-50m. and 150-250m water depth. Most of krill was concentrated at water depth deeper than 150m (Table 4). Exception was found in small block 1 in 2001 where most of krill occurred shallower than 150m water depth.

Biomass estimation

Estimated biomasses of Japanese anchovy, walleye pollock and krill were shown in Tables 5, 6 and 7, respectively. Krill was most abundant in most of blocks except in southern part of the survey area. CVs of the biomass estimates for each species were 0.1-0.6 in most of small block. This level of the precision is satisfactory if we consider the duration of acoustic survey in each small block was two to three days

Prey preference

Proportions of occurrence of prey species in minke and Bryde's whales in each block are shown in Fig. 4 and 5, respectively with proportion of occurrence of prey species in the sea. Proportion of occurrence of prey species in small blocks are not reflected in minke whale stomach contents. Chesson's index showed that minke whales preferred to Japanese anchovy in all survey blocks regardless of season while they seem to avoid krill (Table 8(a)). Bryde's whale showed contradictory results (Table 8(b)). They seem to prefer to Japanese anchovy in August, 2000 while such a preference could not be detected from May to July in 2001.

DISCUSSION

The preliminary results using JARPN II feasibility study data suggest that minke whale seems to have positive preference to Japanese anchovy. Preference to pelagic shoaling fish such as herring (*Clupea harengus*) and capelin (*Mallotus vilosus*) were observed in the northeast Atlantic (Haug *et al*,. 1996; Skaug *et al*,. 1997; Harbitz and Lindstrøm, 2001; Lindstrøm and Haug, 2001; Lindstrøm *et al.*, 2001). Foraging success is measured by maximization of energy intake rate and minimization of time necessary to obtain nutrient (Schoener, 1971). Caloric values of Japanese anchovy, walleye pollock, and krill were 6,402, 6,192 and 3,556 kJ/kg, respectively (Tamura and Fujise, 2002). Japanese anchovy was concentrated shallower than 50m water depth, while walleye pollock and krill were distributed deeper than 100 and 150m water depth, respectively. Considering that usual foraging depth of minke whale was upper 100m (Blix and Folkow, 1995), Japanese anchovy will be the first choice of prey to gain maximum energy intake with minimum dive time. It should be noted that caloric values of prey species could be varied with their body sizes, season and year. Krill was preferred, avoided or randomly selected in the eastern North Atlantic ((Haug *et al*,. 1996; Skaug *et al*,. 1997; Harbitz and Lindstrøm, 2001; Lindstrøm and Haug, 2001; Lindstrøm *et al.*, 2001). In the eastern North Atlantic, krill was well distributed upper 100m water depth whereas it distributed mainly deeper than 150m water depth in this study. Because *Euphausia pacifica* was mainly found at water temperature range 7-8°C, it was mainly distributed in 200-300m water depth range in daytime from June to February where water temperature was less than 8°C (Taki *et al.*, 1996). Availability of krill to minke whale may be varied because the vertical distribution pattern is depend on

water temperatures.

The preliminary analysis of prey preference of Bryde's whale suggests that their preference may change as season progress. In earlier season, result of plankton net sampling suggested that larval stage Japanese anchovy was dominant in Bryde's whale distribution area. No larva of Japanese anchovy was found in sampled Bryde's whale stomach. Smallest size of Japanese anchovy in the stomach was 43mm (Tamura and Fujise, 2002b). Until Japanese anchovy reach that body size, Bryde's whale would not feed on them.

In the feasibility survey, we could not cover the autumn season when Pacific saury was abundant. Because it was extensively consumed by minke whales, whale and the concurrent prey surveys must be conducted in September and October to assess whether minke whale have preference on it. In the western North Pacific, pelagic fish such as Japanese pilchard, Pacific saury, Japanese anchovy and chub mackerel biomass has been showed drastic fluctuation so-called species replacement (Yatsu *et al.*, 2001). Stomach contents of minke whales reflected the historical change in dominant species in survey area (Kasamatsu and Tanaka, 1992). Long term concurrent monitoring of both whale stomach contents and the prey species abundance is critically important to develop a ecosystem model suitable to the western North Pacific.

ACKNOWLEDGEMENT

The authors would like to thank Drs. Hiroshi Hatanaka (the National Research Institute of Fisheries Science, Japan) and Seiji Ohsumi (the Institute of Cetacean Research, Japan) for their critical comments on the manuscript. Dr. Kazushi Miyashita (Hokkaido University) kindly provided critical comments on acoustic data analysis methods. We also thank all of the researchers and crews who engaged in the 2000 and the 2001 JARPNII feasibility surveys.

REFERENCES

Anonymous. 1990. An acoustic assessment of anchovy in the East China Sea and the Yellow Sea. *Mar. Fish. Res. China.* 11 1-141. (in Chinese)

Blix, A. S. and Folkow L. P. 1995. Daily energy expenditure in free living minke whales. *Acta Physysol. Scand.* 153:61-66.

Chesson, J. 1978. Measuring preference in selective predation. *Ecology* .59:211-215.

Foote, K. G. and Traynor, J. J. 1988. Comparison of walleye pollock target strength estimates determined from in situ measurements and calculations based on swim bladder form. *J. Acoust. Soc. Am.* 83:9-17.

Government of Japan. 2000. Research plan for cetacean studies in the western North Pacific under special permit (JARPN II) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC Scientific Committee, June 2000 (unpublished). 68pp. [Paper available from the Office of this Journal]

Harbitz, A. and Lindstrøm, U. 2001. Stochastic spatial analysis of marine resources with application to minke whales *(Balaenoptera acutorostrata)* foraging: Asynoptic case study from the southern Barents Sea. *Sarsia* 86:485-501.

Haug, T., Lindstrøm, U., Nilssen, K. T., Røttingen, I. and Skaug, H. J. 1996. Diet and food availability for northeast Atlantic minke whales, *Balaenoptera acutorostrata*. *Rep. Int. Whal. Commn.* 1996:371-382.

Jolly, G. M. and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Can. J. Fish. Aquant. Sci.* 47:1282-1291.

Kasamatsu, F and Hata, T. 1985. Notes on minke whale 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.

Krebs, C. J. 1999. Ecological methodology. 2nd ed. Addison-Welsey Educational Publishers, Inc. Menlo Park, CA, USA. 581pp.

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.* 48:463-469.

Lindstrøm, U. and Haug, T. 2001. Feeding strategy and prey selectivity in common minke whales (*Balaenoptera acutorostrata*) foraging in the southern Barents Sea during early summer. *J. Cetacean Res. Manage.* 3:239-249.

Lindstrøm, U., Harbitz, A. and Haug, T. 2001. Small-scale studies of minke whale (*Balaenoptera acutorostrata*) foraging behaviour in the southern Barents Sea, with particular reference to predation on capelin (Mallotus villosus). Paper SC/53/O4 presented to the Scientific Committee of the International Whaling Commission, July 2001 (unpublished). [Paper available from the Office of this Journal]

Miyashita, K., Aoki, I. and Inagaki, T. 1996. Swimming behaviour and target strength of isada krill *(Euphausia pacifica). ICES J. Mar. Sci.* 53:303-308.

Miyashita, K., Aoki, I., Seno, K., Taki, K. and Ogishima. 1997. Acoustic identification of isada krill, *Euphausia pacifica* Hansen, off the Sanriku coast, north-eastern Japan. *Fish. Oceanogr.* 6. 266-271.

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

Odate, K. 1987. Fishery biology of the krill, Euphausia pacifica, in the Northeastern coasts of Japan. Japan Fisheries Resource Conservation Association, Tokyo. 100pp. (in Japanese)

Omura, H. and Sakiura, H. 1956. Studies on the little piked whale from the Coast of Japan. *Sci. Rep. Whales Res. Inst.* 11:1-37.

Ona, E. 1993. Hydoroacoustical method for estimation of demersal fish resources. International Symposium on the Investigation of Demersal Fish Resources Hokkaido, University Sept. 21-22, 1993. 22-34.

Pereyra, W. T., Reeves, J. E. and Bakkala, R. G. 1981. Trophic importance of some marine gadids in Northern Alaska and their body-length size relationships. *Fish. Bull.* 79: 187-192.

Schoener, T. W. 1971. Theory of feeding strategies. *Annu. Rev. Ecol. Syst.* 2:369-404.

Simrad. 1997. Simrad EK500 Scientific Echo Sounder Operation Manual P2170G. Simrad AS Horten, Norway.

Skaug, H. J., Gjøsæter, H., Haug, T., Nilssen, K. T. and Lindstrøm, U. 1997. Do minke whales (*Balaenoptera acutorostrata*) exhibit particular prey preferences? *J. Northw. Atl. Fish. Sci.* 22:91-104.

Taki, K., Kotani, Y. and Endo, Y. 1996. Ecological studies of *Euphausia pacifica* Hansen and seasonal change of its environment off Onagawa, Miyagi prefecture III. Distribution and diel vertical migration of *Euphausia pacifica*. *Bull. Tohoku Natl. Fish. Res. Inst.* 58:89-104. (in Japanese with English abstract)

Tamura, T. and Fujise, Y. 2000. Geographical and seasonal changes of prey species in the western North Pacific minke whale. Paper SC/F2K/J22 presented to the JARPN review meeting (unpublished). 26pp. [Paper available from the Office of this Journal]

Tamura, T. and Fujise, Y. 2002a. Food habit of common minke whale based on JARPN II. Appendix 1 of paper SC/54/O17 presented to the IWC Scientific meeting April 2002, XX pp. [Paper available from the Office of this Journal]

Tamura, T. and Fujise, Y. 2002b. Food habit of Bryde's whale based on JARPN II. Appendix 1 of paper

SC/54/O17 presented to the IWC Scientific meeting April 2002, XX pp. [Paper available from the Office of this Journal]

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 of paper SC/54/O17 presented to the IWC Scientific meeting April 2002, XX pp. [Paper available from the Office of this Journal]

Yatsu, A., H. Nishida, M. Ishida, A. Tomosada, T. Kinoshita and T. Wada. 2001. Trajectories of catch and stock abundance of dominant small pelagic fishes and common squid with some related environmental indices around Japan. *PICES Sci. Rep.*, 18: 175-178

Table 1. Summary of stomach contents of minke whale (a) and Bryde's whale (b) used in this analysis. JA: Japanese anchovy; WP: Walleye Pollock; Kr: Krill. n: number of stomachs that contained given species. wt (kg): total weight of each prey species that was found in all sampled animals given survey block. Because some animals fed on 2 species simultaneously, number of sampled animals was not always equal to total number of n.

(a) Minke whale

Year	Survey period		Block	Sampled	Stomach content						
					JA		WP		Kr		Total
	Prey	Cetacean		animal (#)	n	wt (kg)	n	wt (kg)	n	wt (kg)	wt (kg)
2000	5-7 Aug.	7 Aug.	1	1	1	26.3		-		-	26.3
	2-4 Aug.	3-5 Aug.	2	5	5	205.3		-		-	205.3
2001	19-24 Jun.	19-23 Jun.	1	10	5	110.0	8	403.8	2	35.2	549.1
	17-21 May	14-18 May 21-22 May	2	19	19	435.8		-		-	435.8
	22-26 May	22-27 May	3	4	1	162.6		-	3	13.9	176.5
	15-18 Jun.	13-18 Jun.	B	10	4	101.0		-	7	428.3	529.3

(b)Bryde's whale

Year	Survey period		Block	Sampled	Stomach content				
					JA		Kr		Total
	Prey	Cetacean		animal (#)	n	wt (kg)	n	wt (kg)	wt (kg)
2000	22-24 Aug.	22-26 Aug.	4	11	8	4,288.7	4	193.1	4,481.8
2001	22-26 May	22-27 May	3	1		-	1	215.4	215.4
	11-13 Jun.	10-13 Jun.	4	3		-	3	93.8	93.8
	15-18 Jun.	13-18 Jun.	B	12		-	12	1,021.7	1,021.7
	7-15 Jul.	11-13 Jul.	C	7	3	19.1	5	75.7	94.8

Table 2. Vertical distribution of Japanese anchovy in each block in 2000 survey (a) and in 2001 survey (b). Densities were described by SA (mean backscattering area pre square nautical mile of sea surface). No Japanese anchovy was observed deeper than 40m water depth in 2000.

(a) 2000 survey

Small Block 1 (5 - 7 Aug.)
Surveyd dist. = 249 n.miles

Depth	Total SA	SA/n.mile
7-10m	2,025.00	8.13
10-20m	10,858.15	43.61
20-30m	438.80	1.76
30-40m	0.00	0.00

Small Block 2 (2 - 4 Aug.)
Surveyed dist. = 219 n.miles

Depth	Total SA	SA/n.mile
7-10m	770.12	3.52
10-20m	14,530.80	66.35
20-30m	8,593.83	39.24
30-40m	8,086.08	36.92

Small Block 3 (8 and 30 Aug.)
Surveyed dist. = 192 n.miles

Depth	Total SA	SA/n.mile
7-10m	855.65	4.46
10-20m	145.10	0.76
20-30m	233.18	1.21
30-40m	79.89	0.42

Small Block 4 (22 - 24 Aug.)
Survey dist. = 206 n.mile

Depth	Total SA	SA/n.mile
7-10m	3,453.28	16.76
10-20m	1,262.16	6.13
20-30m	59.39	0.29
30-40m	0.00	0.00

Small Block 6 (27 - 29 Aug.)
Surveyed dist. = 251 n.miles

Depth	Total SA	SA/n.mile
7-10m	4,092.40	16.30
10-20m	9,148.69	36.45
20-30m	36.83	0.15
30-40m	281.77	1.12

Small Block 7 (25 - 26 Aug.)
Surveyed dist. = 167 n.miles

Depth	Total SA	SA/n.mile
7-10m	0.00	0.00
10-20m	0.00	0.00
20-30m	0.00	0.00
30-40m	0.00	0.00

(b) 2001 survey

Small Block 1 (19 - 24 Jun.)
Surveyed dist. = 334 n.miles

Depth(m)	Total S_A	S_A/n.miles
7-50	2,152.26	6.44
50-100	9.94	0.03
100-150	0.00	0.00

Small Block 2 (17 - 21 May)
(Surveyed dist. = 414 n.miles)

Depthm	Total S_A	S_A/n.miles
7-50	52,997.36	128.01
50-100	6,830.99	16.50
100-150	131.00	0.32

Small Block 3 (22 - 26 May)
Surveyed dist. = 224 n.miles

Depth(m)	Total S_A	S_A/n.miles
7-50	2,955.33	13.19
50-100	0.00	0.00
100-150	0.00	0.00

Small Block 4 (11 - 13 Jun.)
Surveyed dist. = 193 n.miles

Depth(m)	Total S_A	S_A/n.miles
7-50	1,514.55	7.85
50-100	7,615.34	39.46
100-150	408.16	2.11

Small Block 5 (28 May - 2 Jun.)
(Surveyed dist. = 195 n.miles)

Depthm	Total S_A	S_A/n.miles
7-50	0.00	0.00
50-100	0.00	0.00
100-150	0.00	0.00

Special Blcok A (4 - 10 Jun.)
Surveyed dist. = 249 n.miles

Depth(m)	Total S_A	S_A/n.miles
7-50	0.00	0.00
50-100	0.00	0.00
100-150	0.00	0.00

Special Block B (15 - 18 Jun.)
(Surveyed dist. = 425 n.miles)

Depthm	Total S_A	S_A/n.miles
7-50	8,496.10	19.99
50-100	35.30	0.08
100-150	0.00	0.00

Special Block C (7 - 15 Jul.)
Surveyed dist. = 668 n.miles

Depth(m)	Total S_A	S_A/n.miles
7-50	197,283.47	295.33
50-100	4,562.76	6.83
100-150	5.95	0.01

Table 3. Vertical distribution of walleye pollock in each block in 2001 survey. Densities were described by SA (mean backscattering area pre square nautical mile of sea surface).

Small Block 1 (19 - 24 Jun.)
Surveyed dist. = 334 n.miles

Depth(m)	Total S_A	S_A/n.miles
7-50	188.63	0.56
50-100	27,060.98	81.02
100-150	47,050.53	140.87
150-200	295.34	0.88
200-250	248.30	0.74

Table 4. Vertical distribution of krill in each block in 2000 survey (a) and in 2001 survey (b). Densities were described by SA (mean backscattering area pre square nautical mile of sea surface).

(a) 2000 survey

Small Block 1 (5 - 7 Aug.)
Surveyd dist. = 249 n.miles

Depth	Total SA	SA/n.mile
50-100m	0.00	0.00
100-150m	250.32	1.01
150-200m	16,300.99	65.47
200-250m	13,472.78	54.11

Small Block 2 (2 - 4 Aug.)
Surveyed dist. = 219 n.miles

Depth	Total SA	SA/n.mile
50-100m	5.45	0.02
100-150m	2,155.65	9.84
150-200m	8,138.32	37.16
200-250m	6,753.86	30.84

Small Block 3 (8 and 30 Aug.)
Surveyed dist. = 192 n.miles

Depth	Total SA	SA/n.mile
50-100m	44.11	0.23
100-150m	2,666.78	13.89
150-200m	10,079.04	52.49
200-250m	5,983.31	31.16

Small Block 4 (22 - 24 Aug.)
Survey dist. = 206 n.mile

Depth	Total SA	SA/n.mile
50-100m	0.00	0.00
100-150m	615.99	2.99
150-200m	1,074.31	5.22
200-250m	1,230.79	5.97

Small Block 6 (27 - 29 Aug.)
Surveyed dist. = 251 n.miles

Depth	Total SA	SA/n.mile
50-100m	1.81	0.01
100-150m	222.67	0.89
150-200m	1,647.46	6.56
200-250m	7,559.57	30.12

Small Block 7 (25 - 26 Aug.)
Surveyed dist. = 167 n.miles

Depth	Total SA	SA/n.mile
50-100m	0.00	0.00
100-150m	0.00	0.00
150-200m	0.00	0.00
200-250m	0.00	0.00

(b) 2001 survey

Small Block 1 (19 - 24 Jun.)
Surveyed dist. = 334 n.miles

Depth(m)	Total S_A	S_A/n.miles
12-50	3,195.42	9.57
50-100	1,901.63	5.69
100-150	2,278.50	6.82
150-200	398.89	1.19
200-250	142.25	0.43

Small Block 2 (17 - 21 May)
(Surveyed dist. = 414 n.miles)

Depth(m)	Total S_A	S_A/n.miles
12-50	992.83	2.40
50-100	1,133.10	2.74
100-150	900.04	2.17
150-200	4,019.53	9.71
200-250	3,232.81	7.81

Small Block 3 (22 - 26 May)
Surveyed dist. = 224 n.miles

Depth(m)	Total S_A	S_A/n.miles
12-50	1,295.48	5.78
50-100	14.83	0.07
100-150	143.93	0.64
150-200	1,932.37	8.63
200-250	3,326.44	14.85

Small Block 4 (11 - 13 Jun.)
Surveyed dist. = 193 n.miles

Depth(m)	Total S_A	S_A/n.miles
12-50	350.09	1.81
50-100	61.88	0.32
100-150	45.31	0.23
150-200	469.47	2.43
200-250	2,243.81	11.63

Small Block 5 (28 May - 2 Jun.)
(Surveyed dist. = 195 n.miles)

Depth(m)	Total S_A	S_A/n.miles
12-50	0.00	0.00
50-100	0.00	0.00
100-150	0.00	0.00
150-200	0.00	0.00
200-250	1,024.98	5.26

Special Blcok A (4 - 10 Jun.)
Surveyed dist. = 249 n.miles

Depth(m)	Total S_A	S_A/n.miles
12-50	647.93	2.60
50-100	572.30	2.30
100-150	598.36	2.40
150-200	2,584.71	10.38
200-250	5,101.41	20.49

Special Block B (15 - 18 Jun.)
(Surveyed dist. = 425 n.miles)

Depth(m)	Total S_A	S_A/n.miles
12-50	1,590.61	3.74
50-100	3,181.17	7.49
100-150	1,922.57	4.52
150-200	4,265.89	10.04
200-250	5,562.78	13.09

Special Block C (7 - 15 Jul.)
Surveyed dist. = 668 n.miles

Depth(m)	Total S_A	S_A/n.miles
12-50	174.35	0.26
50-100	1,116.81	1.67
100-150	251.72	0.38
150-200	1,369.76	2.05
200-250	5,833.37	8.73

Table 5. Estimated abundance of Japanese anchovy by block in 2000 survey (August) (a) and in 2001 survey (May-July) (b).

(a) 2000 survey

Small Block	1	2	3	4	6	7
Surveyed area (n.mile^2)	5,467	5,108	9,501	7,736	9,883	9,883
Survey date	5-7 Aug.	2-4 Aug.	8 and 30 Aug.	22-24 Aug.	27-29 Aug.	25-26 Aug.
Mean density (t/n.mile^2)	4.93	10.55	0.60	0.97	3.76	0.00
Estimated Biomass (10^3t)	26.94	53.88	5.66	7.47	37.16	0.00

(b) 2001 survey

Block	Small Block					Special Block		
	1	2	3	4	5	A	B	C
Surveyed area (n.mile^2)	8,260	12,473	11,069	11,057	13,030	5,723	5,292	22,849
Survey date	19-24 Jun.	17-21 May	22-26 May	11-13 Jun.	28 May-2 Jun.	4-10 Jun.	15-18 Jun.	7-12 Jul.
Mean density (t/n.mile^2)	0.43	12.87	1.28	1.21	0.00	0.00	0.18	7.42
Estimated Biomass (10^3t)	3.53	160.59	14.19	13.41	0.00	0.00	0.94	169.49

Table 6.Estimated abundance of walleye pollock by block in 2001 survey.

Small Block	1
Surveyed area (n.mile^2)	8260
Survey date	19-24 Jun.
Mean density (t/n.mile^2)	18.44
Estimated Biomass (10^3t)	152.29

Table 7. Estimated abundance of krill by block in 2000 survey (a) and in 2001 survey (b).

(a) 2000 survey

Small Block	1	2	3	4	6	7
Surveyed area (n.mile^2)	5,467	5,108	9,501	7,736	9,883	9,883
Survey date	5-7 Aug.	2-4 Aug.	8 and 30 Aug.	22-24 Aug.	27-29 Aug.	25-26 Aug.
Mean density (t/n.mile^2)	63.83	43.33	51.20	7.39	19.57	0.00
Estimated Biomass (10^3t)	348.97	221.33	486.41	57.14	193.43	0.00

(b) 2001 survey

Block	Small Block					Special Block		
	1	2	3	4	5	A	B	C
Surveyed area (n.mile^2)	8,260	12,473	11,069	11,057	13,030	5,723	5,292	22,849
Survey date	19-24 Jun.	17-21 May	22-26 May	11-13 Jun.	28 May-2 Jun.	4-10 Jun.	15-18 Jun.	7-12 Jul.
Mean density (t/n.mile^2)	12.34	12.93	15.61	8.56	2.72	19.17	19.28	6.82
Estimated Biomass (10^3t)	101.94	161.30	172.79	94.61	35.48	109.70	102.03	155.82

Table 8. Chesson's index of minke (a) and Bryde's whale (b) for each prey occurrence frequency index (F: Frequency of occurrence of each prey item by stomach number. Bi: Relative frequency of prey species by weight. MBi: Mean relative frequency by weight.). "n" was number of stomachs used in the analysis. Bold face represented positive prey preference. $\alpha = 1/m$: no preference; $\alpha > 1/m$: preferred prey species; $\alpha < 1/m$: avoided prey species. m: total number of prey species in each block.

(a) Minke whale

Year	Block	n	Prey	F α	Bi α	MBi α	1/m
2000	2	5	**JA**	**1.00**	**1.00**	**1.00**	0.50
			Kr	0.00	0.00	0.00	0.50
2001	1	10	**JA**	**0.95**	**0.91**	**0.93**	0.33
			WP	0.04	0.08	0.05	0.33
			Kr	0.01	0.01	0.02	0.33
2001	2	19	**JA**	**1.00**	**1.00**	**1.00**	0.50
			Kr	0.00	0.00	0.00	0.50
2001	3	4	**JA**	**0.80**	**0.99**	**0.80**	0.50
			Kr	0.20	0.01	0.20	0.50
2001	B	10	**JA**	**0.98**	**0.96**	**0.98**	0.50
			Kr	0.02	0.04	0.02	0.50

(b) Bryde's whale

Year	Block	n	Prey	F α	Bi α	MBi α	1/m
2000	4	11	**JA**	**0.94**	**0.99**	**0.95**	0.50
			Kr	0.06	0.01	0.05	0.50
2001	4	3	JA	0.00	0.00	0.00	0.50
			Kr	**1.00**	**1.00**	**1.00**	0.50
2001	B	10	JA	0.00	0.00	0.00	0.50
			Kr	**1.00**	**1.00**	**1.00**	0.50
2001	C	7	JA	0.36	0.19	0.30	0.50
			Kr	**0.64**	**0.81**	**0.70**	0.50

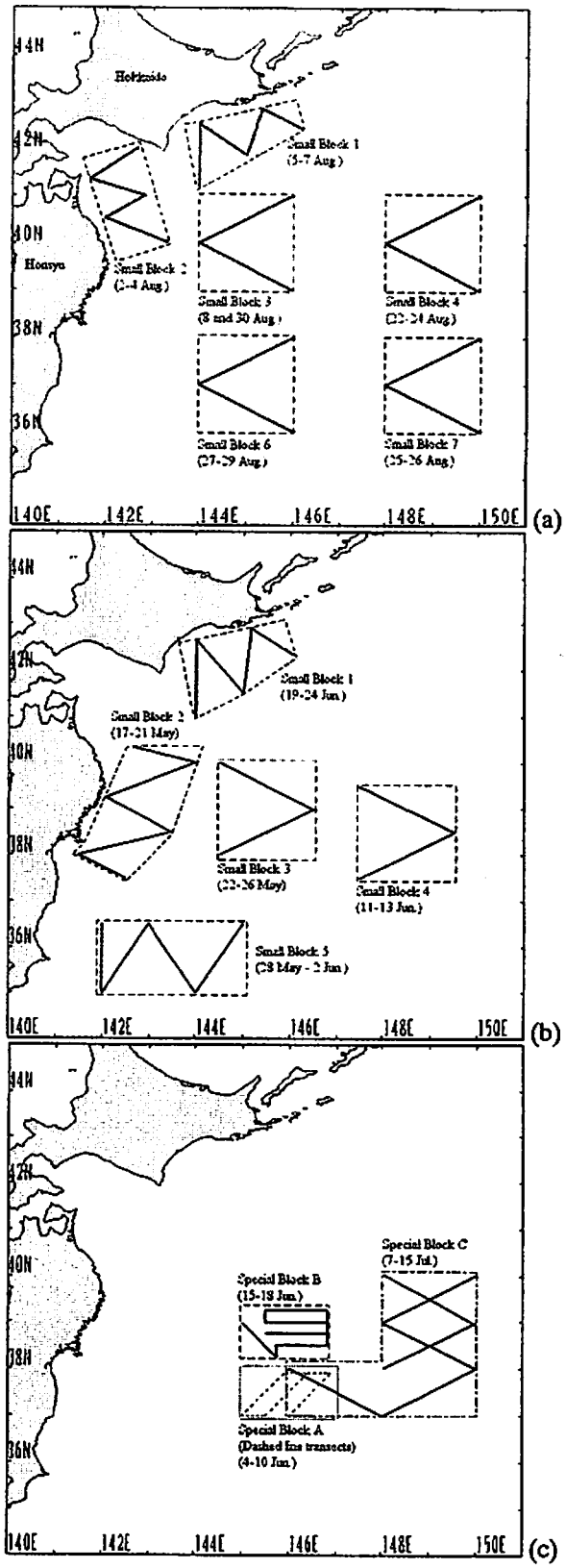


Fig. 1. Research area, small blocks and planed track lines: (a) 2000, (b) 2001 and (c) 2001 (special blocks).

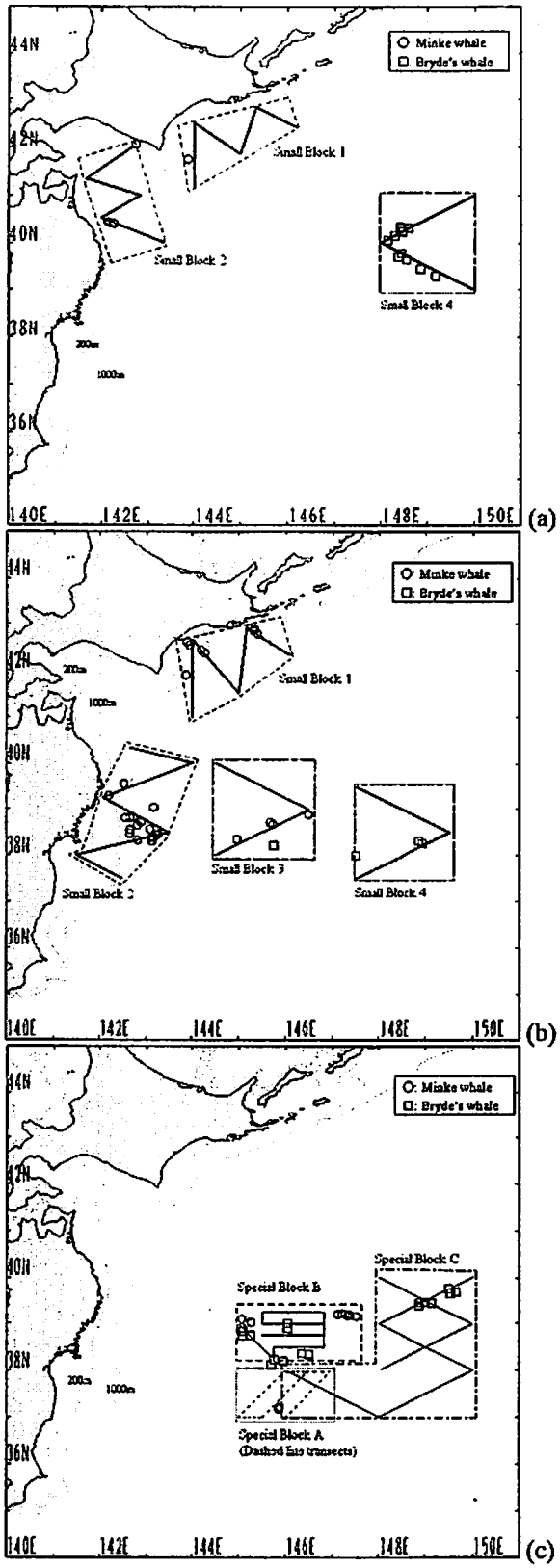


Fig.2. Research area, small blocks and planed track lines: (a) 2000, (b) 2001 and (c) 2001 (special blocks). Sighting positions of sampled minke and Bryde's whales which were used in this analysis were shown. Thin line showed 200 and 1000 m isobath.

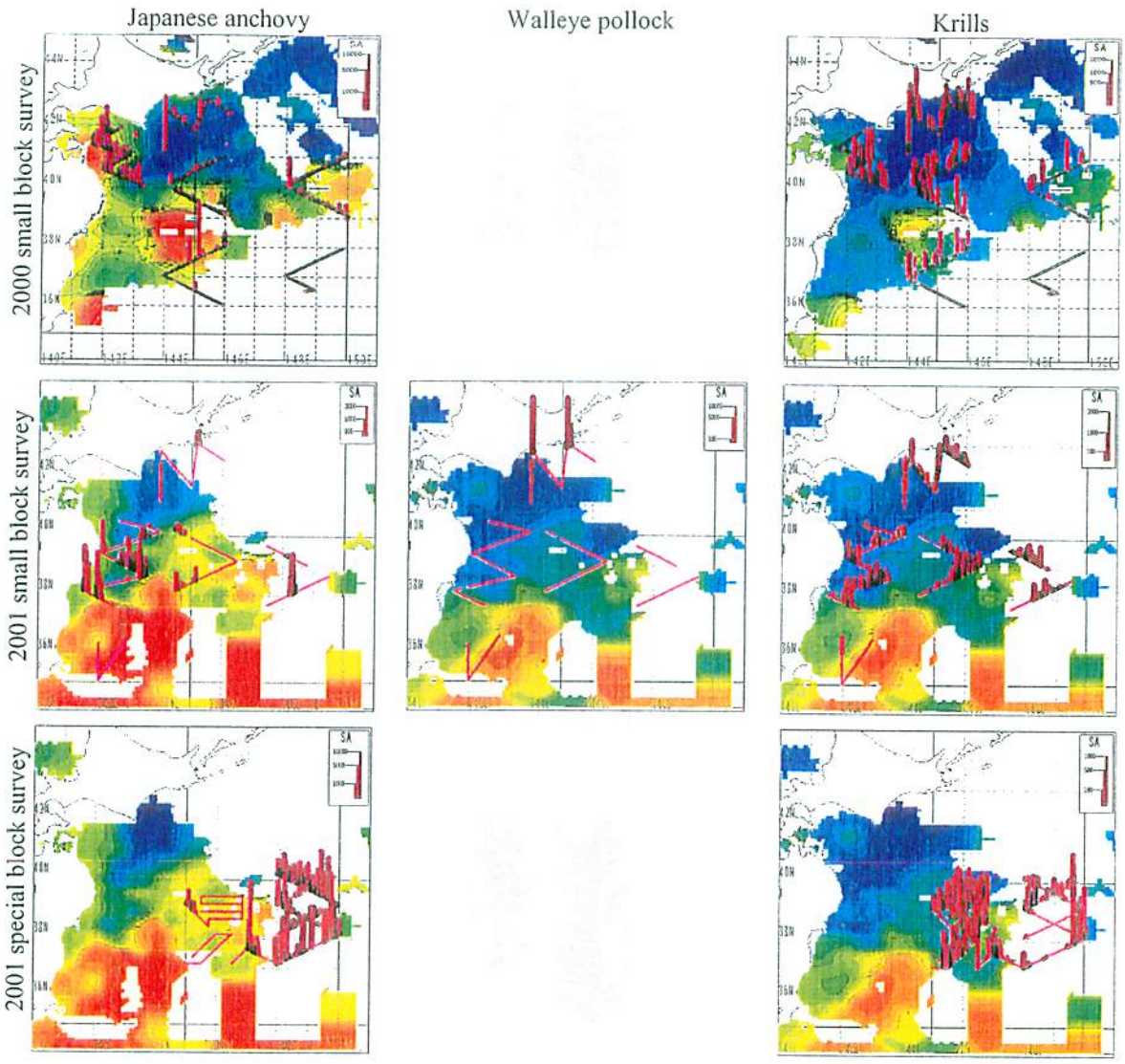


Fig.3. Distribution patterns and densities (S_A(mean backscattering area pre square nautical mile of sea surface)/n.mile) of Japanese anchovy (left), walleye pollock (center) and krill (right) in 2000 (top), 2001 (middle) and 2001 (special blocks) (bottom) were overlaid on water temperature map. Maps published by Tohoku National Fisheries Research Institute (TNFRI), Japan (available from http://ss.myg.affrc.go.jp/) were modified. Water temperature maps at 50m depth were used for Japanese anchovy and at 250m were used for walleye pollock and krill. August monthly mean data were used in 2000. June monthly data were used in 2001.

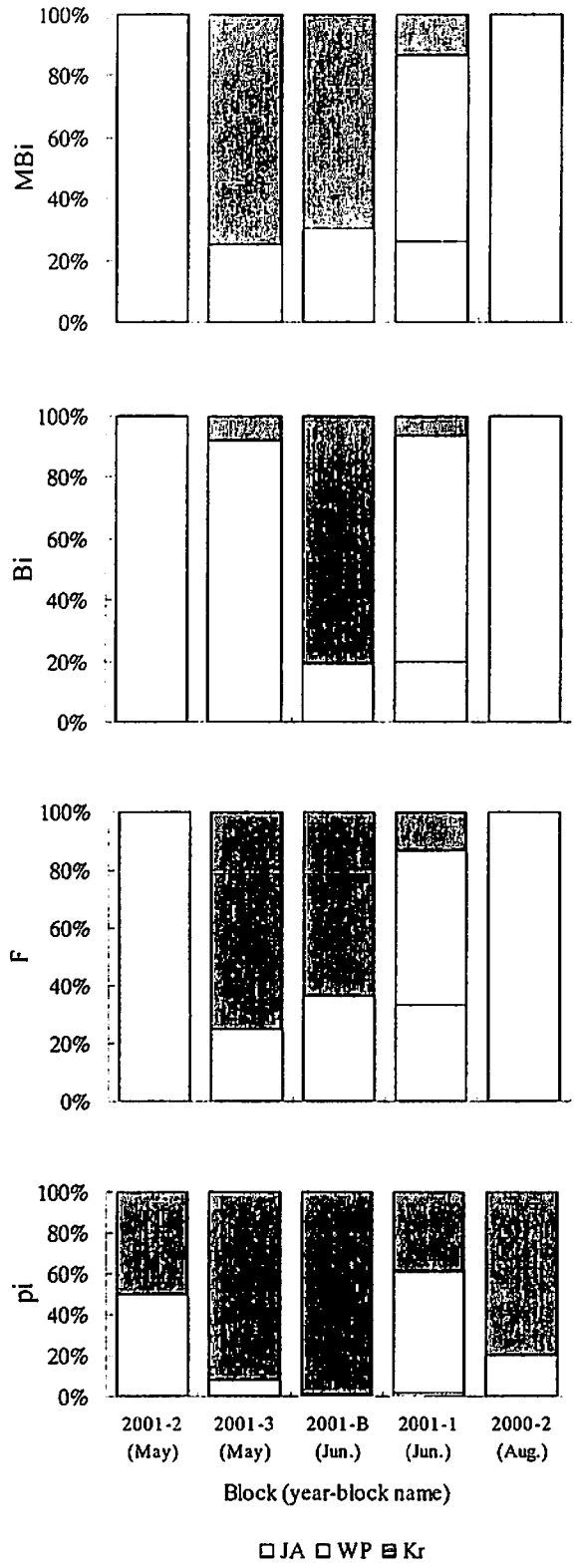


Fig.4. Occurrence of prey species in minke whale stomach contents by each prey occurrence frequency index (F: Frequency of occurrence of each prey item by stomach in number. Bi: Relative frequency of prey species by weight. MBi: Mean relative frequency by weight) and in the environment (pi). JA: Japanese anchovy; WP: Walleye Pollock; Kr: Krill. Surveyed blocks were showed as "surveyed year – block name". For example small block 1 in 2000 was showed as "2000-1".

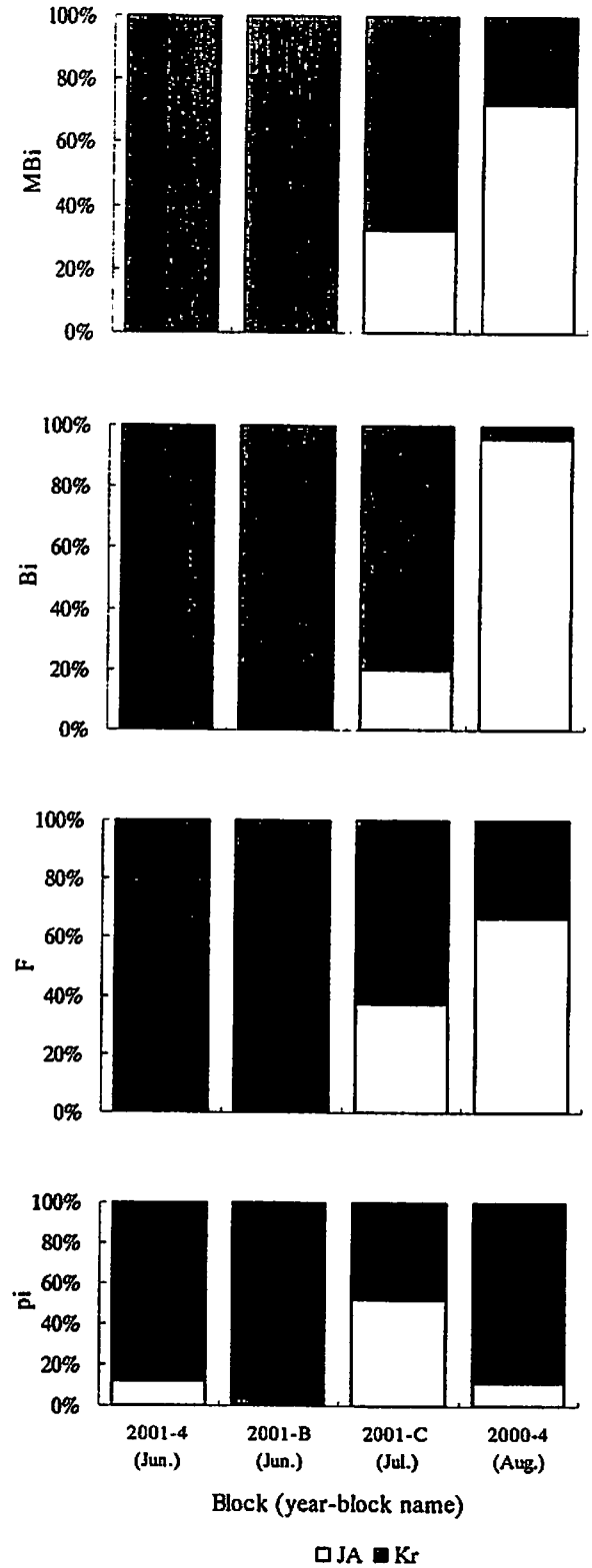


Fig.5. Occurrence of prey species in Bryde's whale stomach contents by each prey occurrence frequency index (F: Frequency of occurrence of each prey item by stomach number. Bi: Relative frequency of prey species by weight. MBi: Mean relative frequency by weight.) and in the environment (pi). JA: Japanese anchovy; Kr: Krill. Surveyed blocks were showed as "surveyed year – block name". For example small block 4 in 2000 was showed as "2000-4".

Appendix 6

The development of the ecosystem model for the western North Pacific area off Japan (SC/53/O9)

Hiroshi Okamura[*1], Akihiko Yatsu[*2], Tomio Miyashita[*1] and Shigeyuki Kawahara[*1]

*1 : National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu, Shizuoka 424-8633 Japan

*2 : National Research Institute of Fisheries Science, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan

ABSTRACT

The Ecopath model for the western North Pacific was constructed as part of JARPN II project and some preliminary analyses were carried out. The model still includes several points to be improved such as poor inclusion of migration and environmental factors, a variety of uncertainty and spatial extension. But some Ecosim simulations showed interesting aspects. When there was no catch of cetaceans in future 50 years, relative biomass of some fishes decreased in the order of several ten percent, and some whales increased in the similar order. Without fisheries except whaling in future 50 years, relative biomass of some fishes increased in the order of several hundred percent and some whales increased in the order of several ten percent. With double fishing rate for cetaceans in future 50 years, some fishes increased in the order of several ten percent. Some squids showed different dynamics from those fishes, probably because of indirect effects. With double fishing rate for fishes in future 50 years, many fishes became extinct. Some cetaceans decreased in the order of a few ten percent, probably because of lack of prey. Fitting our model to the available time series data of some fishes showed that the vulnerability parameter in the model was likely to be high. These results suggest that the competition between cetaceans and fisheries over marine resources could occur in the western North Pacific. Further, the removal of minke whale and sperm whale showed a large impact, but the removal of Bryde's whale showed little effect. The information obtained from JARPN II survey is expected to improve the information on diet composition of cetaceans which will contribute to improve the model and explicate the role of cetaceans on the western North Pacific ecosystem.

Appendix 7

Examination of sperm whales component based on JARPN II data using Ecopath-type model

Hiroshi Okamura[1], Hiroshi Ohizumi[1], Shigeyuki Kawahara[1]

1: National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu 424-8633, Japan

ABSTRACT

Simulations by Ecopath with Ecosim were carried out under some scenarios in order to focus on a role of sperm whales in the western North Pacific. Previous western North Pacific Ecopath model was modified so that deep sea squid was classified into two parts and bottom sea squid was added into the model. Furthermore, it was assumed that sperm whales mainly feed on real deep-sea squids that never migrate to the surface layer. The removal of sperm whales showed conspicuous fluctuations of various prey fishes under the vulnerability parameter of 0.6 though there was no direct relation between sperm whales and them. This suggests that sperm whales can be still important species in the ecosystem even after including data obtained from JRPANII feasibility study.

INTRODUCTION

JARPNII survey made clear the fact that diet composition of sperm whales is strongly dependent upon real deep-sea squids that never migrate to the surface layer more than we could have imagined (Appendix 3). This fact drove us to examine a role of sperm whales in the ecosystem based on data obtained form JARPN II feasibility study, because it means that sperm whales only have indirect relationship with targets by Japanese fishery. Real deep-sea squids that are main preys of sperm whales has little available data until present. If sperm whales are still important even though they are real deep-sea squids feeders, we should promote research on deep-sea squids in the future and it will cost us considerable expense. Therefore, it is very important to examine a role of sperm whales in the ecosystem based on information as much as we can get. This article is one of the trials.

MATERIALS AND METHODS

Some parameters were altered from the first runs of the model (Okamura et. al 2001). Main alterations are as follows:

1. Separate deep-sea squids into vertical migrators (Deep sea squid1) between the deep sea (say, deeper than 400m in depth) and surface layer (shallower than 200m), and real deep-sea squids (Deep sea squid2) which do not migrate to the surface layer.

2. Sperm whales feed on mainly real deep-sea squids based on the results of two-year feasibility JRAPN II surveys.
3. Create deep-sea cod group (Bottom sea fish) as one component of Ecopath

Above alterations required further modifications of other parameters and new assumptions. All the parameters used in Ecopath are shown in Tables 1 to 3.

After changing input data, several test runs were carried out using Ecopath with Ecosim in order to clarify the role of sperm whale in the ecosystem. Setting overall vulnerability parameters to 0.6 as in the base case of the first runs, Ecosim simulations were carried out under the following three scenarios:

1) Remove only minke whales from the ecosystem using the high fishing rate,
2) Remove only Bryde's whales from the ecosystem using the high fishing rate,
3) Remove only sperm whales from the ecosystem using the high fishing rate.

Simulation results were given in the form of relative biomasses of each components of Ecopath with Ecosim.

RESULTS

Figures 1 to 3 give the results of 50-years simulation under the above scenarios. Trajectories in figures show variation of relative biomass of each group. Real deep-sea squids were exceedingly influenced by removing sperm whales. The influence on flying squids became smaller and showed converse effect in comparison with previous analysis. Other prey species were also influenced by the removal of sperm whale as well as in the case of the removal of minke whales. The magnitude of impacts from removals of minke and sperm whales was similar to or bigger than SC/53/O9 (Okamura et al. 2001). The impact of removal of sperm whale was larger than that out of removal of Bryde's whales. We can see that the removal of minke whales generally has positive effect onto commercially important fish groups while the removal of sperm whale generally gives them negative effect.

DISCUSSION

It was surprising that sperm whales still had big impacts on the western North Pacific ecosystem though we reduced direct impacts on target species by fishery, especially flying squids, and the surface layer ecosystem from sperm whales based on JARPNII feasibility study data. Because impacts on squids other than real deep-sea squids by sperm whales were generally reduced, the effects on fishery-target fishes were likely to be caused by indirect interactions, especially through real deep-sea squids. This suggests the importance of the input parameters of deep-sea squids, their predators and preys, for which the information is limited now. Especially, the data on the interaction between those animals, that is the information on diet compositions, should be collected to clarify

the role of sperm whale more precisely.

The assumption that the vulnerability parameter (v) = 0.6 was likely to have strong effect on the results above-mentioned. Therefore, estimation of the vulnerability parameter based on fishery and survey data is also important. The vulnerability parameter is dependent on biomass time series data, diet composition data and prey preference (Okamura and Kawahara 2002). Therefore, the long-term monitoring of whale and fish's absolute abundance and its trend and the examination of diet compositions and prey preference is very important to make clear the truth.

In spite of expensive costs and difficulty for survey, any survey on sperm whales is necessary to understand the ecosystem truly because our simulation showed that sperm whales can still be important in the ecosystem as well as minke whales. Especially, it is useful and interesting to examine the relation between surface layer ecosystem and real deep-sea squid, which is main prey of sperm whales.

Table 1. Basic input parameters. Habitat area is the fraction of the total area in which the group occurs, B is biomass (t/km^2), P/B is production/biomass (/year), Q/B is consumption/biomass (/year), EE is ecotrophic efficiency, P/Q is production/consumption, BA is biomass accumulation (t/km2/year), Unassimil./Q is the fraction of the food that is not assimilated in consumption, and Detr.imp is the import of detritus to the system.

Group name	Habitat area	B	P/B	Q/B	EE	P/Q	BA	Unassimil./Q	Detr.imp
Minke whale	1	0.035	0.02	6.44			0	0.2	
Bryde's whale	1	0.002	0.02	5.444			0	0.2	
Other Baleen whale	1	0	0.02	4.688			0	0.2	
Sperm whale	1	0.024	0.02	4.594			0	0.2	
Baird's beaked whale	1	0.04	0.02	5.791			0	0.2	
Dall's porpoise	1	0.017	0.06	14.39			0	0.2	
Short-finned pilot whale	1	0.036	0.06	8.399			0	0.2	
Other toothed whale	1	0.1	0.06	11.657			0	0.2	
Northern fur seal	1	0.001	0.06	18.744			0	0.2	
Sea birds	1	0.003	0.8	34.375			0	0.2	
Albacore	1	0.004	0.54	2.5			0	0.2	
Swordfish	1	0	0.6	6.4			0	0.2	
Skipjack tuna	1	0.025	1.18	32.57			0	0.2	
Blue Shark	1	0.059	0.48	1.5			0	0.2	
Pollock	1	1.339	0.5	2.64			0	0.2	
Lanternfish	1	5.2	0.9	25.276			0	0.2	
Common squid	1	0.109	3.2	10.667			0	0.2	
Flying squid	1	0.073	3.2	10.667			0	0.2	
Deep sea squid1	1		1.6	5.333	0.95		0	0.2	
Deep sea squid2	1		1.6	5.333	0.95				
Micronectonic squid	1	2.042	3.2	10.667			0	0.2	
Mackerel	1	0.134		9.3		0.3	0	0.2	
Pomfret	1	0.047		6		0.3	0	0.2	
Bottom sea fish	1	0.3	0.5	2.64					
Sardine	1	0.986	1.04	22			0	0.2	
Anchovy	1	1.666	2.15	23			0	0.2	
Saury	1	1.71	1.05	5			0	0.2	
Benthic invertebrates	1		1.48	7.69	0.95		0	0.2	
Large zooplankton	1	50	5	22			0	0.2	
Small zooplankton	1	55	6	22			0	0.2	
Phytoplankton	1	33.083	97.482				0		
Detritus	1	165.415							0

Table 2. Diet composition. The columns sums up 1.

Prey＼Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Minke whale																														
Bryde's whale																														
Other Baleen whale																														
Sperm whale																														
Baird's beaked whale																														
Dall's porpoise																														
Short-finned pilot whale																														
Other toothed whale								0.00																						
Northern fur seal								0.00																						
Sea birds								0.00																						
Albacore																														
Swordfish																														
Skipjack tuna																														
Blue Shark																														
Pollock	0.10																													
Lanternfish	0.10	0.20	0.05		0.20	0.70	0.10	0.17			0.05		0.05	0.02	0.02		0.10	0.10	0.40	0.57		0.02	0.15							
Common squid					0.10	0.05	0.10		0.15	0.09		0.20	0.02	0.20			0.05					0.01	0.45							
Flying squid				0.05	0.05		0.10		0.15	0.05		0.20	0.02	0.20				0.02				0.01	0.10							
Deep sea squid1				0.05	0.05		0.10	0.10		0.05		0.20	0.02	0.20				0.31				0.01	0.10							
Deep sea squid2				0.55	0.05		0.10	0.10																						
Micronectonic squid			0.05	0.05	0.10	0.05	0.20	0.30	0.16	0.09		0.20	0.02	0.20			0.05	0.05	0.10	0.14		0.01	0.05							
Mackerel	0.10	0.20	0.05			0.10	0.20	0.15	0.30		0.05	0.20	0.01	0.02																
Pomfret					0.05	0.05		0.01	0.06	0.14	0.05		0.01	0.04																
Bottom sea fish				0.25	0.30																									
Sardine	0.20	0.10					0.03	0.03	0.06	0.14	0.05		0.40	0.04	0.02			0.10				0.02	0.02							
Anchovy	0.20	0.10	0.05			0.05	0.05	0.10	0.06	0.14	0.05		0.40	0.04	0.04		0.10	0.10	0.10			0.12	0.10							
Saury	0.20						0.03	0.03	0.06	0.14	0.40			0.04	0.02		0.20	0.10	0.10			0.02	0.01							
Benthic invertebrates				0.05	0.10			0.02		0.04					0.10		0.10		0.10					0.80					
Large zooplankton	0.05	0.30	0.40							0.10	0.03		0.05		0.45	0.60	0.30	0.10	0.10	0.14	0.60	0.50	0.02	0.20	0.20	0.20	0.10			
Small zooplankton	0.05	0.10	0.40							0.03	0.32				0.35	0.40	0.10	0.10	0.10	0.14	0.40	0.30			0.80	0.80	0.90		0.10	
Phytoplankton																													0.80	0.90
Detritus																												1.00	0.10	0.10
Import																														
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Catches for whales and fishes separately. The unit is t/km^2/year.

Group name	Whale Catch	Fishery	Total
Minke whale	0.001	0	0.001
Bryde's whale	0	0	0
Other Baleen whale	0	0	0
Sperm whale	0	0	0
Baird's beaked whale	0.001	0	0.001
Dall's porpoise	0.001	0	0.001
Short-finned pilot whale	0.001	0	0.001
Other toothed whale	0.001	0	0.001
Northern fur seal	0	0	0
Sea birds	0	0	0
Albacore	0	0.001	0.001
Swordfish	0	0	0
Skipjack tuna	0	0.005	0.005
Blue Shark	0	0.018	0.018
Pollock	0	0.402	0.402
Lanternfish	0	0	0
Common squid	0	0.033	0.033
Flying squid	0	0.022	0.022
Deep sea squid 1	0	0	0
Deep sea squid 2	0	0	0
Micronectonic squid	0	0.613	0.613
Mackerel	0	0.04	0.04
Pomfret	0	0.014	0.014
Bottom sea fish	0	0.05	0.05
Sardine	0	0.395	0.395
Anchovy	0	0.75	0.75
Saury	0	0.77	0.77
Benthic invertebrates	0	0.1	0.1
Large zooplankton	0	0	0
Small zooplankton	0	0	0
Phytoplankton	0	0	0
Detritus	0	0	0
Sum	0.005	3.213	3.218

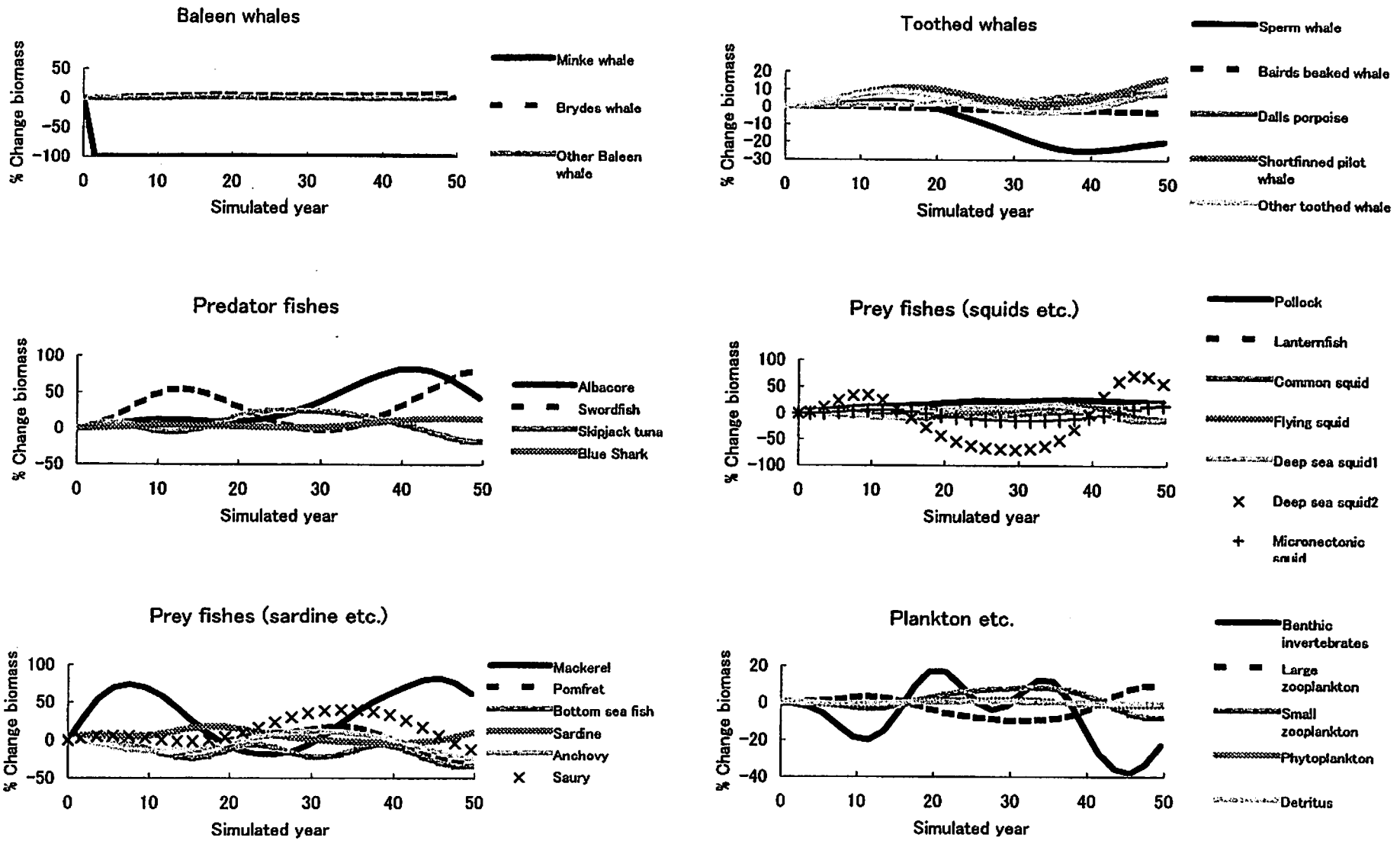


Fig. 1. The result of Ecosim dynamic simulation. The change of relative biomass without minke whale using high fishing rate (F=10) during future 50 years (v = 0.6).

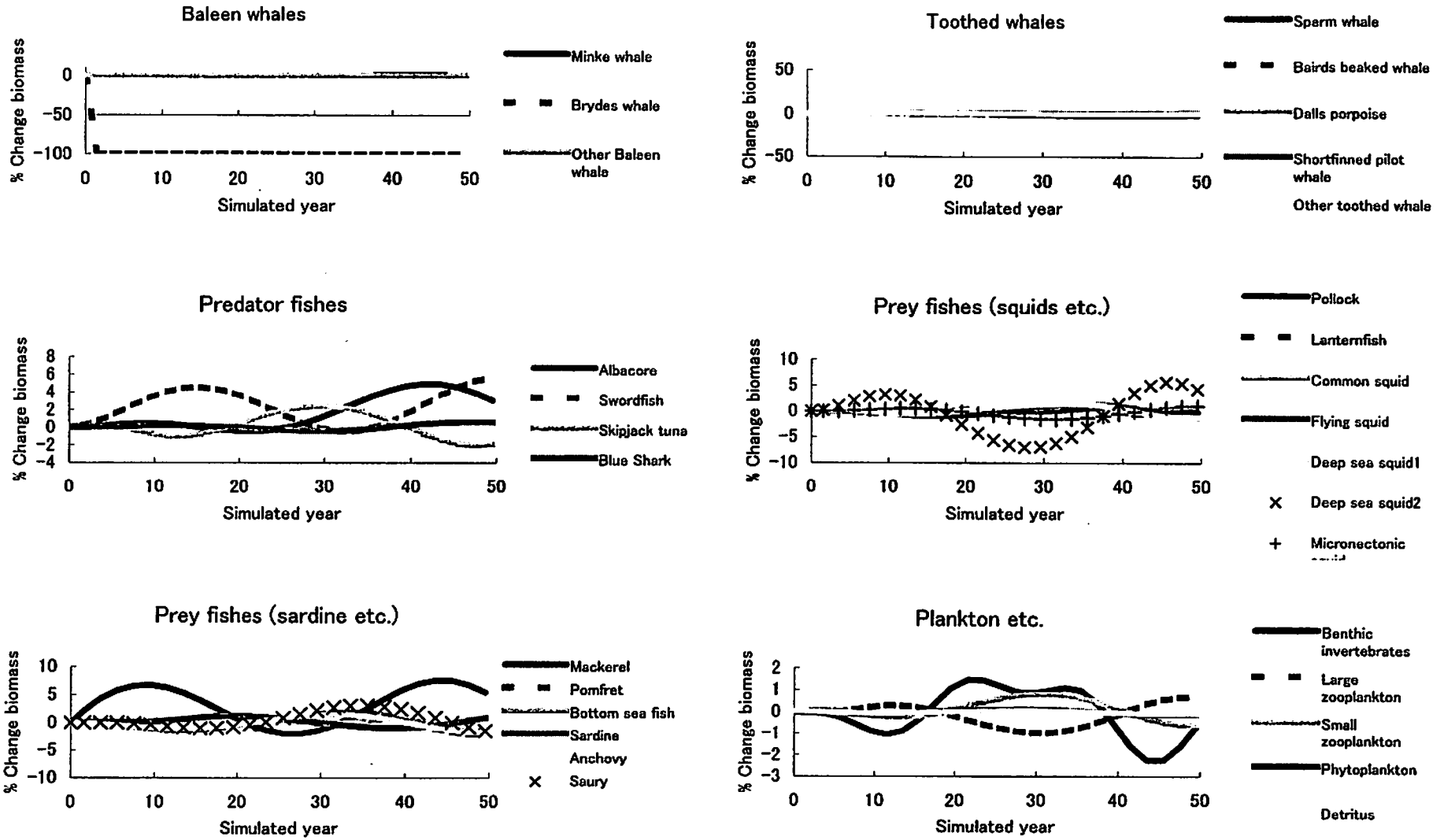


Fig. 2. The result of Ecosim dynamic simulation. The change of relative biomass without Bryde's whale using high fishing rate (F = 10) during future 50 years (v = 0.6).

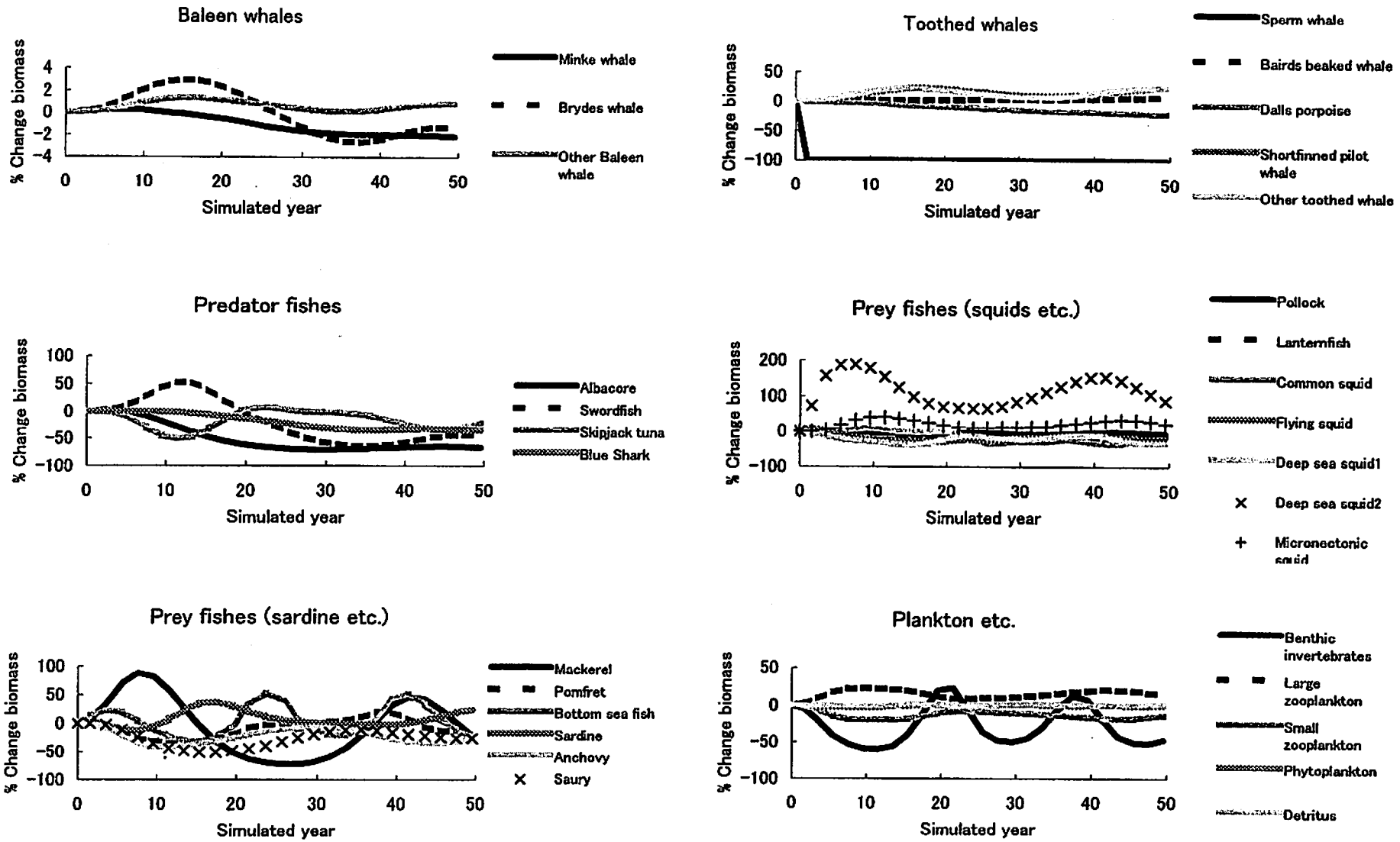


Fig. 3. The result of Ecosim dynamic simulation. The change of relative biomass without sperm whale using high fishing rate (F = 10) during future 50 years (v = 0.6).

Appendix 8

Examination of key cetacenas based on JARPN II data using Ecopath-type model

Hiroshi Okamura, Hiroshi Ohizumi, Shigeyuki Kawahara
National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu 424-8633, Japan

To clarify the role of cetaceans, especially sperm whale, in the ecosystem, several test runs were carried out using Ecopath with Ecosim. Some parameters were altered from the first runs of the model (SC/53/O9). Main alterations are as follows:

1. Separate deep-sea squids into vertical migrators between the deep sea (say, deeper than 400m in depth) and surface layer (shallower than 200m) and real deep-sea squids which do not migrate to the surface layer.
2. Sperm whales eats mainly real deep-sea squids based on the results of two-year feasibility JRAPN II surveys.
3. Create deep-sea cod group as one component of Ecopath

Above alterations required further modifications of other parameters and new assumptions. All the parameters used in Ecopath are shown in Tables 1 to 3. These parameters may need further examination.

After setting overall vulnerability parameters to 0.6 as in the base case of the first runs, Ecosim simulations were carried out under the following three scenarios:

1) Remove only minke whales from the ecosystem using the high fishing rate
2) Remove only Bryde's whales from the ecosystem using the high fishing rate
3) Remove only sperm whales from the ecosystem using the high fishing rate

Figures 1 to 3 give the results of 50-years simulation under the above scenarios. Trajectories in figures show variation of relative biomass of each group. Real deep-sea squids are exceedingly influenced by removing sperm whales. Other prey species are also influenced by the removal of sperm whale as well as in the case of the removal of minke whales. The impact of removal of sperm whale is larger than that out of removal of Bryde's whales. We can see that the removal of minke whales has positive effect onto commercially important fish groups and the removal of sperm whale gives them negative effect. The assumption that the vulnerability parameter (v) = 0.6 was likely to have strong effect on the results above-mentioned. And also, theses results regarding to the sperm whales were strongly dependent on the input parameters of deep-sea squids, their predators and preys, for which the information is limited now. Especially the data on the interaction between those animals should be collected to clarify the role of sperm whale more precisely.

Table1. Biomass, P/B, Q/B etc.

		B	P/B	Q/B	EE	P/Q
Minke whale	1	0.035	0.02	6.44		
Brydes whale	1	0.002	0.02	5.444		
Other Baleen whale	1	0	0.02	4.688		
Sperm whale	1	0.024	0.02	4.594		
Bairds beaked whale	1	0.04	0.02	5.791		
Dalls porpoise	1	0.017	0.06	14.39		
Shortfinned pilot whale	1	0.036	0.06	8.399		
Other toothed whale	1	0.1	0.06	11.657		
Northern fur seal	1	0.001	0.06	18.744		
Sea birds	1	0.003	0.8	34.375		
Albacore	1	0.004	0.54	2.5		
Swordfish	1	0	0.6	6.4		
Skipjack tuna	1	0.025	1.18	32.57		
Blue Shark	1	0.059	0.48	1.5		
Pollock	1	1.339	0.5	2.64		
Lanternfish	1	5.2	0.9	25.276		
Common squid	1	0.109	3.2	10.667		
Flying squid	1	0.073	3.2	10.667		
Deep sea squid	1		1.6	5.333	0.95	
Deep sea squid2	1		1.6	5.333	0.95	
Micronectonic squid	1	2.042	3.2	10.667		
Mackerel	1	0.134		9.3		0.3
Pomfret	1	0.047		6		0.3
Bottom sea fish	1	0.3	0.5	2.64		
Sardine	1	0.986	1.04	22		
Anchovy	1	1.666	2.15	23		
Saury	1	1.71	1.05	5		
Benthic invertebrates	1		1.48	7.69	0.95	
Large zooplankton	1	50	5	22		
Small zooplankton	1	55	6	22		
Phytoplankton	1	33.083	97.482			
Detritus	1	165.415				

Table 2. Diet Composition

	Minke whale	Brydes whale	Other Baleen whale	Sperm whale	Bairds beaked whale	Dalls porpoise	Shortfinned pilot whale	Other toothed whale	Northern fur seal	Sea birds	Albacore	Swordfish	Skipjack tuna	Blue Shark	Pollock	Lanternfish
Minke whale								0.003								
Brydes whale								0								
Other Baleen whale								0.002								
Sperm whale																
Bairds beaked whale																
Dalls porpoise																
Shortfinned pilot whale																
Other toothed whale																
Northern fur seal																
Sea birds																
Albacore																
Swordfish																
Skipjack tuna																
Blue Shark																
Pollock	0.1															
Lanternfish	0.1	0.2	0.05		0.2	0.7	0.1	0.165			0.05		0.05	0.02	0.02	
Common squid					0.1	0.05	0.1		0.15	0.09		0.2	0.02	0.2		
Flying squid				0.05	0.05		0.1		0.15	0.045		0.2	0.02	0.2		
Deep sea squid				0.05	0.05		0.1	0.1		0.045		0.2	0.02	0.2		
Deep sea squid2				0.55	0.05		0.1	0.1								
Micronectonic squid			0.05	0.05	0.1	0.05	0.2	0.3	0.16	0.09		0.2	0.02	0.2		
Mackerel	0.1	0.2	0.05			0.1	0.2	0.15	0.3		0.05	0.2	0.01	0.02		
Pomfret					0.05	0.05		0.01	0.05	0.14	0.05		0.01	0.04		
Bottom sea fish				0.25	0.3											
Sardine	0.2	0.1					0.025	0.025	0.05	0.14	0.05		0.4	0.04	0.02	
Anchovy	0.2	0.1	0.05			0.05	0.05	0.1	0.05	0.14	0.05		0.4	0.04	0.04	
Saury	0.2						0.025	0.025	0.05	0.14	0.4			0.04	0.02	
Benthic invertebrates				0.05	0.1			0.02		0.04					0.1	
Large zooplankton	0.05	0.3	0.4							0.1	0.03		0.05		0.45	0.6
Small zooplankton	0.05	0.1	0.4							0.03	0.32				0.35	0.4
Phytoplankton																
Detritus																

	Pollock	Lanternfish	Common squid	Flying squid	Deep sea squid	Deep sea squid	Micronectonic squid	Mackerel	Pomfret	Bottom se	Sardine	Anchovy	Saury	Benthic inve	Large zo	Small zooplankton
Minke whale																
Brydes whale																
Other Baleen whale																
Sperm whale																
Bairds beaked whale																
Dalls porpoise																
Shortfinned pilot whale																
Other toothed whale																
Northern fur seal																
Sea birds																
Albacore																
Swordfish																
Skipjack tuna																
Blue Shark																
Pollock																
Lanternfish	0.02		0.1	0.103	0.4	0.571		0.02	0.15							
Common squid			0.05					0.005	0.45							
Flying squid				0.021				0.005	0.1							
Deep sea squid				0.309				0.005	0.1							
Deep sea squid2																
Micronectonic squid			0.05	0.052	0.1	0.143		0.005	0.05							
Mackerel																
Pomfret																
Bottom sea fish																
Sardine	0.02			0.103				0.02	0.02							
Anchovy	0.04		0.1	0.103	0.1			0.12	0.1							
Saury	0.02		0.2	0.103	0.1			0.02	0.01							
Benthic invertebrates	0.1		0.1		0.1					0.8						
Large zooplankton	0.45	0.6	0.3	0.103	0.1	0.143	0.6	0.5	0.02	0.2	0.2	0.2	0.1			
Small zooplankton	0.35	0.4	0.1	0.103	0.1	0.143	0.4	0.3			0.8	0.8	0.9		0.1	
Phytoplankton															0.8	0.9
Detritus															0.1	0.1

Table 3. Catch

	Whaling	Fishery	Total
Minke whale	0.001	0	0.001
Brydes whale	0	0	0
Other Baleen whale	0	0	0
Sperm whale	0	0	0
Bairds beaked whale	0.001	0	0.001
Dalls porpoise	0.001	0	0.001
Shortfinned pilot whale	0.001	0	0.001
Other toothed whale	0.001	0	0.001
Northern fur seal	0	0	0
Sea birds	0	0	0
Albacore	0	0.001	0.001
Swordfish	0	0	0
Skipjack tuna	0	0.005	0.005
Blue Shark	0	0.018	0.018
Pollock	0	0.402	0.402
Lanternfish	0	0	0
Common squid	0	0.033	0.033
Flying squid	0	0.022	0.022
Deep sea squid	0	0	0
Deep sea squid2	0	0	0
Micronectonic squid	0	0.613	0.613
Mackerel	0	0.04	0.04
Pomfret	0	0.014	0.014
Bottom sea fish	0	0.05	0.05
Sardine	0	0.395	0.395
Anchovy	0	0.75	0.75
Saury	0	0.77	0.77
Benthic invertebrates	0	0.1	0.1
Large zooplankton	0	0	0
Small zooplankton	0	0	0
Phytoplankton	0	0	0
Detritus	0	0	0
Sum	0.005	3.213	3.218

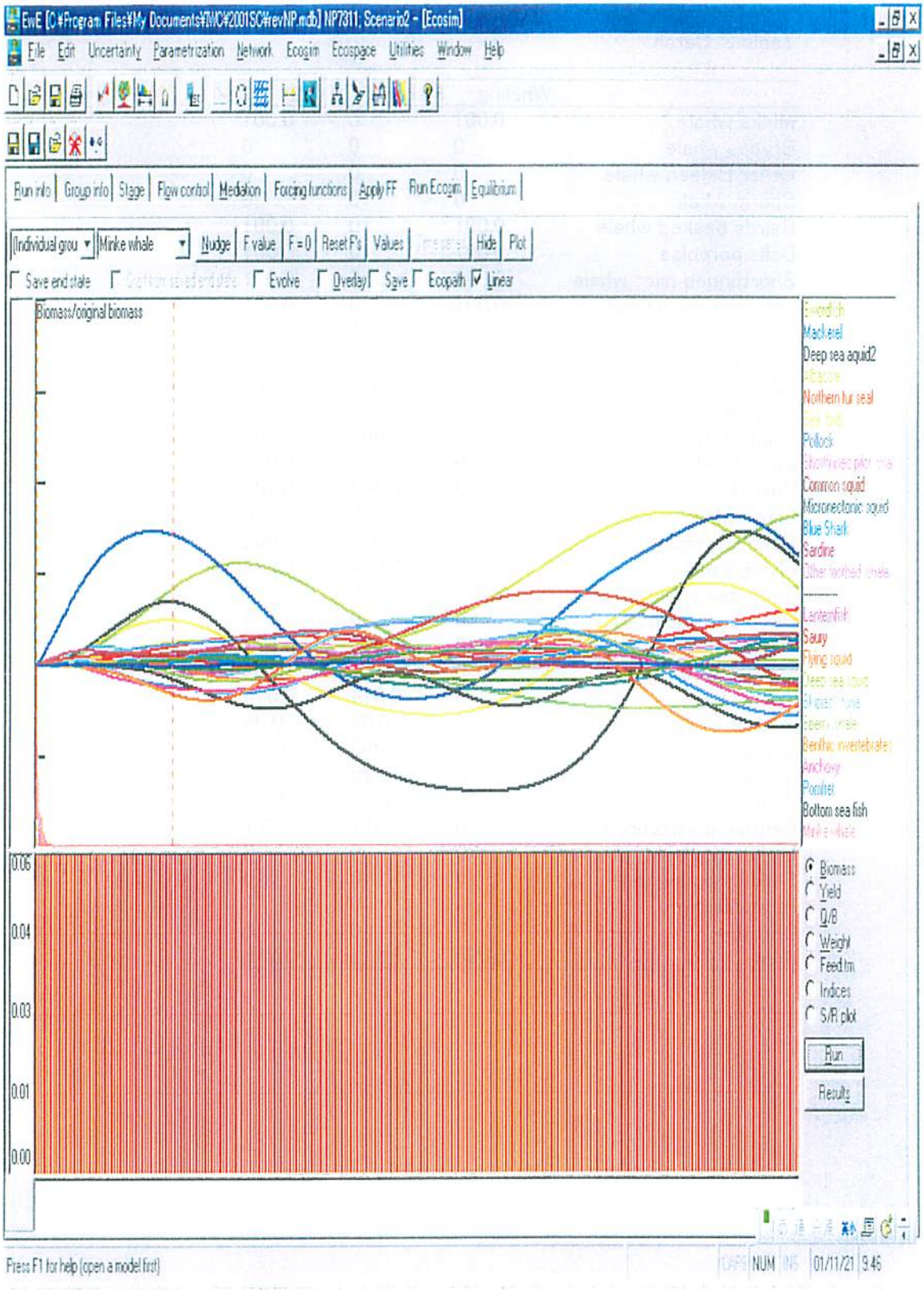


Fig.1. Removal of minke whales

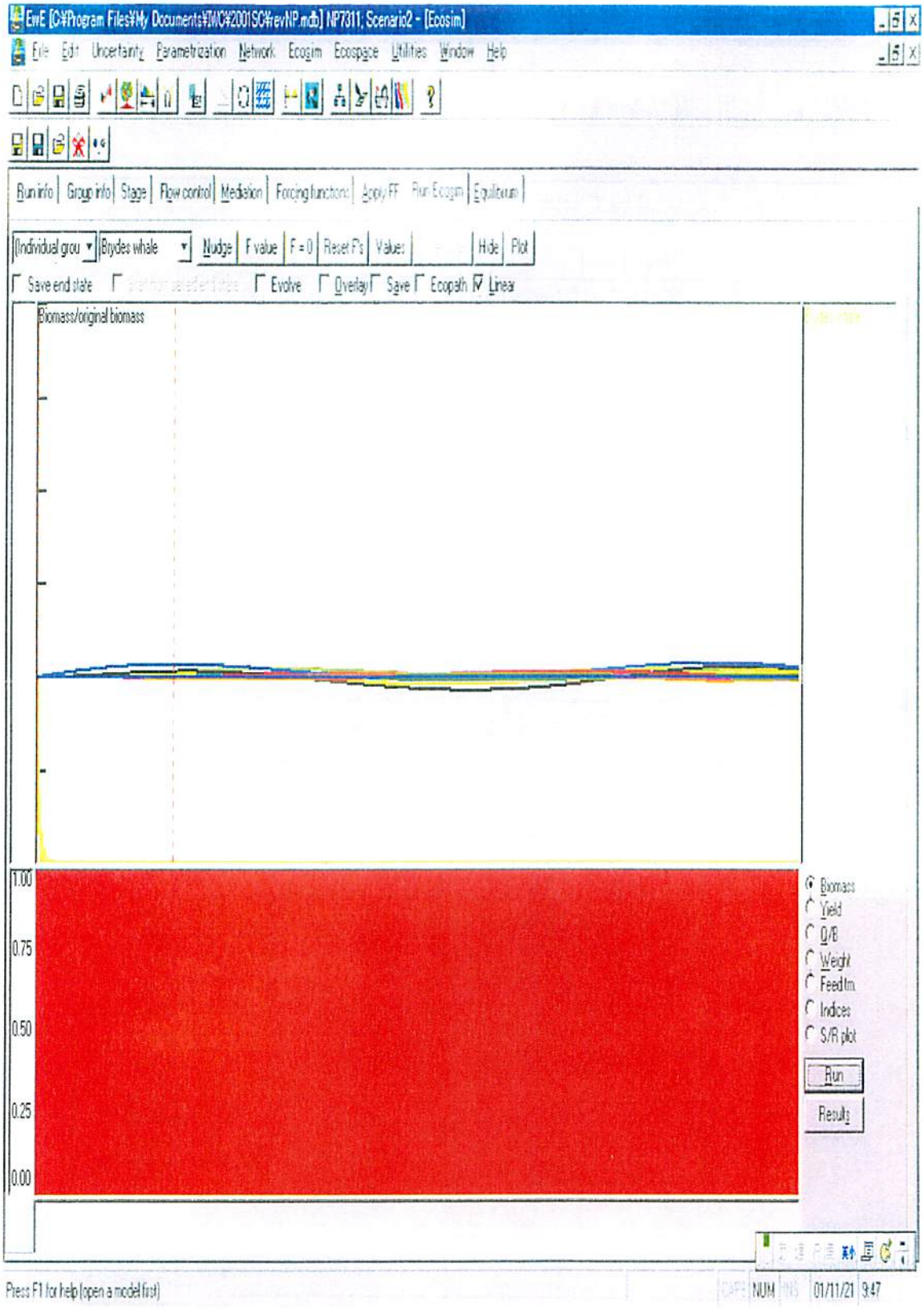


Fig. 2. Removal of Bryde's whales

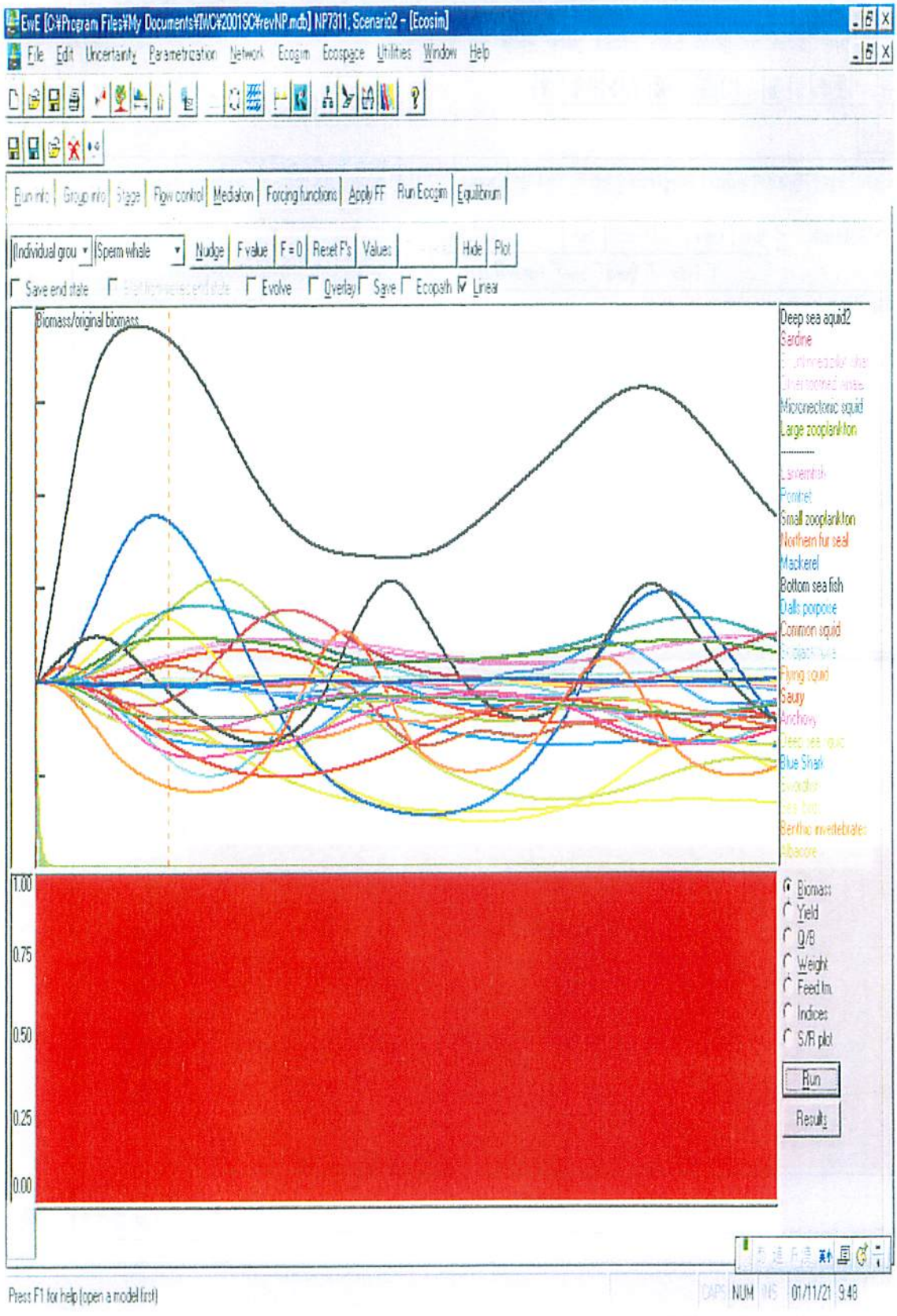


Fig.3 Removal of sperm whales

Appendix 9

Genetic analysis of western North Pacific minke whales taken for JARPN and JARPN II

Mutsuo Goto, Naohisa Kanda and Luis A. Pastene

The Institute of Cetacean Research
4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

Genetic analysis was conducted on the total JARPN and JARPN II samples from 1994 to 2001 using both mitochondrial (mt) DNA (sequencing of a 487bp segment of the control region) and nuclear (n) DNA (seven microsatellite loci). A genetic criterion was used to identify the animals suspected to be the J-Stock and then these animals were excluded from the analysis. We also examined alternative grouping of samples in response to suggestions from a member of the North Pacific Minke Whale RMP IST Steering Group, i.e., SA (7+11) vs SA8, SA (7+11) vs SA9, and SA (7+8+11) vs SA9. The source of some degree of mtDNA heterogeneity found among the sub-areas was attributed to whales sampled in the western part of sub-area 9 in 1995, 2000 and 2001. Because the sample size in 2000 (n=16) and 2001 (n=29) were small compared to that in 1995 (n=78), no definitive conclusion can be obtained for these two years. Excluding the samples from sub-area 9W in 1995, 2000 and 2001, no mtDNA heterogeneity was found in sub-areas 7, 8, 9 and 11 even for the different groupings requested. As regard to microsatellite analysis, no evidence of genetic differences was detected among the samples from SA7, 8, 9, and 11. No evidence of genetic differences was also detected in a comparison between samples collected from west and east of 153 degree. These results support the one-stock scenario in sub-areas 7, 8, 9 and 11 but the possibility that some individuals from a different stock sporadically appear in sub-area 9W cannot be discarded.

INTRODUCTION

Previous genetic analyses based on JARPN samples and hypothesis testing were summarized by Pastene *et al.* (2000). The most recent genetic analysis was based on mtDNA and microsatellite analyses and used samples from the 2000 JARPN II survey, in addition to those from the JARPN surveys (Goto *et al.*, 2001). The results of these genetic analyses provided no firm evidence for a multi-stock scenario in sub-areas 7, 8 and 9. The mtDNA analysis presented in Goto *et al.* (2001) provided some evidence of mtDNA heterogeneity due to samples from sub-area 9W in two years, 1995 and 2000.

In this paper we presented new mtDNA and microsatellite analyses based on the total samples available from JARPN and JARPN II in sub-areas 7, 8, 9 and 11 from 1994 to 2001. In response to a recommendation of the Scientific Committee (IWC, 2002) we used a genetic criteria to identify J Stock like animals present in these sub-areas and exclude them from this analysis. We also conduced heterogeneity tests between the samples from different combinations of these sub-areas to respond the requests made by a member of the North Pacific Minke Whale RMP IST Steering Group.

MATERIALS AND METHODS

Samples and localities

Samples used in this study were taken during the JARPN and JARPN II surveys in sub-areas 7, 8, 9 and 11 from 1994 to 2001. The total number of samples examined in this study (JARPN and JARPN II) is shown in Table 1 by sub-area, month and sex. The geographical localities of minke whales of a total samples is shown in Fig. 1.

Criteria for definition of 'J' type animals

We tentatively defined J stock animals using the following criteria. Firstly we allocated mtDNA-sequencing haplotypes to three categories as follow:

1) JJ type; haplotypes detected in samples from Sea of Japan side only,
2) JO type; haplotypes detected in samples from both Sea of Japan and Pacific side of Japan,
3) OO type; haplotypes detected in samples from Pacific side of Japan only.

In our analysis we used only those samples that were characterized by the OO type criteria. Furthermore, within this OO type sub-set, we excluded those samples that were defined by two-site criteria (i.e. positions 298 and 463), which are likely to be diagnostic sites for the J-stock.

MtDNA analysis

Sequencing of the mtDNA control region

The first half of control region of the mitochondrial genome (487bp) was sequenced by the same method used in our previous study (Goto and Pastene, 2000). All the procedures for DNA extraction and amplification of mtDNA control region were the same as in the previous study.

Data analysis

Homogeneity tests were conducted using the randomized χ^2 test (Roff and Bentzen, 1989) and Hudson *et al.* (1992)'s sequence (Kst*) and haplotype (Hst) statistics.

Microsatellite analysis

Genotyping

Microsatellite polymorphisms were analyzed from seven loci. The details of the seven loci used and all the procedures for DNA extraction, PCR amplification, and electrophoresis were described in our previous papers (e.g., Goto *et al.*, 2001).

Data analysis

All statistical tests were conducted using the computer program GENEPOP (Raymond and Rousset, 1995). Decision of statistically significance on hypothesis testing was made using the chi-square value obtained from summing the negative logarithm of P-values over the seven loci (Fisher, 1950).

RESULTS

MtDNA analysis

Variability of mtDNA control region sequences of JARPN and JARPN II samples

Table 2 shows mtDNA haplotype frequencies in samples taken by JARPN (1994-1999) and JARPN II (2000 and 2001). Haplotype '9' was predominant in sub-area 9W in the 2000 (37.5%) and 2001 (24.1%) samples. These situations are similar to the case in the 1995 sub-area 9W (23.1%) sample. This haplotype

presented a frequency larger than that observed in sub-area 9E in 1995 and those observed in sub-areas 7 and 8.

Homogeneity test

Using three statistical tests, no significant yearly variation was found in sub-areas 7, 8, 9 and 11. In the following analyses we combined samples from different years in these sub-areas. Table 3A shows the results of the homogeneity tests among sub-areas 7, 8 and 9. No significant differences were found between sub-areas 7 and 8 by three statistical tests. On the other hand, the comparison between sub-area 9 and other two sub-areas showed significant differences. These significant differences do not occur when samples from sub-areas 9W in 1995, 2000 and 2001 are excluded from the analysis (Table 3B).

Table 4 shows the results of the homogeneity tests for the comparison between sub-areas 11+7 and 8, sub-areas 11+7 and 9, and sub-areas 11+7+8 and 9. Prior to these analyses, we compared sub-areas 7 and 11. No significant differences were detected (χ^2; P=0.7226, Hst; P=0.7733, Kst*; 0.7491).

There is no significant difference between sub-areas 11+7 and 8. In contrast to that, the comparisons between sub-areas 11+7 and 9 and sub-areas 11+7+8 and 9 shows significant differences, except Kst* statistics (P=0.0842) for the case of sub-areas 11+7 and 9. When the samples from the western part of sub-area 9 in 1995, 2000 and 2001 are excluded from the analysis, no mtDNA heterogeneity is found in sub-areas 7, 8, 9 and 11 for the same groupings used (Table 5).

Table 6 shows the results of comparison between sub-areas 7 + 8W and sub-areas 8E + 9. Sub-area 8 was divided into east and west by 153° E. Significant differences are detected by χ^2 and Hst. When the samples from the western part of sub-area 9 in 1995, 2000 and 2001 are excluded from the analysis, however, no mtDNA heterogeneity is found in this combination (Table 7).

Comparisons between sub-areas 8E and 9 show significant differences by Hst and Kst* and near to significant by χ^2 (P=0.0539)(Table 8).

Microsatellite analysis

Homogeneity test

We first tested if there was any evidence of genetic differences at seven microsatellite loci analyzed between samples collected from each sub-area in different years. If no genetic difference exists, then we combine the samples from the same sub-areas into one in the following analysis. Contingency table chi-square analysis for heterogeneity of allele frequencies at the seven loci indicated no evidence of statistically significant heterogeneity among the samples within SA7 (P=0.088), 8 (P=0.172), 9 (P=0.194)[1], and 11 (P=0.106), respectively.

---

[1] We previously reported a statistically significant microsatellite heterogeneity among the samples collected from SA9 (P=0.030) in different years (i.e., SC/J02/NP11). Since then, we have analyzed more samples of minke whales (mostly by-catches), and found that a few JARPNII samples were not correctly scored. Their genotypes were therefore rescored (generally heterozygotes became homozygotes for one of the two alleles), and the rescoring slightly changed the result (i.e., loss of SA9 heterogeneity). We, however, emphasize that main conclusion do not differ between previous and current documents.

Table 9 shows the results of heterogeneity test for the allele frequencies at seven microsatellite loci among samples of minke whales collected from SAs 7, 8, 9 and 11. Contingency table chi-square analysis for heterogeneity of allele frequencies indicated that the chi-square value combined for the seven loci was not statistically significant among the samples, indicating these whales appeared to have come from a genetically same group of minke whales. We also found no evidence of statistically significant deviation from expected random-mating genotypic distribution in the combined samples of SAs 7, 8, 9, and 11, supporting the existence of only single population of minke whales in the North Pacific (Table 9).

Table 10 shows the results of heterogeneity tests for a comparison between samples collected from west and east of longitude 153 degree. The comparison showed no evidence of statistically significant heterogeneity, supporting again the existence of only the single stock in the study area.

DISCUSSION

In this paper we presented new mtDNA and microsatellite analyses based on the total samples available from JARPN and JARPN II in sub-areas 7, 8, 9 and 11. Following a recommendation from the Scientific Committee we excluded the suspected J Stock animals from these sub-areas. To identify J-Stock individuals we used a method based on genetic criteria. We feel that most of the J Stock animals had been removed from the research area as we uses an 'extreme' criterion to identify J Stock animals. However we also feel that the results of this genetic method should be contrasted with those based on non-genetic methods (e.g. occurrence of scar, fetal length). Some inconsistencies have been found in the past among results derived from genetic and non-genetic methods. This requires further consideration.

In the 2001 JARPN II survey in sub-area 9W we found a similar scenario to that observed in 1995 and 2000 (Goto *et al.* 2001). The frequency of a particular haplotype '9' in this sample was higher than in the other sub-areas. When the total samples are considered in the statistical analysis, we found some degree of mtDNA heterogeneity due to sub-area 9. However when these samples are excluded, no genetic heterogeneity was observed for the different combinations made. Because the sample sizes in sub-area 9W in 2000 and 2001 is small compared to that in 1995, no firm conclusion may not be obtained from these samples.

In conclusion, the results from our analysis using both mtDNA and nDNA provide no strong evidence for additional stock structure in sub-areas 7, 8, 9 and 11. It is important to note, however, that the mtDNA difference we observed among the samples collected from the sub-area 9 in different years could indicate that some members of the different stock of minke whales might occasionally enter west side of the sub-area 9.

ACKNOWLEDGMENTS

We thank H. Hatanaka for helpful comments and suggestions on this manuscript. We gratefully acknowledge the researchers and crew members that participated in JARPN surveys during the 1994 and 1999 and JARPN II surveys in 2000 and 2001. H. Oikawa and S. Azumi (ICR Ayukawa Laboratory) collaborated in the process of DNA extraction.

REFERENCES

Fisher, R. A. 1950. Statistical Methods for Research Workers. 11th edn. Oliver and Boy, London.

Goto, M. and Pastene, L.A. 2000. Population structure in the western North Pacific minke whale based on RFLP and sequencing analyses of mtDNA control region, using data from the 1994-1999 JARPN surveys. Paper SC/F2K/J11 presented to the IWC Scientific Committee Workshop to Review the Japanese Whale Research Programme under Special Permit for North Pacific Minke Whales (JARPN), Tokyo, 7-10 February 2000 (unpublished). 15pp.

Goto, M., Kanda, N. and Pastene, L.A. 2001. Genetic examination of western North Pacific minke whales including samples from JARPN II. Paper SC/53/RMP11 presented to the IWC Scientific Committee, July 2001 (unpublished). 11pp.

Hudson, R.R., Boos, D.D. and Kaplan, N.L. 1992. A statistical test for detecting geographic subdivision. *Mol. Biol. Evol.* 9(1): 138-151.

International Whaling Commission. 2002. Report of the Scientific Committee. Annex D. Report of the sub-committee on the Revised Management Procedure. *J. Cetacean Res. Manage. (Suppl.)* 4:00–00.

Pastene, L.A., Goto, M., Fujise, Y. 2000. Review of the studies on stock identity in the minke whale *Balaenoptera acutorostrata* from the North Pacific. Paper SC/F2K/J1 presented to the IWC Scientific Committee Workshop to Review the Japanese Whale Research Programme under Special Permit for North Pacific Minke Whales (JARPN), Tokyo, 7-10 February 2000 (unpublished). 22pp+Addendum 4pp.

Raymond, M. and Rousset, F. 1995. GENEPOP (version 1.2): population genetics software for exact tests and ecumenicism. *Journal of Heredity* 83: 248-249.

Roff, D.A. and Bentzen, P. 1989. The statistical analysis of mtDNA polymorphisms: chi-square and the problem of small samples. *Mol. Biol. Evol.* 6(5):539-45.

Table 1. Number of samples collected during the JARPN surveys from 1994 to 1999 and JARPN II in 2000 and 2001, by sub-area, year, month, period and sex.

Sub-area	Year	Month										Total
		Early				Late						
		May		June		July		August		September		
		Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	
7	1996					1			15	2	13	31
	1997				2							2
	1998	7	49									56
	1999			7	43							50
	2000							1	5	4	14	24
	2001	3	25		22							50
8	1996						11		5			16
	1997					1	30					31
	1998	1	7	3	33							44
	2001					1	20					21
9	1994					2	6	1	8		4	21
	1995				14	5	56	4	21			100
	1997	7	20	5	35							67
	2000								16			16
	2001					3	21		5			29
11	1996							11	19			30
	1999					22	28					50
	Total	18	101	15	149	35	172	17	94	6	31	638

Table 2. MtDNA haplotype frequencies in samples taken by JARPN (1994-1999) and JARPN II (2000-2001).

	JARPN+JARPN II 1994-2001			JARPN 1995		JARPN II	
Hap.	SA7	SA8	SA9	West	East	2000 SA9	2001 SA9
1	9	1	2	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	3	1	1	0	0	0	1
5	0	0	0	0	0	0	0
6	12	3	10	4	0	1	0
7	20	12	20	5	4	3	2
8	7	1	3	1	2	0	0
9	22	10	43	18	0	6	7
Freq.	0.103	0.089	0.185	0.231	0.000	0.375	0.241
10	1	0	0	0	0	0	0
11	8	5	12	7	1	0	2
12	6	5	7	2	2	0	0
13	15	9	4	1	1	0	0
14	8	7	13	4	1	0	2
15	6	4	7	2	0	0	1
16	16	4	12	4	1	0	1
17	9	6	19	5	3	2	1
18	2	2	3	2	0	0	0
19	2	1	1	0	0	0	0
20	4	0	1	0	0	0	1
21	3	1	3	1	0	0	0
22	1	0	0	0	0	0	0
23	2	0	1	0	1	0	0
24	1	0	0	0	0	0	0
25	1	2	4	2	0	0	0
26	1	1	0	0	0	0	0
27	1	0	1	0	0	0	0
28	2	0	0	0	0	0	0
29	5	4	6	0	0	0	1
30	9	1	10	1	2	1	0
31	2	1	3	2	0	0	1
32	1	0	0	0	0	0	0
33	2	0	0	0	0	0	0
34	3	4	4	1	1	1	0
35	2	2	0	0	0	0	0
36	4	5	3	1	0	0	2
37	3	0	2	1	0	0	0
38	2	1	1	1	0	0	0
39	1	2	5	3	0	0	0
40	0	1	0	0	0	0	0
41	0	1	0	0	0	0	0
42	0	1	0	0	0	0	0
43	1	3	1	0	0	0	1
44	0	1	0	0	0	0	0
45	1	2	1	0	0	0	1
46	1	1	0	0	0	0	0
47	0	1	0	0	0	0	0
48	0	1	1	1	0	0	0
49	0	1	1	0	0	0	0
50	0	1	2	0	0	1	0
51	0	1	1	0	0	0	0
52	0	0	6	2	1	0	1
53	3	0	4	3	0	0	0
54	0	0	1	1	0	0	0
55	0	0	1	1	0	0	0
56	0	0	1	1	0	0	0
57	0	0	1	1	0	0	0
58	0	0	1	0	1	0	0
59	0	0	3	0	1	0	1
60	0	0	3	0	0	0	1
61	0	0	1	0	0	0	0
62	1	0	0	0	0	0	0
64	1	0	0	0	0	0	0
66	3	0	0	0	0	0	0
75	0	2	0	0	0	0	0
81	2	0	0	0	0	0	0
87	1	0	0	0	0	0	0
88	0	0	1	0	0	1	0
89	1	0	0	0	0	0	0
90	1	0	0	0	0	0	0
91	1	0	0	0	0	0	0
92	0	0	1	0	0	0	1
93	0	0	1	0	0	0	1
Total	213	112	233	78	22	16	29

Table 3A. Comparison among sub-areas 7, 8 and 9 by three statistical tests (χ^2; upper, Hst; middle, Kst*; lower). Figures shown are P-values.

		SA7 n=173	SA8 n=96
		0.1542	
SA8	n=96	0.5020	
		0.4233	
		0.0149	0.0500
SA9	n=192	0.0156	0.0177
		0.0570	0.0042

Table 3B. Comparison among sub-areas 7, 8 and 9 by three statistical tests (χ^2; upper, Hst; middle, Kst*; lower). Samples from west side of sub-area 9 in 1995, 2000 and 2001 were excluded from these analyses. Figures shown are P-values.

		SA7 n=173	SA8 n=96
		0.1573	
SA8	n=96	0.5003	
		0.4320	
		0.1631	0.1812
SA9	n=92	0.6918	0.3646
		0.6310	0.1487

Table 4. Results of comparison by three statistical tests (χ^2, Hst and Kst*) between sub-areas 11+7 and 8, sub-area 11+7 and 9 and sub-areas 11+7+8 and 9. Figures shown are P-values.

			χ^2	Hst	Kst*
SA11+7 N=224	vs	SA8 n=96	0.1588	0.572	0.3275
SA11+7 N=224	vs	SA9 n=192	0.0255	0.0256	0.0842
SA11+7+8 N=320	vs	SA9 n=192	0.0162	0.0049	0.0083

Table 5. Results of comparison by three statistical tests (χ^2, Hst and Kst*) between sub-areas 11+7 and 8, sub-area 11+7 and 9 and sub-areas 11+7+8 and 9. Samples from west side of sub-area 9 in 1995, 2000 and 2001 were excluded from these analyses. Figures shown are P-values.

			χ^2	Hst	Kst*
SA11+7 n=224	vs	SA8 n=96	0.1588	0.572	0.3275
SA11+7 n=224	vs	SA9 n=92	0.1977	0.7272	0.7763
SA11+7+8 n=320	vs	SA9 n=92	0.1826	0.5889	0.4948

Table 6. Results of comparison by three statistical tests (χ^2, Hst and Kst*) between sub-areas 7 + 8W and sub-areas 8E + 9. Sub-area 8 was divided into east and west by 153° E. Figures shown are P-values.

Sample size		P value		
SA7+8W	SA8E+9	χ^2	Hst	Kst*
213	248	0.0270	0.0291	0.2096

Table 7. Results of comparison by three statistical tests (χ^2, Hst and Kst*) between sub-areas 7 + 8W and sub-areas 8E + 9. Sub-area 8 was divided into east and west by 153° E. Samples from west side of sub-area 9 in 1995, 2000 and 2001 were excluded from these analyses. Figures shown are P-values.

Sample size		P value		
SA7+8W	SA8E+9	χ^2	Hst	Kst*
213	148	0.1671	0.4138	0.7536

Table 8. Results of comparison by three statistical tests (χ^2, Hst and Kst*) between sub-areas 8E and 9. Sub-area 8 was divided into east and west by 153° E. Figures shown are P-values.

Sample size		P value		
SA8E	SA9	χ^2	Hst	Kst*
56	192	0.0539	0.0396	0.0099

Table 9. Results (P-values) of heterogeneity tests for the allele frequencies at seven microsatellite loci among the samples of minke whales collected from sub-areas 7, 8, 9 and 11. H-W then indicates the results of tests for deviation from expected random-mating genotypic distribution in combined samples of SAs 7, 8, 9, and 11. P-value for All was calculated from summation of -2ln(P).

	Microsatellite locus							
Sample	EV1	EV104	GT211	GT509	GATA28	GATA417	GATA98	All
SA7x8x9x11	0.022	0.252	0.607	0.292	0.064	0.945	0.666	0.121
H-W*	0.122	0.887	0.217	0.706	0.464	0.114	0.275	0.275

* Samples from SAs 7, 8, 9, and 11 were all combined for the Hardy-Weinberg test.

Table 10. Results (P-values) of heterogeneity tests for the allele frequencies at seven microsatellite loci between samples from west and east of longitude 153 degree (samples from SA11 were excluded). P-value for All was calculated from summation of -2ln(P).

	Microsatellite locus							
Sample	EV1	EV104	GT211	GT509	GATA28	GATA417	GATA98	All
west x east	0.025	0.546	0.692	0.390	0.229	0.872	0.045	0.112

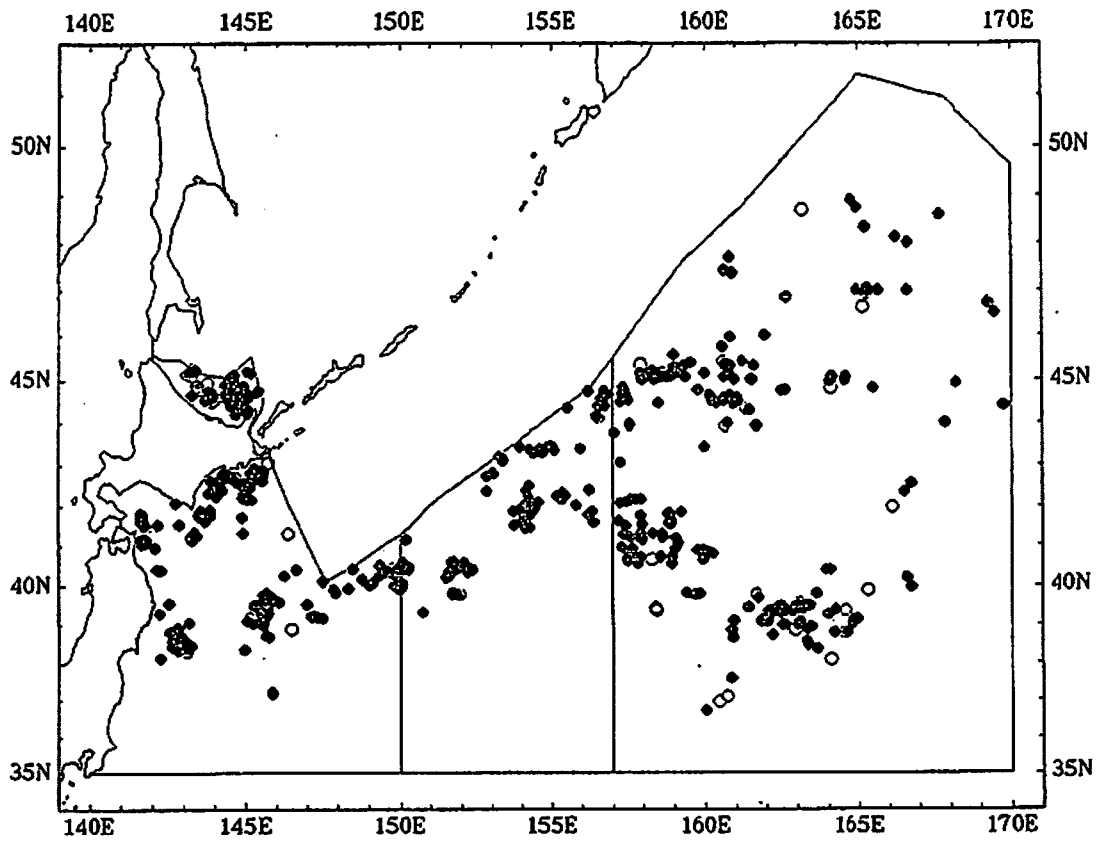


Fig. 1. Geographical positions of North Pacific minke whales sampled in the JARPN and JARPN II surveys from 1994 to 2001. ○: female, ●: male.

Appendix 10

Mitochondrial DNA and microsatellite analyses in the western North Pacific Bryde's whale, including samples from JARPN II 2000 and 2001 surveys

Luis A. Pastene, Mutsuo Goto and Naohisa Kanda

The Institute of Cetacean Research 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

Mitochondrial DNA control region sequencing and microsatellite analyses were conducted on samples of the ordinary form Bryde's whales from different localities of the western North Pacific (WNP). The mtDNA analysis involved the following samples from this oceanic region: JARPN II (surveys conducted in 2000 and 2001, n=85); Ogasawara (former coastal whaling in 1983, 1984, n=103) and central western North Pacific (CWNP, former pelagic whaling in 1979, n=95). As out-groups, Bryde's whales from the western South Pacific (WSP, n=24), eastern South Pacific (ESP, n=33) and eastern Indian Ocean (EIO, n=23) were used. A total of 58 unique mtDNA sequences (haplotypes) were discriminated in the total samples. The analysis of molecular variance using PHIst and Fst statistics revealed no significant differences among the three localities in the North Pacific. In contrast striking mtDNA differences were found among oceanic regions. Additional analyses using a randomized chi-square test found some degree of heterogeneity between historical samples from Ogasawara and recent JARPN II samples but the same test found no significant heterogeneity between JARPN II and CWNP or between Ogasawara and CWNP. The microsatellite analysis with five loci involved the same localities in the WNP: JARPN II (n=85), Ogasawara (n=50) and CWNP (n=50). The following out-groups were used: WSP (n=25) and EIO (n=10). No significant deviation from the Hardy-Weinberg equilibrium was observed in the three WNP localities and no significant differences in allele frequencies were found among these localities. In contrast striking nuclear DNA differences were found among WNP, WSP and EIO. Results of the present analysis confirm the occurrence of different genetic populations in the western North Pacific, western and eastern South Pacific and in the eastern Indian Ocean. These results provide support for the stock structure scenario defined by the Scientific Committee in the North Pacific. The mtDNA heterogeneity found by the chi-square test between Ogasawara and JARPN II should be further investigated in the future.

INTRODUCTION

The comprehensive assessment of North Pacific Bryde's whale began during the 47th meting of the IWC Scientific Committee (IWC, 1996). On the basis of the information derived from genetics and non-genetics analyses, the Committee defined five stocks: eastern China stock (including inshore waters of Kochi), western North Pacific stock, eastern Tropical stock, Gulf of California stock and Solomon Island/Southeast Asia dwarf stock.

In 1998 the IWC Scientific Committee agree that there should be two sub-areas (sub-areas 1 and 2) in the western North Pacific Stock divided at 180°, which would allow the testing of two alternative stock hypotheses for IST (see Fig. 1). In 1999 some members of the Committee expressed their concern that sub-area 1 is very large and that there is limited information for some parts. Specifically they were referring to the scarce genetic samples in some parts of sub-area 1 as shown in Appendix 14 of Annex D in IWC (1999).

In this report we presents the results of further genetic analyses based on the new samples obtained by the JARPN II surveys in sub-area 1. These samples come from a region of sub-area 1 not covered by the previous genetic analysis that used historical samples only. The genetic analysis included both the maternally- inherited mitochondrial DNA (mtDNA) and the bi-parental inherited nuclear DNA (microsatellite).

MATERIALS AND METHOD

Samples

Samples from the western North Pacific (WNP) used in this study were from three sources/localities (Table 1): JARPN II surveys conducted in 2000 and 2001; historical samples from former coastal whaling around the Ogasawara Islands in 1983 and 1984 and historical samples from former pelagic whaling in the central western North Pacific (CWNP) in 1979. Geographical distribution of samples in the WNP is shown in Fig. 1. As out-group we used historical samples from past commercial or research whaling in the eastern South Pacific (ESP), western South Pacific (WSP) and eastern Indian Ocean (EIO). In the case of the eastern South Pacific we also used biopsy samples obtained during a SOWER cruise off the coast of Chile in 1997.

Mitochondrial DNA analysis

The samples used for the mtDNA analysis are summarized in Table 1. A total of 283 samples were examined in the WNP (three localities) (see Fig. 1). The JARPN II surveys in 2000 and 2001 included eight calf/cow pairs. Only one individual from these pairs was examined. Thus the sample size in the genetic analysis (85) is smaller than the total individuals sampled in these surveys (Fig. 1). In the WSP, ESP and EIO, 24, 33 and 23 whales were examined respectively (Table 1).

Biochemical methods used to obtain mtDNA control region sequences are reported in Pastene *et al.* (1997a).

The geographic differentiation of mtDNA variation was tested using the Analysis of Molecular Variance (AMOVA) (Excoffier *et al.*, 1992). Both PHIst and Fst statistics were used to test for intra-oceanic genetic differences as well differences among oceanic basins. The randomized chi-square Test of Independence (Roff and Bentzen, 1989) was also used to test genetic differences within the WNP.

Microsatellite analysis

Table 2 shows the number of samples used for the microsatellite analysis, by geographical locality. A total of 185 samples were examined in the WNP in three localities (see Fig. 1), including 85 from JARPN II surveys. From the WSP and EIO a total of 25 and 10 samples were examined respectively.

Microsatellite polymorphisms were analyzed from five loci (EV1, EV104, GATA417, GATA28 and GGAA520) for the three localities in the WNP. The comparison among WNP, WSP and EIO involved the use of three loci (EV1, GATA 417 and GGAA520).

All the statistical tests were conducted using the computer program GENEPOP (Raymond and Rousset, 1995). Decision of statistically significance on hypothesis testing was made using the chi-square value obtained from summing the negative logarithm of P-values over the total loci (Fisher, 1950).

RESULTS

Mitochondrial DNA analysis

A segment of 360bp of the mtDNA control region was determined in all individuals. Among the total sample of 363 whales we detected 58 unique sequences (haplotypes). The frequencies of mtDNA haplotypes in the three localities of the WNP are shown in Fig. 2. JARPN II samples in 2000 and 2001 were combined as no significant differences were found in haplotype frequencies (chi-square P value=0.128). Also the two samples from the Ogasawara whaling grounds (1983, 1984) were pooled as

they did not differ significantly in haplotype frequencies (chi-square P value=0.600). In the WNP the three localities shared five main haplotypes (A-E) in Fig. 2. Symbol 'F' in Fig. 2 is a set of rare haplotypes specific to WNP. From Fig. 2 we note that frequencies of 'C' (the main haplotype) and 'F' are similar among the three localities. Frequencies of 'A' and 'B' are somewhat different in the Ogasawara locality.

In Fig. 3 the three localities in the North Pacific were pooled into a single WNP and compared with the other oceanic regions. Here haplotypes 'A'-'F' are the same as in Fig. 2. 'H', 'I' and 'J' refers to a set of haplotypes specific to WSP, ESP and EIO, respectively. 'G' is an individual haplotype shared by the WSP and ESP populations. From this figure differences among oceanic populations are evident. Differences among oceans (Indian Ocean and Pacific Ocean) are larger than differences within Pacific Ocean. Some haplotypes are shared among the Pacific Ocean populations. Oceanic region-specific haplotypes accounted for 100%, 84% and 13% of the animals examined in the EIO, ESP and WSP, respectively. It is noted that the main haplotype in the WSP was haplotype 'B' (58%), which was also present in the WNP, although in lower percentage.

AMOVA

The hierarchical analysis by AMOVA was conducted considering four oceanic regions (WNP, WSP, ESP and EIO) with three groups in WNP (Ogasawara, JARPN II and central western North Pacific) and two in ESP (Peru and Chile). The nested analysis of molecular variance using PHIst (Table 3A) revealed that 36.7% of the total molecular variance is due to among oceanic partitions. A negative value accounted for the division within oceanic region and 63.5% accounted for diversity within groups. Significant P values were estimated for the among oceanic region partition and for the within groups. A large P value was estimated for the category among groups within oceanic region. According to this analysis there is not significant heterogeneity among localities in the WNP.

The nested analysis of molecular variance using Fst (Table 3B) revealed that 18.6% of the total molecular variance is due to among oceanic partitions, 0.54% accounted for the division within oceanic region and 80.9% accounted for diversity within groups. Significant P values were estimated for the among oceanic region partition and for the within groups. No significant P value was estimated for the category among groups within oceanic region. According to this analysis there is not significant heterogeneity among WNP localities. It should be noted that for the 'among group within oceanic region' category the P-value was smaller than that obtained using PHIst.

Chi-square analysis

We further examined the three localities within the WNP using chi-square test. Pairwise comparisons using chi-square test showed some degree of heterogeneity between JARPN II and Ogasawara but not between Ogasawara and CWNP and JARPN II and CWNP (Table 4).

Microsatellite

No significant departure from the Hardy-Weinberg proportion at five microsatellite loci was found in the three localities in the WNP (Table 5). Table 6 shows the results of the homogeneity test comparing three localities in the WNP. No significant differences were found among these localities when each locus was considered or when all loci were combined. In the subsequent analyses samples from the three localities in the North Pacific were combined as WNP.

No significant deviation from the Hardy-Weinberg proportion was observed for the WNP, WSP and EIO samples (Table 7). The homogeneity test revealed significant differences among these three oceanic regions (Tables 8 and 9).

DISCUSSION

In a previous study Pastene *et al.* (1997b) examined the intra- and inter-oceanic patterns of mtDNA in the Bryde's whale using restriction fragment length polymorphism (RFLP) analysis. The results of the AMOVA analysis revealed striking genetic differences among oceanic regions but no significant

differences were found within the WNP. Samples from only two localities were available for this oceanic region, Ogasawara and central western North Pacific (as in Fig. 1).

Two important issues were addressed in the present analysis. The first deal with the genetic techniques used. While in the previous analysis a low-resolution level technique was used, the present analysis involved the use of two higher resolution techniques, mtDNA control region sequencing and nuclear DNA using microsatellite. The second issue deals with the geographical covering of the genetic analysis in the WNP. The previous analysis had covered two different longitudinal localities within sub-area 1 (see Fig. 1) between latitudes 20°N and 30°N. JARPN II surveys provided samples from higher latitudes within sub-area 1 e.g. between 35° and 45°N approximately.

Results of the analysis using mtDNA and microsatellite were similar. The occurrence of different genetic populations in the WNP, WSP, ESP and EIO was confirmed. However, the analysis within oceanic regions e.g. three localities within the WNP and two localities within the ESP revealed no evidence of additional population structure. It should be noted here that the sample sizes involved within the WNP were large while those within the ESP were low, then we feel more confident on the results found in the former case.

Based on the mtDNA analysis, which was more extensive than microsatellite, genetic differences are larger between oceans i.e. between Indian Ocean and Pacific Ocean than within ocean i.e. among regions within the Pacific Ocean. No shared haplotypes were found between the two oceans while some haplotypes were shared among different populations within the Pacific Ocean. While the AMOVA revealed no significant mtDNA heterogeneity in the WNP, the analysis using the chi-square test revealed a weak heterogeneity between the historical samples from Ogasawara and those from JARPN II. The same test revealed no significant heterogeneity between JARPN II and historical samples from the central western North Pacific and between Ogasawara and central western North Pacific.

The results of the present genetic analysis provide support for the stock scenario defined by the Scientific Committee. Further analyses should consider regions within sub-area 1 not covered by the genetic survey yet as well regions within sub-area 2 from where no genetic samples are available at all. The weak mtDNA heterogeneity found by the chi-square test between Ogasawara and JARPN II deserve further consideration in the future. One issue, which should be further discussed, is the fact the genetic analysis conducted in the North Pacific involved samples taken in very different years. For instance the central western North Pacific samples were from 1979, the Ogasawara samples from 1983 and 1984 while the JARPN samples from 2000 and 2001. This raises the possibility that the differences found between Ogasawara and JARPN II (if confirmed by additional studies) are temporal rather spatial.

ACKNOWLEDGMENTS

We thank researchers and crew members of the JARPN II surveys in 2000 and 2001 for sample collection. We also thank H. Kato, National Research Institute of Far Seas Fisheries, for access to historical samples of the Bryde's whale from different oceanic regions.

REFERENCES

Excoffier, L., Smouse, P.E. and Quatro, J.M. 1992. Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. *Genetics* 131:479-91.

Fisher, R. A. 1950. Statistical Methods for Research Workers. 11th edn. Oliver and Boy, London.

International Whaling Commission. 1996. Report of the Scientific Committee, Annex G. Report of the sub-committee on North Pacific Bryde's whales. *Rep. int. Whal. Commn* 46:147-59.

International Whaling Commission. 1999. Report of the Scientific Committee, Annex D. Report of the sub-committee on the Revised Management Procedure. *J Cetacean Res. Manage.* 1 (Suppl.):61-116.

Pastene, L.A., Goto, M., Palsboll, P.J. and Kato, H. 1997a. Population structure of the Bryde's whale (*Balaenoptera edeni*) in the North Pacific based on analysis of mitochondrial DNA control region sequences. Document SC/49/NP5 presented to the IWC Scientific Committee, September 1997 (unpublished). 12pp.

Pastene, L.A., Goto, M., Itoh, S., Wada, S. and Kato, H. 1997b. Intra- and inter-oceanic patterns of mitochondrial DNA variation in the Bryde's whale, *Balaenoptera edeni*. *Rep. int. Whal Commn* 47:569-574.

Raymond, M. and Rousset, F. 1995. GENEPOP (version 1.2): population genetics software for exact tests and ecumenicism . *J. Heredity* 86:248-249.

Roff, D.A. and Bentzen, P. 1989. The statistical analysis of mtDNA polymorphisms: chi-square and the problem of small samples. *Mol. Biol. Evol.* 6(5): 539-45.

Table 1. Samples used in this study for the mtDNA analysis (see also Fig. 1)

Locality	n	Source	Date
WNP			
Ogasawara	103	Coastal whaling	Apr-June 1983, Apr-June 1984
JARPNII	85	JARPN II	Aug-Sept 2000 May-July 2001
Central Western NP (CWNP)	95	Pelagic whaling	Apr-May 1979
WSP			
Fiji	24	Research catch	Oct-Nov 1977
ESP			
Peru	24	Coastal whaling	1983
Chile	9	SOWER biopsy	Dec. 1997
EIO			
Java	23	Research catch	Nov. 1978

WNP=western North Pacific; WSP=western South Pacific; ESP=eastern South Pacific; EIO=eastern Indian Ocean

Table 2: Samples of Bryde's whales used in the microsatellite analysis

Oceanic region/locality	Sample size
WNP	
JARPN II	85
Central Western NP (CWNP)	50
Ogasawara	50
WSP (Fiji)	25
EIO (Java)	10

Table 3A: Results of the nested analysis of molecular variance of Bryde's whale mtDNA control region haplotypes (using PHIst).

Partitions	df	% total variance	PHI	P
Among oceanic regions	3	36.68	0.367	<0.0005
Among groups within oceanic regions	3	-0.12	-0.002	0.6302
Within groups	356	63.45	0.366	<0.0005

Table 3B: Results of the nested analysis of molecular variance of Bryde's whale mtDNA control region haplotypes (using Fst).

Partitions	df	% total variance	PHI	P
Among oceanic regions	3	18.57	0.186	<0.0005
Among groups within oceanic regions	3	0.54	0.007	0.0900
Within groups	356	80.90	0.191	<0.0005

Table 4: Pairwise comparisons using the randomized chi-square test, among localities in the western North Pacific. CWNP=central western North Pacific

Comparison	P-value (standard error)
Ogasawara/JARPN II	0.021 (0.0032)
Ogasawara/CWNP	0.122 (0.0073)
JARPN II/CWNP	0.171 (0.0084)

Table 5: Results of the chi-square test by the Markov chain method for deviation from Hardy-Weinberg proportion at five microsatellite loci analyzed in samples of Bryde's whale taken in the WNP (P-value)

Sample	Microsatellite locus				
	EV1	EV104	GATA417	GATA28	GGAA520
JARPN II	0.255	0.435	0.752	0.291	0.693
CWNP	0.135	0.798	0.286	0.599	0.209
Ogasawara	0.491	0.127	0.986	0.666	0.407

Table 6: Results of the heterogeneity test using probability test by the Markov chain method for the allele frequencies at five microsatellite loci among samples of Bryde's whales taken from the WNP (P-value)

	Microsatellite locus					
	EV1	EV104	GATA417	GATA28	GGAA520	All
JARPNII/CWNP/OGA	0.354	0.471	0.067	0.308	0.473	0.233

Table 7: Results of chi-square test by the Markov chain method for deviation from Hardy-Weinberg proportion at three microsatellite loci analyzed in the samples of Bryde's whales taken from the WNP (JARPNII+CWNP+Ogasawara), WSP (Fiji) and EIO (Java) (P-value)

Sample	Microsatellite locus			
	EV1	GATA417	GGAA520	All
WNP	0.120	0.467	0.161	0.152
WSP	0.607	0.257	0.676	0.609
EIO	0.277	0.880	0.100	0.283

Table 8: Results of heterogeneity test using probability test by the Markov chain method for the allele frequencies at three microsatellite loci among the samples of Bryde's whales taken from WNP, WSP and EIO (P-value)

	Microsatellite locus			
	EV1	GATA417	GGAA520	All
WNP/WSP/EIO	0.004	0.120	0.000	0.000

Table 9: Results of pairwise heterogeneity test using probability test by the Markov chain method for the allele frequencies of three microsatellite loci analyzed in samples of Bryde's whales taken from WNP, WSP and EIO (P-value)

	Microsatellite locus			
	EV1	GATA417	GGAA520	All
WNP/WSP	0.014	0.149	0.000	0.000
WNP/EIO	0.083	0.272	0.001	0.001
WSP/EIO	0.001	0.091	0.000	0.000

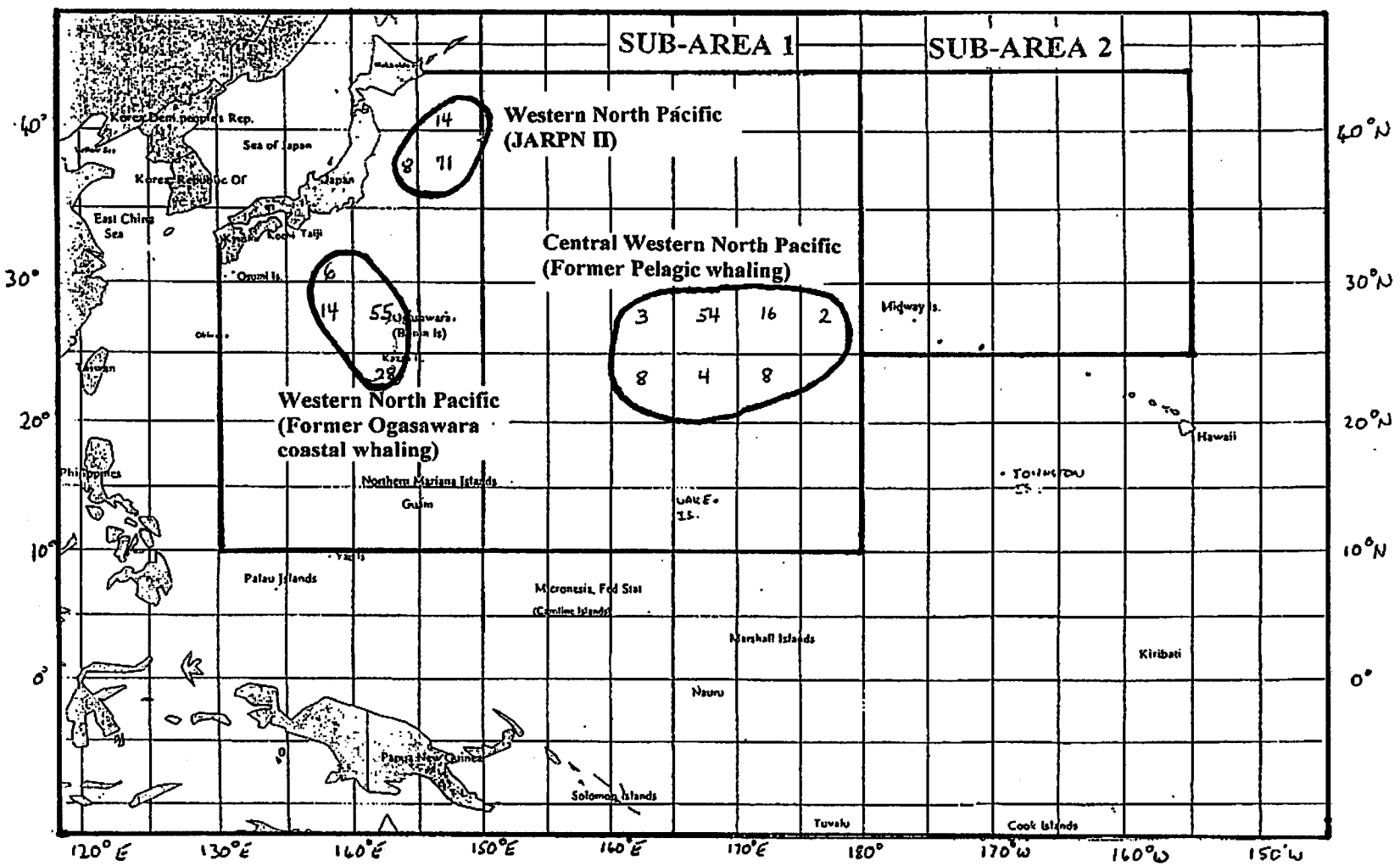


Fig. 1: Geographic distribution of Bryde's whales used in the present genetic analysis in the North Pacific. Figures are shown by 5° square. Details of the sampling are given in Table1.

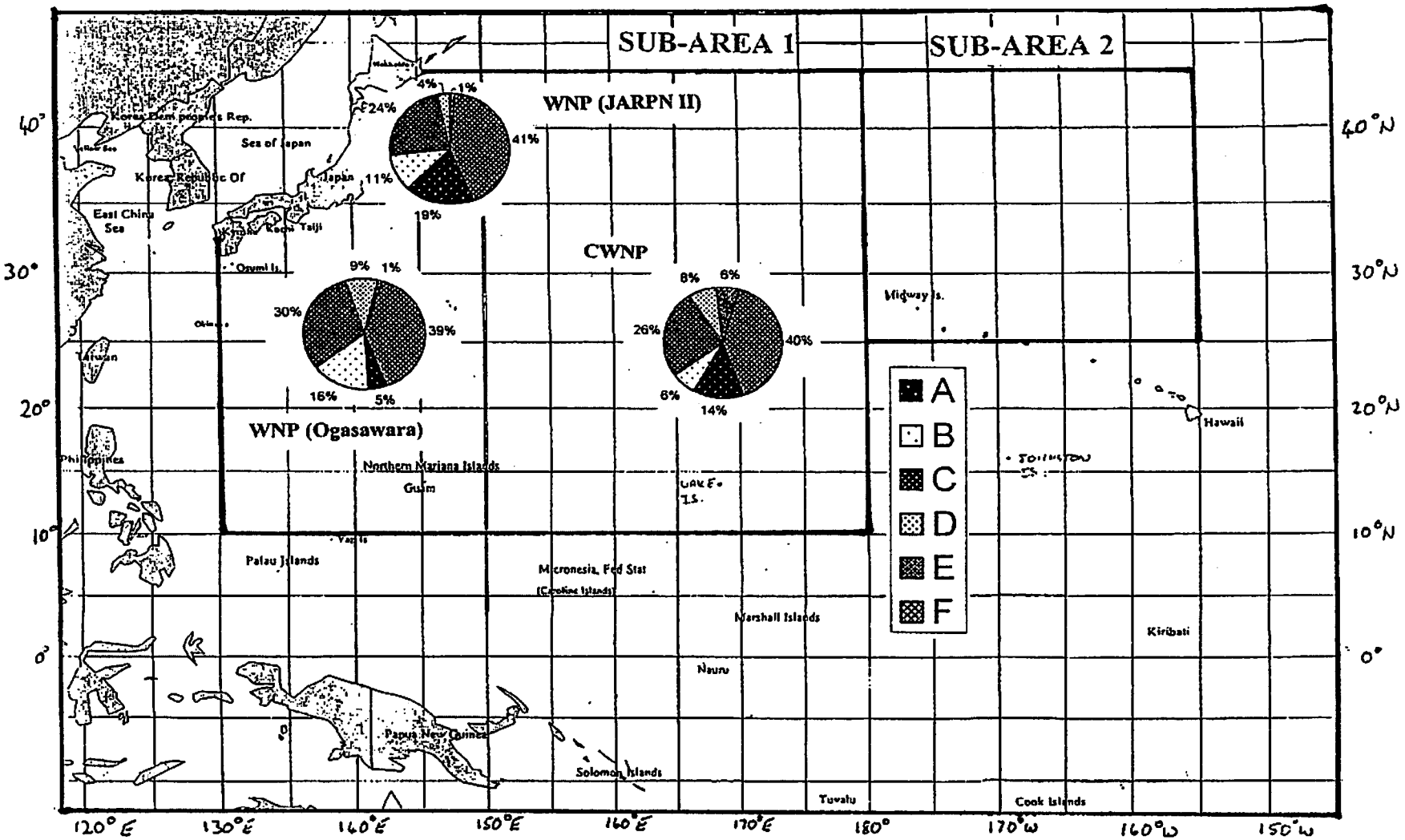


Fig. 2: Geographical distribution of mtDNA haplotype frequencies in the western North Pacific. Haplotypes A, B, C, D and E are the main individual haplotypes found in the western North Pacific Bryde's whale. 'F' refers to a set of rare haplotypes found only in the western North Pacific but not in other oceanic regions. Sample sizes are shown in Table 1. WNP= western North Pacific; CWNP= central western North Pacific.

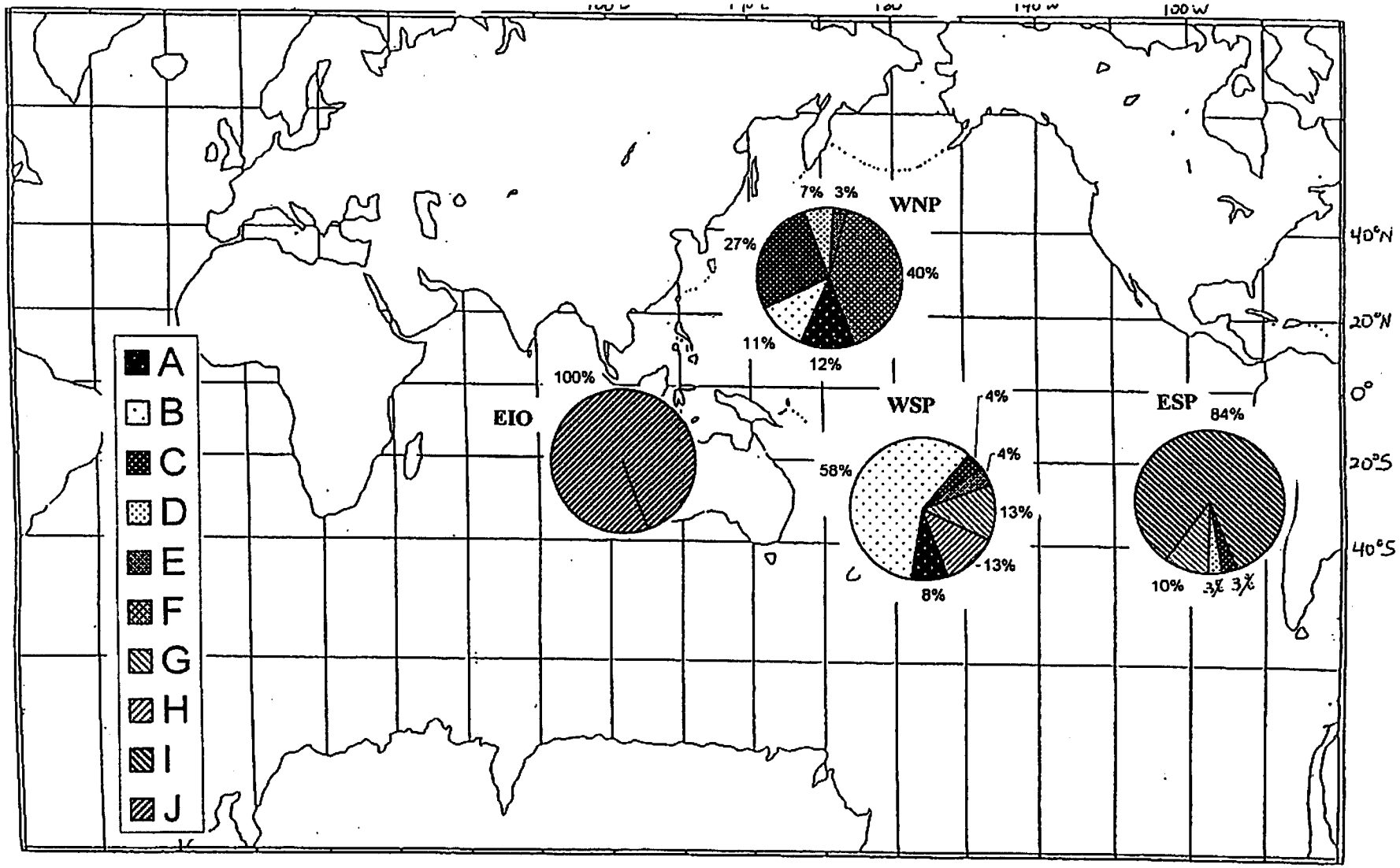


Fig. 3: Geographic distribution of mtDNA haplotypes frequencies in four oceanic regions. Haplotypes 'A'-'F' are the same as in Fig. 2. Haplotype 'G' is an individual haplotype shared by WSP and ESP. 'H', 'I' and 'J' refer to a set of rare haplotypes found only in the WSP, ESP and EIO, respectively.

Appendix 11

Genetic analysis of sperm whales sampled during JARPNII in 2000 and 2001

Naohisa Kanda, Mutsuo Goto and Luis A. Pastene

The Institute of Cetacean Research
4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan

ABSTRACT

We analyzed sequences of a 340bp segment of mitochondrial (mt) DNA control region and genetic variation at seven microsatellite DNA loci in samples of sperm whales collected during JARPNII in order to examine effectiveness of these genetic markers for stock structure study of the species. A total of the 31 samples consisting of 13 research takes and 18 biopsy skins indicate that these genetic markers are variable enough to explore stock structure of sperm whales. Statistical tests found no evidence of deviation from expected random-mating genotypic distribution at the seven microsatellite loci, suggesting that these 31 individuals might have come from a genetically same group of sperm whales. We also compared the levels of genetic variability (microsatellite heterozygosity, number of microsatellite alleles per locus, mtDNA nucleotide diversity, and mtDNA haplotype diversity) observed from these markers among sperm, Bryde's and minke whales collected during JARPN and JARPNII. Although the nucleotide diversity was substantially lower in sperm whales, the levels of other indices were similar among these species.

INTRODUCTION

Identification of the genetic structure of stocks over a species' geographic range is of primary importance for effective management (e.g., see Dufault *et al.*, 1999 for sperm whales). The objective of the stock structure part of JARPNII feasibility survey for sperm whales is then to obtain any information useful for describing stock structure of sperm whales inhabiting western North Pacific. The information is also surely helpful for future CA of this species. As a first step to accomplish the objective, we used mitochondrial DNA sequencing and microsatellites to examine effectiveness of these genetic markers to explore genetic characteristics of sperm whales in the western North Pacific.

MATERIALS AND METHODS

Samples and DNA extraction

A total of 31 sperm whales used in this analysis were collected during JARPNII feasibility survey in 2000 and 2001 as either research takes or biopsy (Table 1). Skin tissues of research takes were stored in 95% ethanol and biopsy skins were in –70°C until DNA extraction. Genomic DNAs were extracted from 0.05g each of these skin tissues using Wizard® genomic DNA purification kit (Promega) and were stored in TE.

Microsatellites

Microsatellite polymorphisms were analyzed using seven sets of primers: GATA028 (Palsbøll *et al.*, 1997), EV1*Pm*, EV5*Pm*, EV37*Mn*, EV94*Mn* (Vasecchi and Amos, 1996), DlrFcB14, and DlrFcB17 (Buchanan *et al.*, 1996). GATA028, EV37*Mn*, and EV94*Mn* were developed from a humpback whale, *Megaptera novaeanglia*, and EV1*Pm* and EV5*Pm* from a sperm whale, *Physeter macrocephalus*, and DlrFcB14, and DlrFcB17 from a beluga whale, *Delphinapterus leucas*. All primers except GATA028 are di-nucleotide repeat and GATA028 primer is tetra-nucleotide repeat. Primer sequences follow those of the original authors. Annealing temperature during PCR is 50°C for EV1*Pm*, EV94*Mn*, GATA028, DlrFcB14, and DLRFcB17, and 55°C for EV5*Pm* and EV37*Mn*.

PCR amplifications were performed in 15µl reaction mixtures containing 10-100ng of DNA, 5 pmole of each primer, 0.625 units of Ex Taq™ DNA polymerase (Takara Shuzo), and 2mM of each dNTP, and 10x reaction buffer containing 20mM $MgCl_2$ (Takara Shuzo). Amplified products with internal size standard (TAMRA 500) were run on a 4% polyacrylamide denaturating gel (Long Ranger™) using an ABI 377 DNA Prism sequencer (PE Biosystems Japan).

MtDNA

The 340bp control region of mitochondrial genome was amplified using a set of primers: light-strand MT4 (*5'*-CCTCCCTAAGACTCAAGGAAg-*3'*; Arnason *et al.*, 1993) and heavy-strand P2

(*5'*-GAAGAGGGATCCCTGCCAAGCGG-*3'*; Hori *et al.*, 1994). PCR products were purified using MicroSpin S-400HR columns (Pharmacia Biotech). Cycle sequencing was performed with the same primers using AmpliTaq FS Sequencing Kit (Perkin-Elmer, Inc). The cycle sequencing products were purified using AutoSeq G-50 spin Columns (Pharmacia Biotech) and then sequenced on an ABI 377 Automated DNA Sequencer (Applied Biosystems, Inc) following the protocols of the manufacture. For each sample, both light and heavy strands were sequenced. Observed sequences were aligned using Sequence Navigator computer program (Applied Biosystems, Inc).

RESULTS AND DISCUSSION

Microsatellites

Genotypes at the seven microsatellite loci showed that 18 biopsy skins were collected from different individuals.

All of the seven microsatellite loci were polymorphic (Table 2). Average number of alleles per locus was 9.4 and average expected heterozygosity was 0.741 (Table 3). The high levels of genetic variation detected indicate that these loci can be effectively used for the study of stock structure of sperm whales in western North Pacific.

We tested for deviation from Hardy-Weinberg equilibrium at each locus treating the analyzed 31 sperm whales as a single population. We found no evidence of deviation from expected random-mating distribution at all of the loci analyzed (Table 2), suggesting that these 31 individuals might have come from a genetically same group of sperm whales.

We compared these observed genetic diversity values obtained from the microsatellite loci to those of minke and Bryde's whales collected during JARPN and JARPNII in western North Pacific (Table 3). These values were similar among the three species except higher allele numbers detected in the minke whales. Because the levels of heterozygosity were quite similar among the samples from the different species, the difference in allele numbers probably simply reflects the difference in sample sizes analyzed. We detected many alleles with very low frequencies in the sample of minke whales.

MtDNA

A 340 base pair sequence of mtDNA control region (the 5'L) analyzed in the 31 individuals generated a total of 11 polymorphic site defining 10 haplotypes (Table 4). All substitutions among the haplotypes were transitions. Nucleotide (π) and haplotype diversities (*He*) observed within the samples were 0.0043 (SE=0.0011) and 0.725, respectively. Among the 10 haplotypes, five were found only in the single specimen.

For a comparison to our data, haplotypes found by Lyrholm *et al.* (1996) are also given in Table 4. Twelve of the 13 haplotypes in Lyrholm *et al.* (1996) were assigned to eight of the 10 haplotypes we detected. The predominant haplotype 1 as well as haplotype 3 in our study was shared by the samples from different ocean basin (NA; North Atlantic and SH; Southern Hemisphere) in Lyrholm *et al.* (1996). Likewise, haplotypes 2 and 4 were shared with samples from NA, while haplotypes 9 and 10 with samples from SH. It is important to note, however, that this observation probably do not give us phylogeographic inference because it was resulted from the fact that we sequenced shorter region than Lyrholm *et al.* (1996) did. For instance, our sequence did not include diagnostic site that differentiated between sperm whales from Northern and Southern Hemisphere. We will make the same primers used in Lyrholm *et al.* (1996) near future in order to cover the diagnostic site for further analysis.

We then compared the values of nucleotide (π) and haplotype (*He*) diversities to those of minke and Bryde's whales collected during JARPN and JARPNII in western North Pacific (Table 5). Although the nucleotide diversity estimate was the lowest in sperm whales, the haplotype diversity was similar among the three. Both nucleotide and haplotype diversities observed in this analysis were similar to those reported by Lyrholm *et al.* (1996) (π = 0.0038 ±0.00059 SE and *He* = 0.74). These findings, therefore, support Lyrholm *et al.* (1996) that mtDNA control region of sperm whales likely be very conservative.

ACKNOWLEDGMENTS

We thank H. Hatanaka for helpful comments and suggestions on this manuscript. We gratefully acknowledge the researchers and crew members that participated in JARPN (1994-1999) and JARPN II (2000-2001) surveys. H. Oikawa and S. Azumi (ICR Ayukawa Laboratory) collaborated in the process of DNA extraction.

REFERENCES

Arnason, U., Gullberg, A. and Widegten, B. 1993. Cetacean mitochondrial DNA control region: Sequences of all extant baleen whales and two sperm whale species. Mol. Biol. Evol. 10: 960-970.

Buchanan, F.C., Friesen, M.K., Littlejohn, R.P. and Clayton, J.A. 1996. Microsatellites from beluga whale *Delphinapterus leucas*. Mol. Ecol. 5: 571-575

Dufault, S., Whitehead, H. and Dillon, M. 1999. An examination of the current knowledge on the stock structure of sperm whales (*Physeter macrocephalus*) worldwide. J. Cetacean Res. Manage 1: 1-10.

Hori, H., Bessho, Y., Kawabata, R., Watanabe, I., Koga, A. and Pastene, L. A. 1994.World-wide population structure of minke whales deduced from mitochondrial DNA control region sequences. Paper SC/46/SH14 presented to the IWC Scientific Committee, May 1994, (unpublished), 11pp.

Lyrholm, T., Leimar, O. and Gyllensten, U. 1996. Low diversity and biased substitution patterns in the mitochondrial DNA control region of sperm whales: Implications for estimates of time since common ancestry. Mol. Biol. Evol. 13(10): 1318-1326.

Palsbøll, P. J., Bérubé, M., Larsen, A.H. and Jørgensen, H. 1997. Primers for the amplification of tri- and tetramer microsatellite loci in baleen whales. Mol. Ecol. 6: 893-895.

Valsecchi, E. and Amos, W. 1996. Microsatellite markers for the study of cetacean populations. Mol. Ecol. 5: 151-156.

Table 1. Sperm whales samples analyzed.

Year	Research take	Biopsy
2000	5	9
2001	8	9

Table 2. Number of alleles detected (A), expected heterozygosity (He), result of test for the deviation from expected Hardy-Weinberg proportion (HW) at each of seven microsatellite loci analyzed in samples (N=31) of sperm whales collected during JARPNII.

	Microsatellite locus						
	EV1	EV94	GATA28	DlrFcB14	DlrFcB17	EV5	EV37
A	7	8	3	9	14	8	17
He	0.541	0.729	0.620	0.786	0.895	0.740	0.876
HW (p-value)	0.265	0.171	0.330	0.777	0.956	0.931	0.990

Table 3. Number of individuals analyzed, number of microsatellite loci analyzed, number of alleles (A) per locus, and expected heterozygosity (He) per locus in samples of sperm, minke, and Bryde's whales taken during JARPN and JARPNII.

	Sperm*	Minke*	Bryde's*
No. individuals	31	436	85
No. loci	7	7	6
A/locus	9.4	14.4	8.5
He/locus	0.741	0.746	0.785

*Sperm: 2000 - 2001 JARPNII
*Minke: 1994 - 2001 JARPN and JARPNII
*Bryde's: 2000 - 2001 JARPNII

Table 4. Variable sites defining 11 North Pacific sperm whale unique sequences (haplotypes) in the mtDNA control region.

JARPN II			Lyrholm *et al.*, 1996	
Haplotype	Polymorphic site 11222333 56286778012 82140238594	# of samples	Haplotype	Geographic region (# of samples)
1	TCCTAACACGC	16	A, G, K	NA (4), NP (8), SH (6)
2	.T.....G...	2	B, E	NA (3), NP (2)
3	.T.....	3	C, I	NA (2), NP (4), SH (2)
4	..T.....	2	D	NA (1)
5	C.....	3	F	NP (1)
6	C.....T..	1		
7	.....TG...	1		
8	.T.CGG...AT	1	H	NP (1)
9	.T.....A.	1	L	SH (1)
10	.....G...	1	J	SH (1)
11	.T.CG....AT		M	SH (1)
Total		31		37

NA = North Atlantic, NP = North Pacific, SH = Southern Hemisphere.

Table 5. Number of samples examined, number of base pair (bp) examined, nucleotide diversity (π) and haplotype diversity (*He*) at mtDNA control region in samples of sperm, minke and Bryde's whales taken during JARPN and JARPN II surveys.

	Sperm	Minke	Bryde's
# of samples	31	461	85
bp examined	340	487	360
π (SE)	0.0043 (0.0011)	0.0080 (0.0002)	0.0099 (0.0010)
He	0.7247	0.9356	0.7997

Appendix 12

Further examination of some biological parameters to clarify stock structure of western North Pacific minke whales

Ryoko Zenitani*, Yoshihiro Fujise*, Hidehiro Kato** and Takeharu Bando*

*: The Institute of Cetacean Research, 4-5, Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan.
**: National Research Institute of Far Seas Fisheries, 5-7-1, Orido, Shimizu, Shizuoka 424-0902, Japan.

ABSTRACT

To clarify some degree of genetic heterogeneity by the mtDNA analysis found in western part of sub-area 9, the present study examines some biological parameters such as, conception date, growth curve, mean body length in physically mature animals (mean body length of animals older than 14 years) and scars of bite marks by *Isistitus* sp.. We used the biological data from 213 individuals (188 males and 25 females) from sub-area 7, 112 individuals (106 males and 6 females) from sub-area 8, 149 individuals (134 males and 15 females) from sub-area 9W and 84 individuals (72 males and 12 females) from sub-area 9E collected during JARPN surveys from 1994 to 1999 and JARPN II surveys from 2000 to 2001. Conception date shows that six foetuses collected in sub-area 7, 8 and 9W during JARPN II surveys were considered to have roughly the same conception date as the O Stock. No specific difference of growth curves for males was found throughout sub-areas. Analysis of variance in the mean body length for physical mature males revealed no statistical significant difference by local and yearly. As well, no statistical difference among sub-areas was found for females. Observation of scars on the skin of whales collected during JARPN II surveys from 2000 to 2001 indicates all mature animals were considered O stock animals. Maturity status compositions of animals indicate mature males dominance with few mature females and few immature animals distributed in sub-area 8 and 9W during JARPN II surveys. Relatively more immature animals were found in the coastal sub-area 7 during JARPN II surveys compared with JARPN surveys. Incomplete representation (few mature females and few immature animals) of sex and sexual status of minke whales found in sub-area 7, 8, 9W and 9E indicate that existence of independent stock in every sub-area is highly unlikely. It is likely that one independent stock of western North Pacific minke whales is distributed widely from coastal sub-area 7 to offshore sub-area 9E. The present analysis of biological parameters using both JARPN and JARPN II data did not confirm the existence another independent stock in sub-area 9.

INTRODUCTION

In the workshop in the JARPN review meeting held in February 2000, stock structure of western North Pacific minke whales was examined by genetic markers such as mtDNA, biological markers such as morphometric, pollutant burdens, parasite loads, and biological parameters (Goto *et al.*, 2000; Hakamada and Fujise, 2000; Fujise *et al.*, 2000; Kuramochi *et al.*, 2000; Okamura *et al.*, 2000; Zenitani *et al.*, 2000). The mtDNA analysis indicated certain degree of mtDNA heterogeneity found in the western part of sub-area 9 in 1995 (Goto *et al.*, 2000). Consequently, in order to elucidate the mtDNA heterogeneity, JARPN II program also focused on stock structure (Government of Japan, 2000).

The mtDNA analysis using samples collected in the western part of sub-area 9 during JARPN II surveys indicated that a possibility of existence of another independent stock (Goto *et al.*, 2001). However, this finding from JARPN II was not examined by using other biological markers. Therefore, the present study examines the possibility using biological parameters such as; (1) conception date which provides a key to clearly discriminate two different stocks of minke whales (Kato, 1992; Best and Kato, 1992), (2) growth curve and mean body length in physically mature animals (mean body length of animals older than 14 years) which are biological parameters supports stock identification by genetic marker (Zenitani *et al.*, 2000), (3) scars of bite marks by *Isistitus* sp. which are useful in determining stocks that are separated by different habitat environment (Fujise *et al.*, 2001), to clarify stock structure of the western North Pacific minke whales.

MATERIALS AND METHODS

Grouping of samples

Based on the results of mtDNA analysis that found some degree of genetic heterogeneity in the western part of sub-area

9 in 1995 and 2000 (Goto *et al.*, 2000, 2001), we examine sub-area 9 for two sectors western and eastern divided at 162°E (9W: western part of sub-area 9, 9E: eastern part of sub-area9).

Biological data used in the present study
Table 1 indicates samples collected during JARPN surveys from 1994 to 1999 and JARPN II surveys from 2000 to 2001 by sub-area. The present study used the biological data obtained from 213 individuals (188 males and 25 females) from sub-area 7, 112 individuals (106 males and 6 females) from sub-area 8, 149 individuals (134 males and 15 females) from sub-area 9W and 84 individuals (72 males and 12 females) from sub-area 9E

Age determination
It has been believed that age readability for North Pacific minke whales is poor (Kato, 1992). This was due to two reasons (1) poor formation of growth laminae and (2) low sampling rate of earplugs during the flensing. Under JARPN program, the sampling rate was greatly improved because of careful treatment of carcasses, led to increase in age readability. Kato did age reading using the standard method developed by Kato (1987), counting the number of growth layers on the core of the earplug with stereoscopic microscope under reflecting light.

Determination of sexual maturity
Sexual maturity for males was determined by examination of histological status of testis tissues. Males with seminiferous tubules over 100 μ m diameter or spermatid in the tubule were determined to be sexually mature (Kato, 1986; Kato *et al.*, 1990, 1991). Sexual maturity for females was determined by the presence of at least one corpus luteum or albicans in both ovaries.

Statistical analyses
We used the analysis of variance (significant level of 5%) for mean body length in physically mature animals for local (sub-area) and yearly variation.

RESULTS

Conception date (the relations between the sampling date and the foetal body length)
Kato (1992) and Best and Kato (1992) already indicated that difference in conception date is one of biological parameters provides a key to clearly discriminate two different stock of minke whales.

Fig.1 shows the relations between sampling date and foetal body length, with those sampled during JARPN and JARPN II surveys from 1994 to 2001 and during the past Japanese coastal whaling. A total of three fetuses were sampled in sub-area 7 during JARPN II survey in 2000. During 2001 JARPN II surveys, one featus and two featuses were collected in sub-areas 8 and 9W, respectively. As well as the results of JARPN surveys, the six foetuses from JARPN II surveys were considered to have conception date at roughly the same time as the Okhotsk-Western North Pacific Stock (O Stock).

Growth curve
The age information of JARPN II surveys was available, although age readability is about 50.0%. Also age readability by earplug generally has age-specific aspect which increases with age (Kato, 1984), its does not give serious bias to analysis of asymptotic length using older animals. Then this section examined the growth curve using earplug age reading for stock identification.

Fig.2 shows plotting of mean body length of all of animals against age by sub-area in each sex. Although we compare the plots for males among sub-areas, no specific difference can be found throughout all sub-areas. For females it was difficult to compare the growth curve between sub-areas due to extremely small sample sizes.

Mean body length in physically mature animals (mean body length of animals older than 14 years)
It can be interpreted that mean body length of animals older than cessation points of growth curve (i.e. physical maturity) gives asymptotic length or maximum body length of each sample group that is a useful key to discriminate the biological stock. However, this study could not estimate asymptotic length because of physical maturity data were not available at this time. As an alternative, based on examination of growth curve in the above section, we used the mean body length of individuals older than 14 years as mean body length in physically mature animals.

Table 2 indicates the respective values of mean body length for physically mature animals by sex, sub-area and year. Mean body length of males were 7.52m in sub-area 7, 7.61m in sub-area 8, 7.63m in sub-area 9W and 7.57m in sub-area 9E. Consequently, values of mean body length of males in these sub-areas are close to each other and there was no statistical difference among sub-areas by analysis of variance ($F=0.764$, $p=0.518$). The range of yearly mean body length of males each sub-area was respectively 7.44-7.56m in sub-area 7, 7.43-7.90m in sub-area 8, 7.31-7.75m in sub-area 9W and 7.45-7.60m in sub-area 9E. In each sub-area, there was no significant yearly variation (sub-area 7: $F=0.256$, $p=0.856$, sub-area 8: $F=2.577$, $p=0.082$, sub-area 9W: $F=1.639$, $p=0.220$, sub-area 9E: $F=0.344$, $p=0.724$). While for

females, those values were 8.30m (yearly range: 8.19-8.52m) in sub-area 7, 7.75m (yearly range: 7.75-7.75m) in sub-area 8, 7.84m (yearly range: 7.50-8.18m) in sub-area 9W and 8.00m (yearly range: 8.00-8.00m) in sub-area 9E. Analysis of variance found no statistical difference among sub-areas (F=0.685, p=0.618). The yearly variation of females in each sub-area was not compared due to extremely small sample size.

The scar (bite marks by *Isistitus* sp.)

The numerous white scars that are considered to be bite marks by *Isistitus* sp. on the skin of minke whales were frequently observed from samples collected in the JARPN surveys. Since *Isistitus* sp. inhabits in tropical and subtropical waters, when minke whales migrate into these waters, they have been inflicted. Thus, older (mature) animals tend to have more scars than the younger ones. Fujise *et al.* (2001) examined the utility of non-genetic markers (external morphological scars, conception date and accumulations of pollutants) for stock identification based on the JARPN data and indicated that the scars were useful for mature animals in determining stocks that inhabits different environment (unscarred animals are J stock animals, scarred animals are O stock animals).

Examination on the skin of animals collected by JARPN II surveys from 2000 to 2001 revealed that the scars have found on the skin of all mature animals.

Distribution of minke whales

Table 3 indicates proportion of males in the sample set (male sex ratio), maturity status compositions and sexual maturity rate by sub-area and year. Proportion of males (male sex ratio) is higher in all sub-areas and years (sub-area 7: 79.2-100.0%, sub-area 8: 90.9-100.0%, sub-area 9W: 73.7-100.0%, sub-area 9E: 85.4-86.4%). Sexual maturity rates of males in sub-areas and years are higher and the values are 78.7% (range: 50.0-83.7%) in sub-area 7, 92.57% (range: 87.5-100.07%) in sub-area 8, 95.57% (range: 71.4-100.0%) in sub-area 9W and 86.1% (range: 80.5-94.7%) in sub-area 9E. While sexual maturity rates of females are 48.0% (range: 0.0-100.0%) in sub-area 7, 66.7% (range: 50.0-100.0%) in sub-area 8, 66.7% (range: 0.0-100.0%) in sub-area 9W and 41.7% (range: 33.3-50.0%) in sub-area 9E.

Maturity status composition showed mature males dominance with few mature females and few immature animals distributed in sub-areas 7, 8, 9W and 9E. More immature animals were found in sub-area 7 in comparison with other sub-areas 8, 9W and 9E (Fig. 3).

DISCUSSION

The present study confirmed that no difference was found in biological parameters among sub-areas. As well as the results of JARPN surveys, conception date analysis showed that six foetuses collected in sub-area 7, 8 and 9W during JARPN II surveys were considered to have conception date at roughly the same time as the O Stock. Growth curve for males showed that no specific difference could be found throughout sub-areas. Analysis of variance in the mean body length for physical mature males revealed no statistical significant difference by local and yearly. As for females, no statistical difference among sub-areas was found by analysis of variance. Examination of scars on the skin of animals collected in sub-areas 7, 8 and 9W during JARPN II surveys from 2000 to 2001 indicated that all mature animals could be considered O stock animals. It was clear that minke whales collected in sub-areas 7, 8 and 9W during JARPN II surveys also showed incomplete composition of sex and maturity status (dominant mature males, few mature females and few immature animals). Relatively more immature animals found in the coastal sub-area 7 during JARPN II surveys than JARPN surveys. Incomplete representation (few mature females and few immature animals) of sex and maturity status of minke whales found in sub-areas 7, 8, 9W and 9E indicate that the existence one independent stock in each sub-area is higher unlikely.

In conclusion, the present analysis of above biological parameters using both JARPN and JARPN II data did not confirm the existence another independent stock in sub-area 9. It is reasonable to consider that one independent stock of western North Pacific minke whales distributes widely from coastal sub-area 7 to offshore sub-area 9E. Results from the present study also support the previous assumption derived from examination of biological parameters using JARPN data (Zenitani *et al.*, 2000, 2001).

ACKNOWLEDGMENTS

We are greatly indebted to Dr. Hiroshi Hatanaka of the Fisheries Research Agency useful comment and suggestion. We are also greatly indebted to Dr. Kayo Ohmagari of Institute of Cetacean Research for valuable suggestion in preparing this manuscript.

REFERENCES

Best, P. B. and Kato, H. 1992. Report of the sub-committee on North Pacific minke whales, Appendix 5. Possible evidence from foetal length distributions of the possible mixing of different components of the Yellow Sea-East China Sea-Sea of Japan-Okhotsk Sea minke whale population(s). *Rep. int. Whal. Commn* 42: 166.

Fujise, Y., Hakamada, T., Aoki, M., Niimi, S., Nakata, H., Honda, K and Tanabe, S. 2000. An attempt to identify stocks in western North Pacufuc minke whale (Balaenoptera acutorostrata) using the accumulation levels of heavy metals and organochlorines as ecological tracers. Paper SC/F2K/J18 presented to the IWC International Working Group to Review Of the Japanese Whale Research Programme under Special Permit for North Pacific minke whales: JARPN, February 2000 (unpublished). 18pp.

Fujise, Y., Zenitani, R. and Goto, M. 2001. Utility of non-genetic information for stock identification –The case of the western North Pacific minke whale-. Paper SC/53/SD5 presented to the IWC Scientific Committee, July 2001 (unpublished). 9pp.

Goto, M., Abe, H. and Pastene, L.A. 2000. Additional analyses of mtDNA control region sequences in the western North Pacific minke whales using JARPN samples. Paper SC/F2K/J32 presented to the IWC International Working Group to Review Of the Japanese Whale Research Programme under Special Permit for North Pacific minke whales: JARPN, February 2000 (unpublished). 5pp.

Goto, M., Kanda, N and Pastene, L.A. 2001. Genetic examination of western North Pacific minke whales including sample from JARN II. Paper SC/53/RMP11 presented to the IWC Scientific Committee, July 2001 (unpublished). 11pp.

Government of Japan, 2000. Research plan for cetacean studies in the western North Pacific under special permit (JARPN II) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC Scientific Committee, June 2000 (unpublished). 25pp.

Hakamada, T. and Fujise, Y. 2000. Preliminary examination of the heterogeneity of exterminary measurements of minke whales in the western part of the North Pacific, using data collected during 1994-1999 JARPN surveys. Paper SC/F2K/J15 presented to the IWC International Working Group to Review Of the Japanese Whale Research Programme under Special Permit for North Pacific minke whales: JARPN, February 2000 (unpublished). 12pp.

Kato, H. 1984. Readability of Antarctic Minke Whale Earplugs. *Rep. int. Whal. Commn* 34: 719-22.

Kato, H. 1986. Study on changed in biological parameters and population dynamics of southern minke whales. *Doctoral Thesis, Hokkaido University*. 145pp. (in Japanese).

Kato, H. 1987. Density dependent changes in growth parameters of the southern minke whale. *Sci. Rep. Whales Res. Inst.*, Tokyo 38: 47-73.

Kato, H., Kishino, H. and Fujise, Y. 1990. Some analyses on age composition and segregation of southern minke whales using samples obtained by the Japanese feasibility study in 1987/88. *Rep. int. Whal. Commn* 40:249-56.

Kato, H., Fujise, Y. and Kishino, H. 1991. Age structure and segregation of southern minke whales by the data obtained during Japanese research take in 1988/89. *Rep. int. Whal. Commn* 41: 287-92.

Kato, H. 1992. Body length, reproduction and stock separation of minke whales off Northern Japan. *Rep. int. Whal. Commn* 42:443-53.

Kuramochi, T., Araki, J., Uchida Machida, A., Moriyama, N., Hayashi, N., Wakao, H., Machida, M. and Nagasawa, K. 2000. Summary of parasite and epizoit investigations during JARPN surveys 1994-1999, with reference to stock structure analysisi for the western North Pacific minke whales. Paper SC/F2K/J19 presented to the IWC International Working Group to Review Of the Japanese Whale Research Programme under Special Permit for North Pacific minke whales: JARPN, February 2000 (unpublished). 14pp

Okamura, H., Zenitani, R., Hiramatsu, K. and Kato, H. 2000. Some analyses on the possibility of the existence of W-stock minke whale in sub-area 9 using the information on conception dates. Paper SC/F2K/J14 presented to the IWC International Working Group to Review Of the Japanese Whale Research Programme under Special Permit for North Pacific minke whales: JARPN, February 2000 (unpublished).

Zenitani, R., Kato, H. and Fujise, Y. 2000. Some analyses on biological parameters of western North Pacific minke whales, from a view point of stock identification. Paper SC/F2K/J13 presented to the IWC International Working Group to Review Of the Japanese Whale Research Programme under Special Permit for North Pacific minke whales: JARPN, February 2000 (unpublished).

Zenitani, R., Fujise, Y., Okamura, H. and Kato, H. 2001.Futher examination of the distribution of western North Pacific minke whales applying alogistic regression analysis for reproductive data collected by the JARPN surveys. Paper SC/52/RMP17 presented to the IWC Scientific Committee, June 2001 (unpublished). 8p.

Table 1. Number of samples collected during JARPN survey from 1994 to 1999 and JARPN II survey from 2000 to 2001 by sub-area and year.

Sub-area	Year	Male	Female	Total
7	1996	28	3	31
	1997	2	0	2
	1998	49	7	56
	1999	43	7	50
	2000	19	5	24
	2001	47	3	50
	Combined	188	25	213
8	1996	16	0	16
	1997	30	1	31
	1998	40	4	44
	2001	20	1	21
	Combined	106	6	112
9W	1994	6	1	7
	1995	72	6	78
	1997	14	5	19
	2000	16	0	16
	2001	26	3	29
	Combined	134	15	149
9E	1994	12	2	14
	1995	19	3	22
	1997	41	7	48
	Combined	72	12	84

Table 2. Maximum body length of minke whales older than 14 years by sex, sub-area and year.

Sub-		Male					Female				
area	Year	n	Mean	S.D.	Min.	Max.	n	Mean	S.D.	Min.	Max.
7	1996	1	7.44		7.44	7.44	2	8.19	0.37	7.93	8.45
	1997										
	1998	10	7.56	0.29	7.21	8.05					
	1999	5	7.43	0.33	7.05	7.93					
	2000						1	8.52		8.52	8.52
	2001	12	7.54	0.28	7.24	8.29					
	Combined	28	7.52	0.28	7.05	8.29	3	8.30	0.32	7.93	8.52
8	1996	7	7.43	0.33	6.96	7.86					
	1997	3	7.58	0.29	7.26	7.26	1	7.75		7.75	7.75
	1998	8	7.57	0.24	7.31	7.31					
	2001	6	7.90	0.37	7.63	7.63					
	Combined	24	7.61	0.34	6.96	8.62	1	7.75		7.75	7.75
9W	1994	1	7.31		7.31	7.31					
	1995	7	7.57	0.25	7.33	8.13	1	8.18		8.18	8.18
	1997	1	7.47		7.47	7.47	1	7.50		7.50	7.50
	2000	1	7.72		7.72	7.72					
	2001	8	7.75	0.18	7.46	7.46					
	Combined	19	7.63	0.23	7.31	8.13	2	7.84	0.48	7.50	8.18
9E	1994	1	7.45		7.45	7.45					
	1995	1	7.53		7.53	7.53					
	1997	6	7.60	0.16	7.31	7.31	1	8.00		8.00	8.00
	Combined	8	7.57	0.15	7.31	7.77	1	8.00		8.00	8.00

Table 3. Maturity status composition, male ratio and maturity rate of minke whales collected during JARPN survey from 1994 to 1999 and JARPN II survey from 2000 to 2001 by sub-area and year.

Sub-area	Year	Male			Female						Total			Male ratio	Maturity rate (%)	
						Mat.										
		Imm.	Mat.	Total	Imm.	Ovu.	Rest.	Preg.	Total	Total	Imm.	Mat.	Total		Male	Female
7	1996	5	23	28	0	0	1	2	3	3	5	26	31	90.3	82.1	100.0
	1997	1	1	2	0	0	0	0	0	0	1	1	2	100.0	50.0	
	1998	8	41	49	4	1	0	2	3	7	12	44	56	87.5	83.7	42.9
	1999	8	35	43	5	0	0	2	2	7	13	37	50	86.0	81.4	28.6
	2000	7	12	19	1	0	1	3	4	5	8	16	24	79.2	63.2	80.0
	2001	11	36	47	3	0	0	0	0	3	14	36	50	94.0	76.6	0.0
	Combined	40	148	188	13	1	2	9	12	25	53	160	213	88.3	78.7	48.0
8	1996	2	14	16	0	0	0	0	0	0	2	14	16	100.0	87.5	
	1997	1	29	30	0	0	0	1	1	1	1	30	31	96.8	96.7	100.0
	1998	5	35	40	2	0	0	2	2	4	7	37	44	90.9	87.5	50.0
	2001	0	20	20	0	0	0	1	1	1	0	21	21	95.2	100.0	100.0
	Combined	8	98	106	2	0	0	4	4	6	10	102	112	94.6	92.5	66.7
9W	1994	0	6	6	1	0	0	0	0	1	1	6	7	85.7	100.0	0.0
	1995	1	71	72	0	0	0	6	6	6	1	77	78	92.3	98.6	100.0
	1997	4	10	14	3	0	0	2	2	5	7	12	19	73.7	71.4	40.0
	2000	1	15	16	0	0	0	0	0	0	1	15	16	100.0	93.8	
	2001	0	26	26	1	0	0	2	2	3	1	28	29	89.7	100.0	66.7
	Combined	6	128	134	5	0	0	10	10	15	11	138	149	89.9	95.5	66.7
9E	1994	1	11	12	1	0	0	1	1	2	2	12	14	85.7	91.7	50.0
	1995	1	18	19	2	0	0	1	1	3	3	19	22	86.4	94.7	33.3
	1997	8	33	41	4	0	0	3	3	7	12	36	48	85.4	80.5	42.9
	Combined	10	62	72	7	0	0	5	5	12	17	67	84	85.7	86.1	41.7

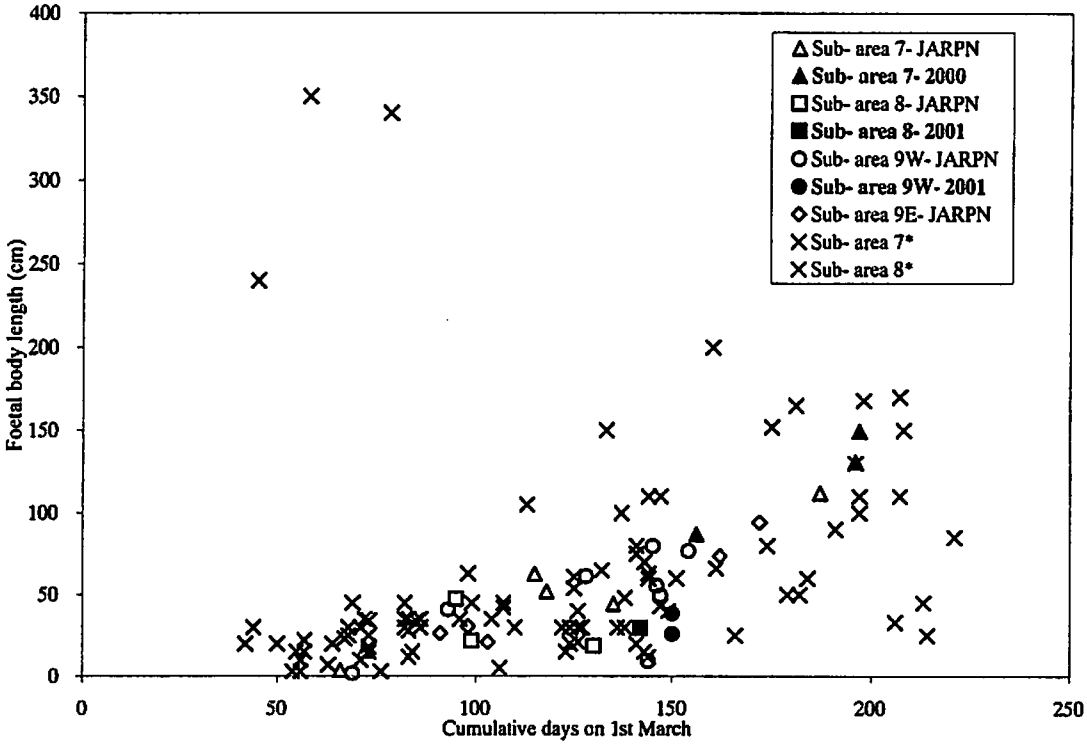


Fig. 1. Plots of foetal body length of of minke whales collected during the JARPN survey from 1994 to 1999, JARPN II survey from 2000 to 2001 and the past Japanese coastal whaling against collection date by sub- area. * : Data for Japanese coastal whaling samples (Kato,1992).

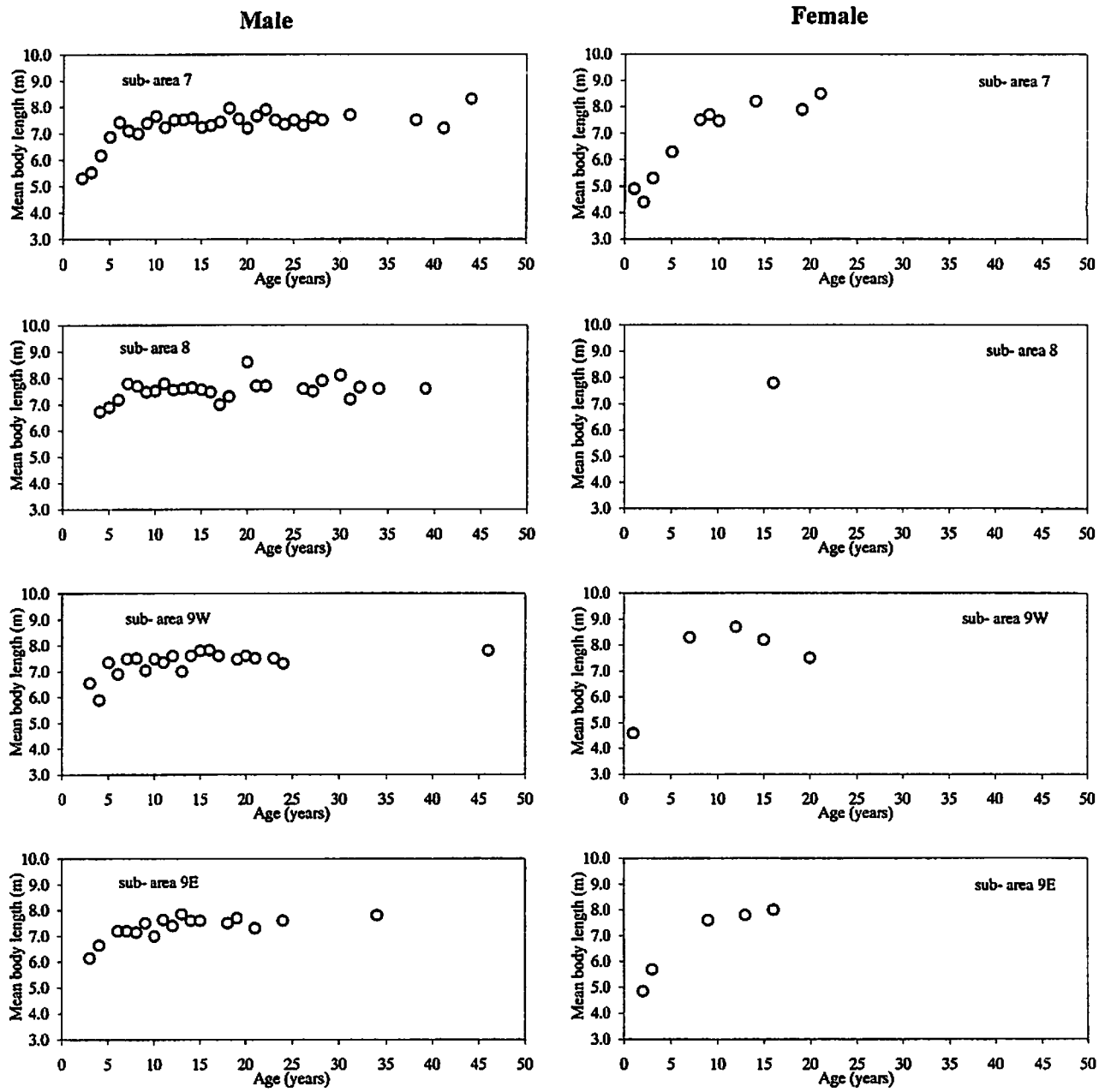


Fig. 2. Mean body length of all animals collected during the JARPN and JARPN II surveys against animal age by sub- area in each sex.

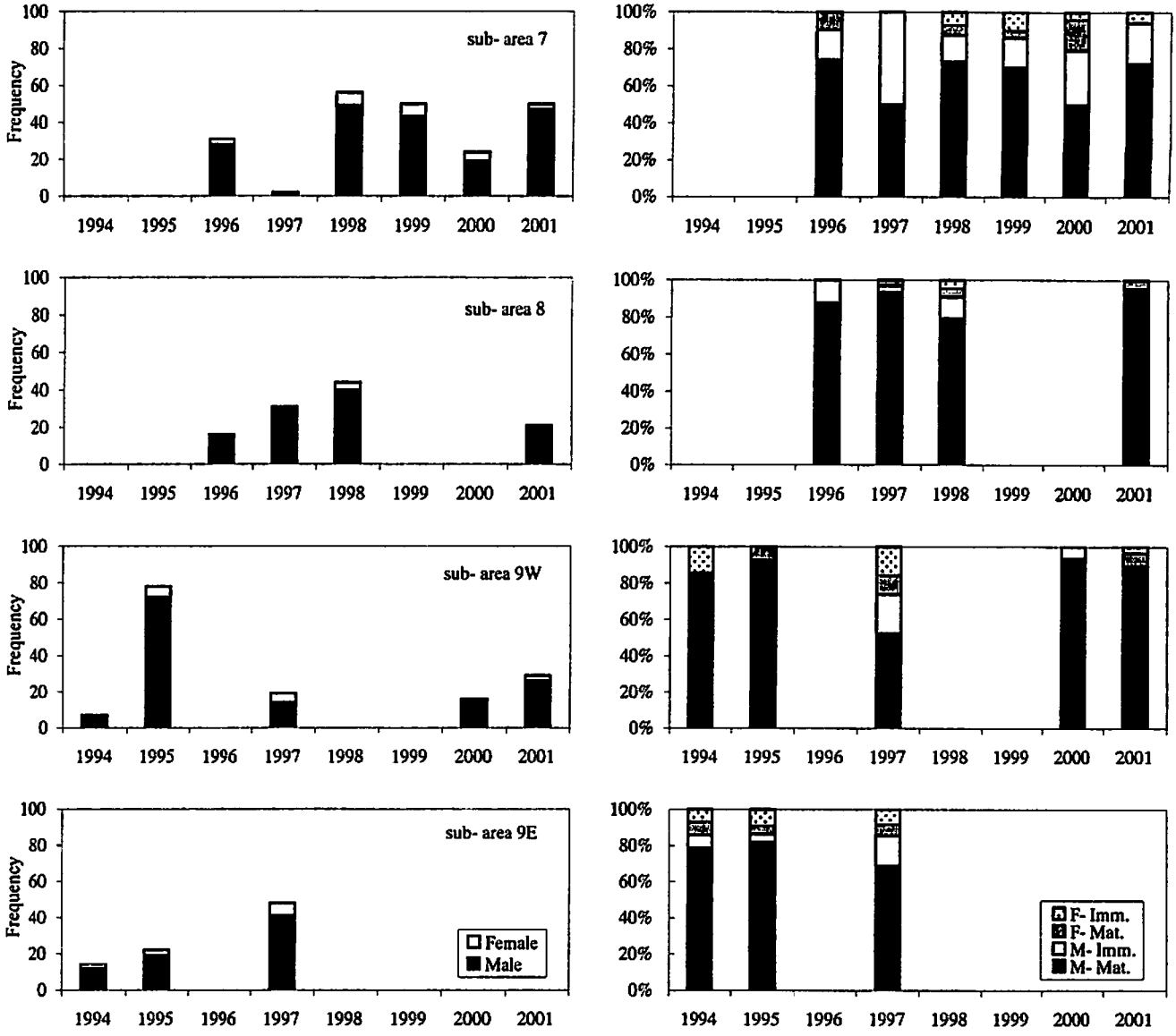


Fig. 3. Male ratio (left: frequency) and maturity status composition (right: ratio) of minke whales collected during JARPN and JARPN II surveys from 1994 to 2001 by sub- area and year.

Appendix 13

Preliminary results of accumulation features and temporal trends of trace elements in North Pacific minke whales from JARPN and JARPN II feasibility surveys

Genta YASUNAGA*, Ryoko ZENITANI*, Yoshihiro FUJISE* and Hidehiro KATO**

(*: *The Institute of Cetacean Research*, **: *National Research Institute of Far Seas Fisheries*)

ABSTRACT

A study was conducted to examine the relationships between trace element (Mn, Fe, Cu, Zn, Se, Cd, Pb, total Hg and methyl Hg) concentrations and biological data of common minke whale (*Balaenoptera acutorostrata*) such as sex, body length and age. Also the temporal trend of the concentration level of these elements and stock identification were examined. In each tissue a significant positive correlation was observed between total Hg, Cd and Fe, and body length and age. No significant differences between sexes were found in the accumulation level of most of the elements examined. No temporal trends were observed in hepatic total Hg and Cd concentrations for the period 1994-2000. To check a stock hypothesis derived from the mtDNA analysis, the level of concentration of elements was examined for both western and eastern parts of sub-area 9 in 1995. No differences were found between both parts.

INTRODUCTION

We construct a comprehensive monitoring system of pollutants in the marine ecosystem of North Pacific Ocean as part of the JARPN II survey, which was described under the third sub-goal in SC/52/O1 (2000). This report presents a preliminary analysis of accumulation features and temporal trends of trace elements, such as Mn, Fe, Cu, Zn, Se, Cd, Pb and Hg (total mercury: THg and methyl mercury: MeHg), in common minke whales (*Balaenoptera acutorostrata*) collected from the western North Pacific during the JARPN and JARPN II surveys between 1994 and 2000. The relationships between trace element concentrations and biological data such as sex, body length and age as well as the temporal trends of the levels of trace elements and stock estimate with those in sub-area 8, 9 are examined.

MATERIALS AND METHODS

A total of 432 animals was used in this study. These samples were collected during the six JARPN surveys (1994-1999) and the first year of the JARPN II (2000) feasibility surveys. A summary of these samples is shown in Table 1. Liver, kidney and muscle were used for this study. Eight trace elements (Mn, Fe, Cu, Zn, Se, Cd and Pb) were measured by ICP-AES spectrometry using external standard method. THg concentrations were determined by CV-AAS and MeHg concentrations were

determined by Westöö method (Westöö, 1966). Concentrations are given on wet weight basis.

RESULTS

Table 2 shows the relationships between the trace element concentrations and, age and body length. Significant positive correlations were observed between toxic elements, such as THg (Figs1-2) and Cd (Figs. 3-4), and Fe in each tissue. Table 3 shows the gender differences for mature individuals. Differences were not observed for most elements in each tissue. Figs. 5-6 show temporal trends in hepatic THg and Cd concentrations of North Pacific minke whales during the period 1994-2000. The sample in 1995 is divided into western sub-area 9 (W stock that might exist) and other sample. No temporal trends were observed for these elements.

DISCUSSION

Since age determination of North Pacific minke whale is difficult, both age and body length are compared with the trace element concentrations (Table 2, Figs. 1-4). For toxic elements, such as THg and Cd, and Fe positive correlations are observed and for essential elements, such as Cu, Mn and Zn, negative correlations are observed. Only mature samples were used for examinations of gender difference of trace elements. No significant gender difference in North Pacific minke whales was observed. This is supported by previous reports that no gender differences of trace elements are generally observed in wildlife (Yasunaga *et al.*, 2000), as compared with organochlorines. However, for relatively younger animal, higher THg concentrations were found in the liver of some mature males in sub-areas 8 and 9. This is inconsistent with age-dependent accumulations of toxic elements (Honda *et al.*, 1986). Due to the gender difference among trace elements, the following time trend discussion were considered using the only mature males. No temporal trends were observed for hepatic THg and Cd concentrations in North Pacific minke whales during the period 1994-2000 (Figs, 5-6). This result argues against the existence of the hypothesized W stock in sub-area 9.

REFERENCES

Government of Japan. 2000. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPN II) (Feasibility Study Plan for 2000 and 2001).

Honda, K., Fujise, Y. and Tatsukawa, R. 1986. Age-related accumulation of heavy metals in bone of the striped dolphin, *Stenella coeruleoalba*. *Marine Environ. Res.* 20:143-160

Yasunaga, G., Watanabe, I., Prudente, M.S., Subramanian, A.N., Qui, V. and Tanabe, S. Trace elements accumulation in waders from Asia. *Toxicol. Environ. Chem.* 77:75-92.

Westöö, G. 1966. Determination of methylmercury compounds in foodstuffs. *Acta Chem. Scand.*20:2131.

Table 1 Number and sex of samples analyzed in each sub-area.

Year	Sub area 7, 8, 9	
	male	female
1994	16	3
1995	87	9
1996	43	3
1997	82	12
1998	84	11
1999	41	6
2000	30	5
Total	383	49

Table 2 Relationships between body length and age, and trace element concentrations of liver, kidney and muscles of minke whales collected from sub-area 7, 8 and 9 in western North Pacific during 1994 and 2000.

					Mn	Fe	Cu	Zn	Se	Cd	THg	MeHg	Pb
Liver	Body length (m)	Sub-area 7	Male	129	(*)	***				***	***		
			Female	21	(*)	*					*		
			Total	150	(**)	***				***	***		
		Sub-area 8 & 9	Male	254	(**)	***	*			**	***		
			Female	28		*			-	***	***	-	
			Total	282	(***)	***				***	***		
		Combined	Male	283	(***)	***	***			***	***		
			Female	49	(**)	**				***	***		
			Total	432	(***)	***	**			***	***		
	Age (year)	Sub-area 7	Male	129		**		(**)					
			Female	21	(*)								
			Total	150	(*)	**		(**)					
		Sub-area 8 & 9	Male	254	(*)	*				*	***		
			Female	28					-		*	-	
			Total	282	(*)	*				*	***		
		Combined	Male	383									
			Female	49	(**)	***		(*)		*	***		
			Total	432	(**)	***		(**)	(*)	*	***	(*)	
Kidney	Body length (m)	Sub-area 7	Male	129			(**)	(*)			***		
			Female	21							*		
			Total	150			(***)	(**)			***		
		Sub-area 8 & 9	Male	254			(*)	(*)			***		
			Female	28					-	*	***	-	
			Total	282			(*)	(*)			***		
		Combined	Male	283	(**)		(***)	(**)			***		
			Female	49				(*)			***		
			Total	432	(**)		(***)	(***)			***		
	Age (year)	Sub-area 7	Male	129			(**)	(*)			*		
			Female	21			(*)	(*)		(**)			
			Total	150			(**)	(**)			*		
		Sub-area 8 & 9	Male	254			(**)	(*)			**		
			Female	28					-		*	-	
			Total	282			(*)	(*)			***		
		Combined	Male	383	(**)		(***)	(**)			***		
			Female	49									
			Total	432	(*)		(***)	(***)			***		
Muscle	Body length (m)	Sub-area 7	Male	129	(**)	***	(*)				***		
			Female	21	(*)	*	(*)						
			Total	150	(***)	***					***		
		Sub-area 8 & 9	Male	254	(***)	***	(*)			*	**		
			Female	28					-		***	-	
			Total	282	(***)	***	(*)			*	***		
		Combined	Male	283	(***)	***	(**)	(*)			***		
			Female	49	(**)	**					***		
			Total	432	(***)	***	(***)	(*)			***		
	Age (year)	Sub-area 7	Male	129		***							
			Female	21									
			Total	150		***							
		Sub-area 8 & 9	Male	254		***				**			
			Female	28					-		*	-	
			Total	282		***					***		
		Combined	Male	383		***					***		
			Female	49		*							
			Total	432		***					***	(*)	

p<0.05: *, p<0.01: **, p<0.001: ***

Parentheses represent negative correlations.

Table 3. Significant gender difference of trace element concentrations in liver, kidney and muscles of western North Pacific minke whales in JARPN and JARPN II during 1994 and 2000 using Mann- Whitney U test.

Area	Liver								
	Mn	Fe	Cu	Zn	Se	Cd	THg	MeHg	Pb
Sub-area 7									
Sub-area 8,9		* M<F							
Combined									

Area	Kidney								
	Mn	Fe	Cu	Zn	Se	Cd	THg	MeHg	Pb
Sub-area 7									
Sub-area 8,9									
Combined							* M>F		

Area	Muscle								
	Mn	Fe	Cu	Zn	Se	Cd	THg	MeHg	Pb
Sub-area 7									
Sub-area 8,9									
Combined			* M>F	* M<F				* M<F	

*: p <0.05

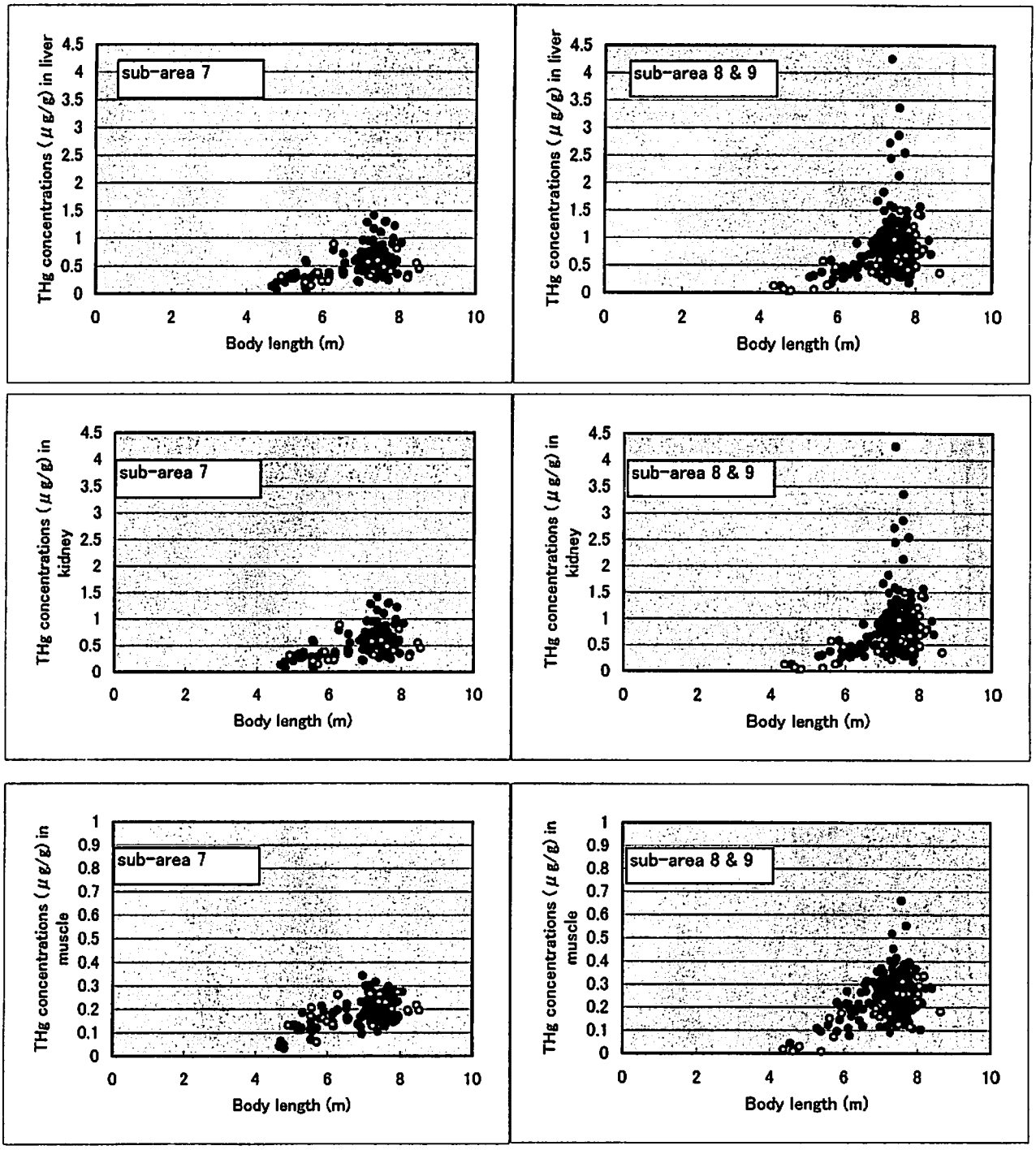


Fig. 1 Relationship between THg concentrations (μ g/g wet wt) of liver, kidney and muscle, and body length (m) in minke whales from North Pacific during 1994 and 2000.
male=●; female=○

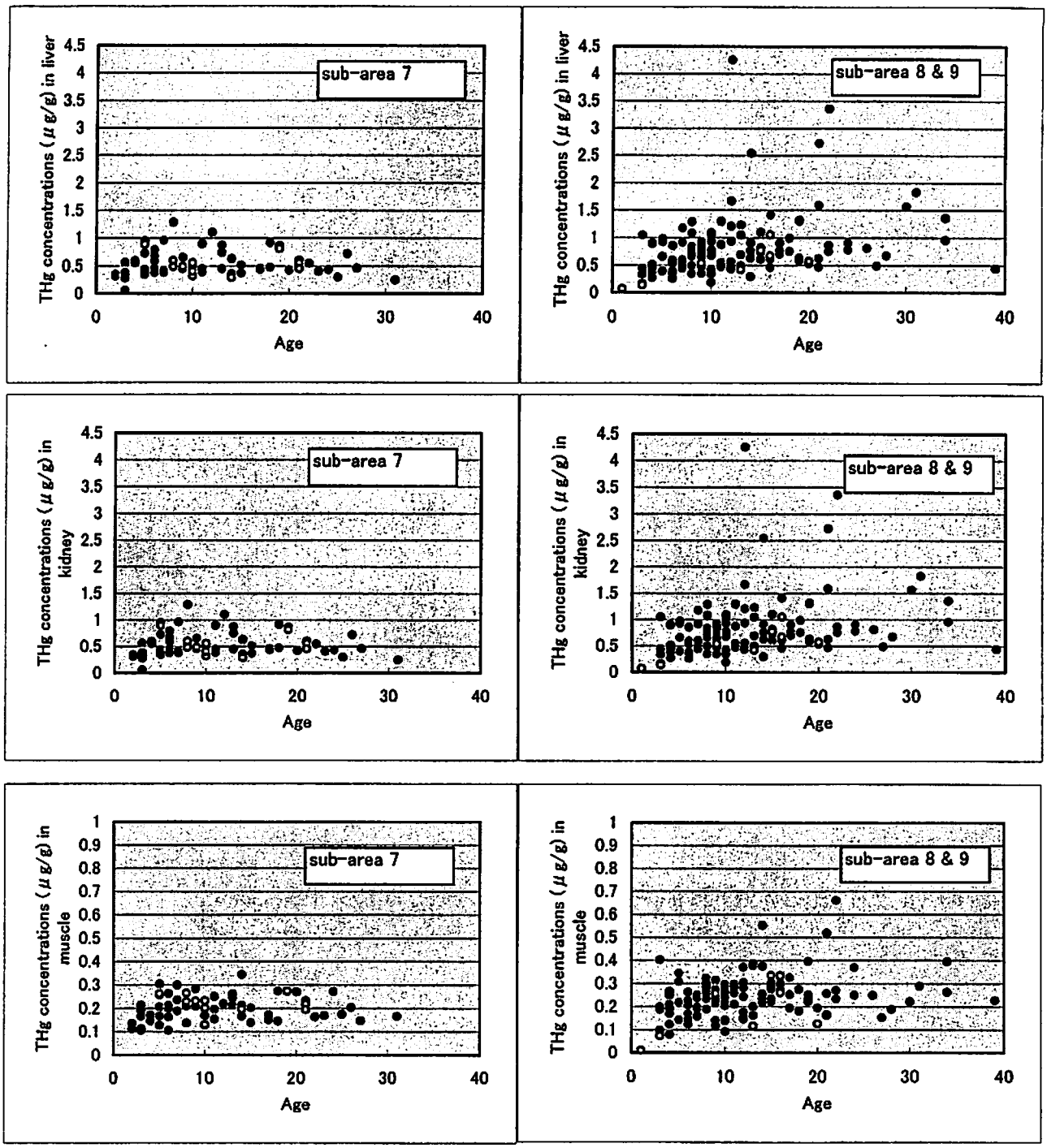


Fig. 2 Relationship between THg concentrations (μg/g wet wt) of liver, kidney and muscle, and age in minke whales from North Pacific during 1994 and 2000.
male=●; female=○

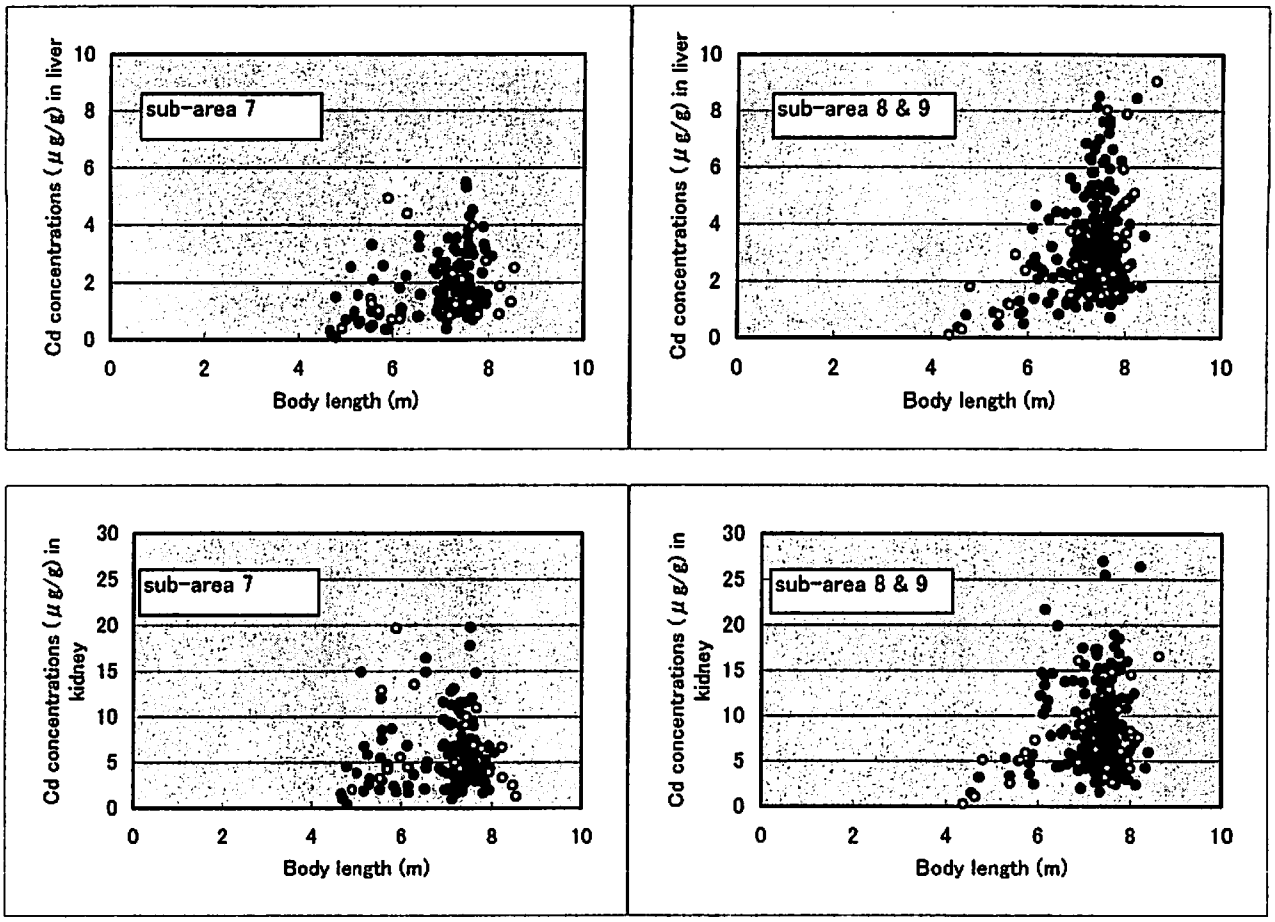


Fig. 3 Relationship between Cd concentrations (μ g/g wet wt) of liver and kidney, and body length (m) in minke whales from North Pacific during 1994 and 2000.
male=●; female=○

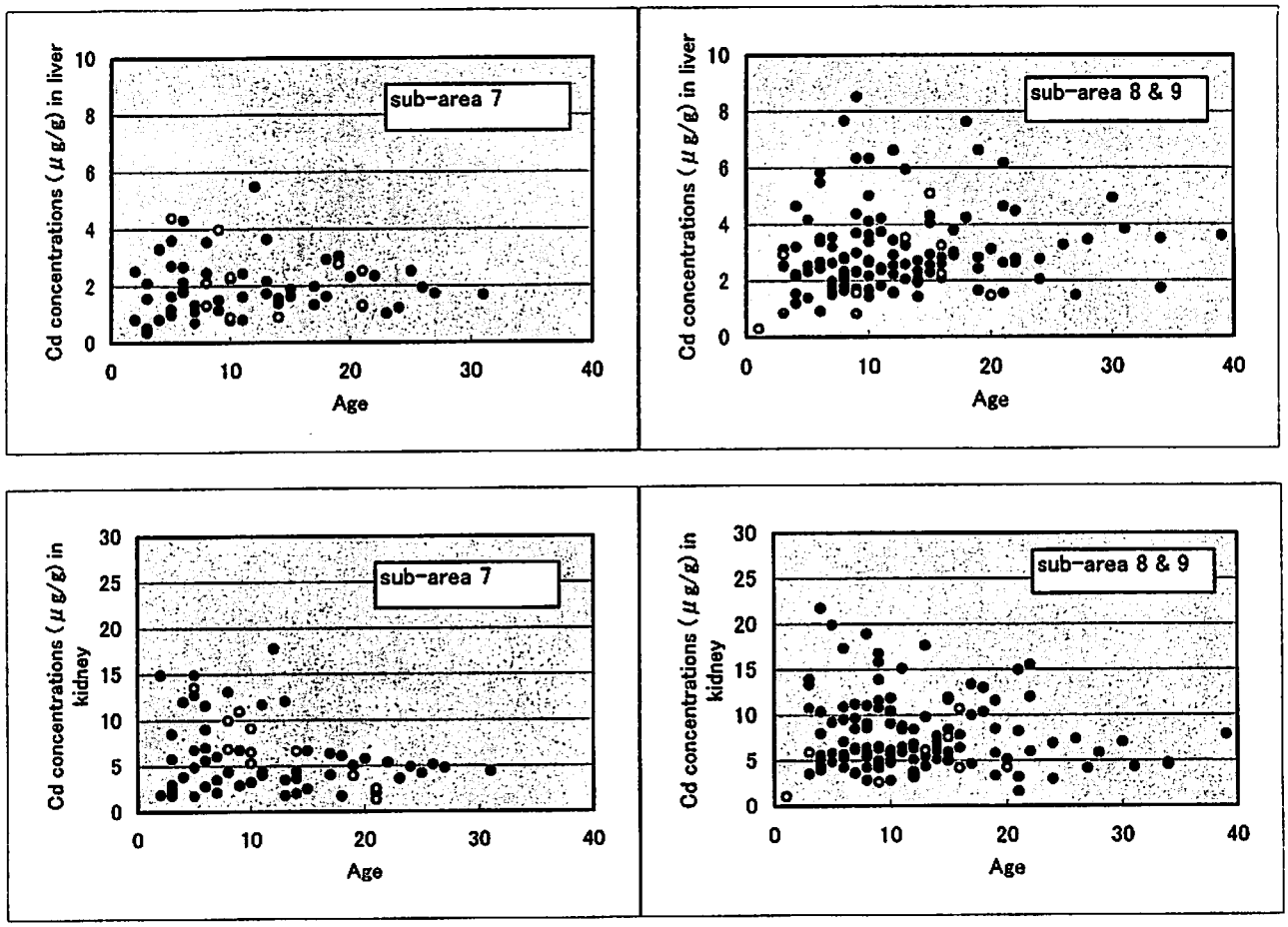


Fig. 4 Relationship between Cd concentrations (μ g/g wet wt) of liver and kidney, and age in minke whales from North Pacific during 1994 and 2000.
male=●; female=○

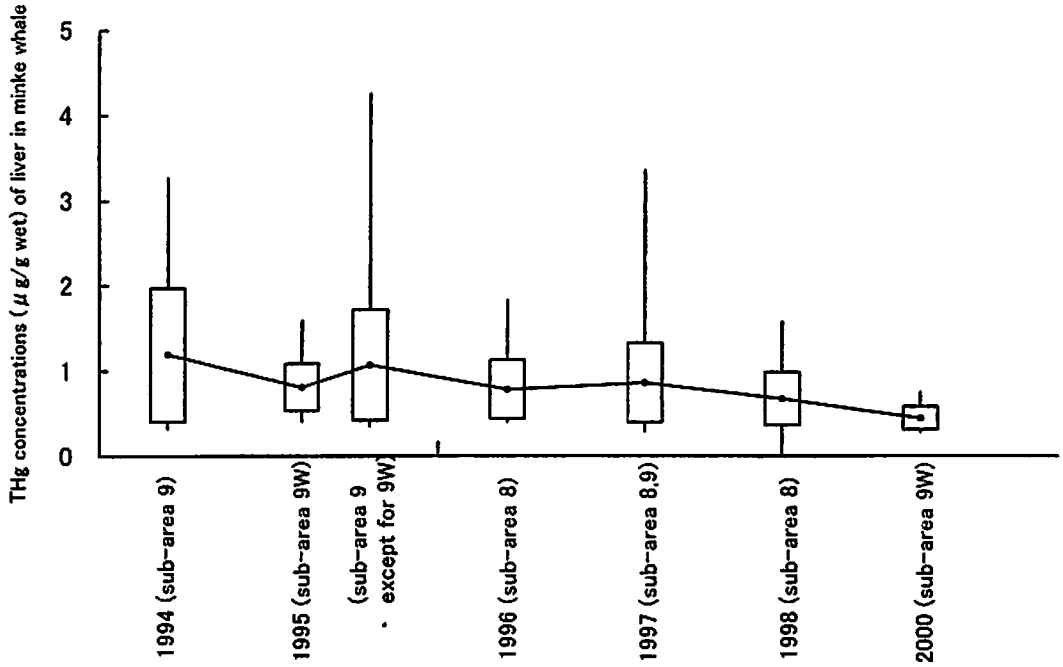


Fig. 5 Comparison of hepatic THg concentrations in minke whales from sub-area 8, 9 during 1994 and 2000.

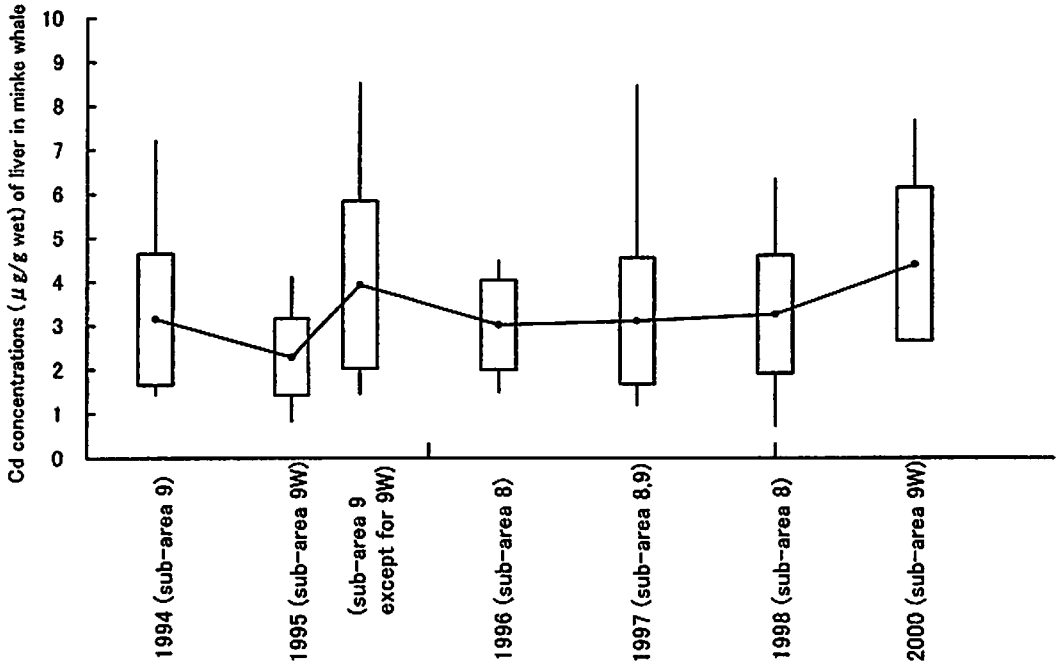


Fig. 6 Comparison of hepatic Cd concentrations in minke whales from sub-area 8, 9 during 1994 and 2000.

Appendix 14

Preliminary results of persistent organochlorine levels in the oceanic air and surface seawater in the western North Pacific Ocean during the JARPN II feasibility survey

Genta YASUNAGA*, Yoshihiro FUJISE* and Shinsuke TANABE**

(*: *The Institute of Cetacean Research*, **: *Ehime University*)

ABSTRACT

Persistent organochlorines such as PCBs, DDTs, HCHs, HCB and CHLs were examined in 3 air and 4 surface seawater samples during 2001 JARPN II survey in the western North Pacific. No regional differences were observed in the level of organochlorines concentration in air and surface seawater samples in the present study, except for PCBs and HCHs. Residue levels of PCBs, DDTs and HCHs in 3 air sample were lower than those in 1989-90 previously reported from North Pacific. The CHLs levels were similar to those in 1989-90. Residue levels of PCBs, DDTs and CHLs in 4 surface seawater samples were lower than those in 1989-90, and HCHs levels were showed similar or lower concentrations than those in 1989-90.

INTRODUCTION

In order to construct a comprehensive monitoring system of pollutants in the marine ecosystem of North Pacific as part of the JARPN II survey, persistent organochlorines, such as polychlorinated biphenyls (PCBs), DDTs, hexachlorocyclohexane (HCHs), hexachlorobenzene (HCB) and chlordane compounds (CHLs) in North Pacific common minke whale during JARPN survey (1994-1999) were monitored. Additionally, concentrations of these organochlorines in air and surface seawater were measured during JARPN II surveys. In this paper we present the organochlorine levels of air and surface seawater in 2001 JARPN II survey and compare these with previously reported levels in North Pacific common minke whale (*Balaenoptera acutorostrata*).

MATERIALS AND METHODS

Air and surface seawater samples were collected from the western North Pacific on JARPN II feasibility surveys in 2001 (Table 1). A total of 4 air samples and 3 surface seawater samples was collected. Organochlorines were analyzed following the procedure of Iwata *et al.* (1993). Blubber samples were analyzed using the method described by Tanabe *et al.* (1994).

RESULTS

Concentrations of PCBs, DDTs, HCHs, HCB and CHLs in air and seawater samples are shown in Figs. 1-2. No regional differences were observed in organochlorines levels in air and surface seawater except for PCBs and HCHs. Residue levels of PCBs, DDTs and HCHs in air sample of 4 sites were apparently lower than those collect in 1989-90 which was reported by Iwata *et al.*, 1993. The CHLs levels were similar to those in 1989-90 (Iwata *et al.*, 1993). Residue levels of PCBs, DDTs and CHLs in surface seawater samples were apparently lower than those in 1989-90, and HCHs levels were showed similar or lower concentrations than those in 1989-90 (Iwata *et al.*, 1993).

DISCUSSION

Tanabe *et al.* (1994) suggested that temporal variation of PCB and DDT residues showed maximum levels around 1976 and then decrease, whereas HCH residues levels revealed a very slow declining pattern during 1971-88, according to monitoring with northern fur seals on the Pacific coast of Japan (Tanabe *et al.*, 1994). Our preliminary results are consistent with those, however, the temporal trend of organochloine levels in North Pacific minke whales are not consistent with these. Therefore, we should continually monitor organochlorine levels in environmental samples, as well as in cetaceans, to confirm temporal and spatial trends in further detail.

REFERENCES

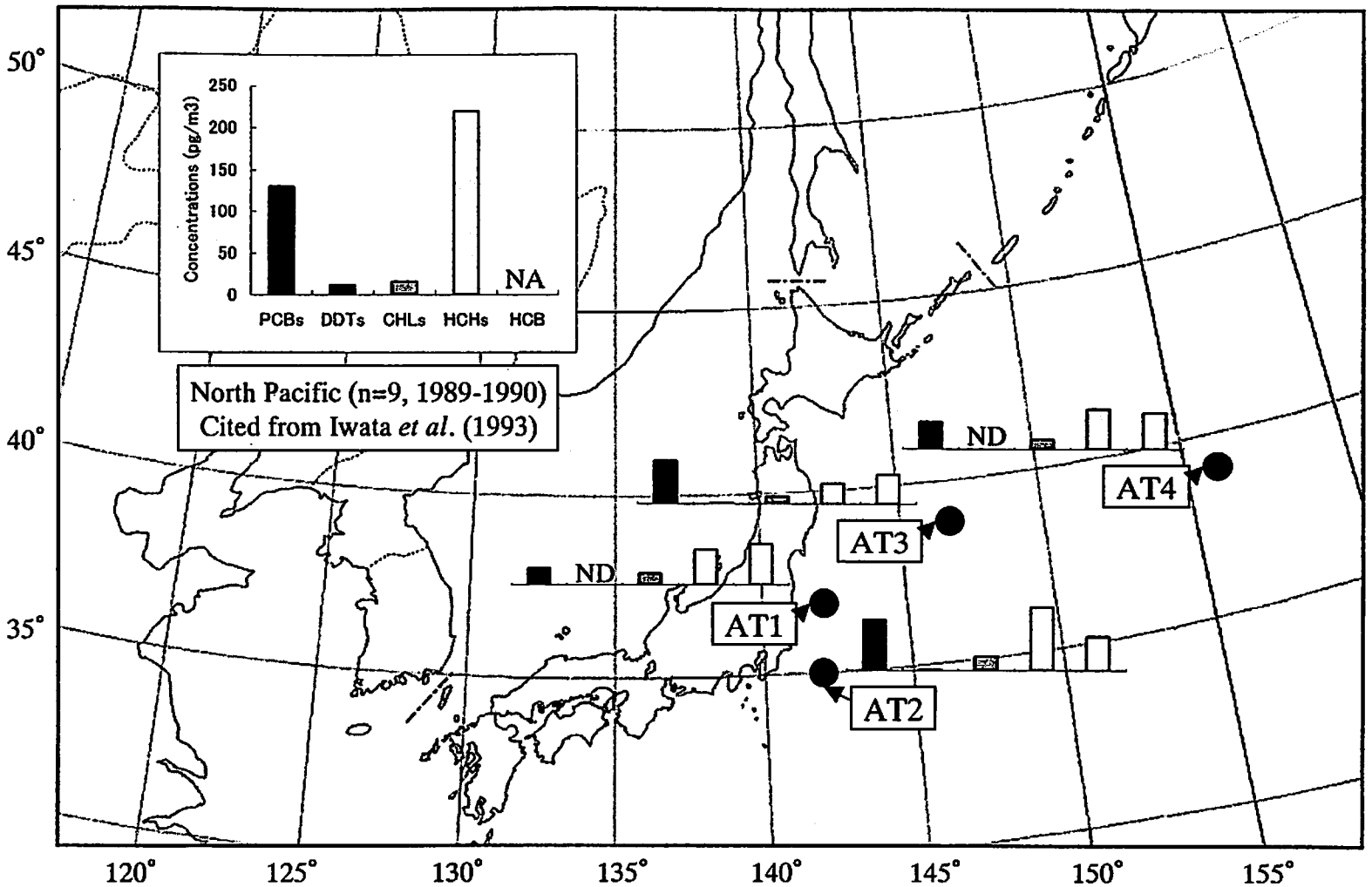
Government of Japan. 2000. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPN II) (Feasibility Study Plan for 2000 and 2001).

Iwata, H., Tanabe, S., Sakai, N. and Tatsukawa, R. 1993. Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. *Environ. Sci. Technol.*, 27: 1080-1098

Tanabe, S., Sung, J. K., Choi, D. Y., Baba, N., Kiyota, M., Yoshida, K. and Tatsukawa, R. 1994. Persistent organochlorine residues in northern fur seal from the Pacific coast of Japan since 1971. *Environ. Pollut.* 85:305-314.

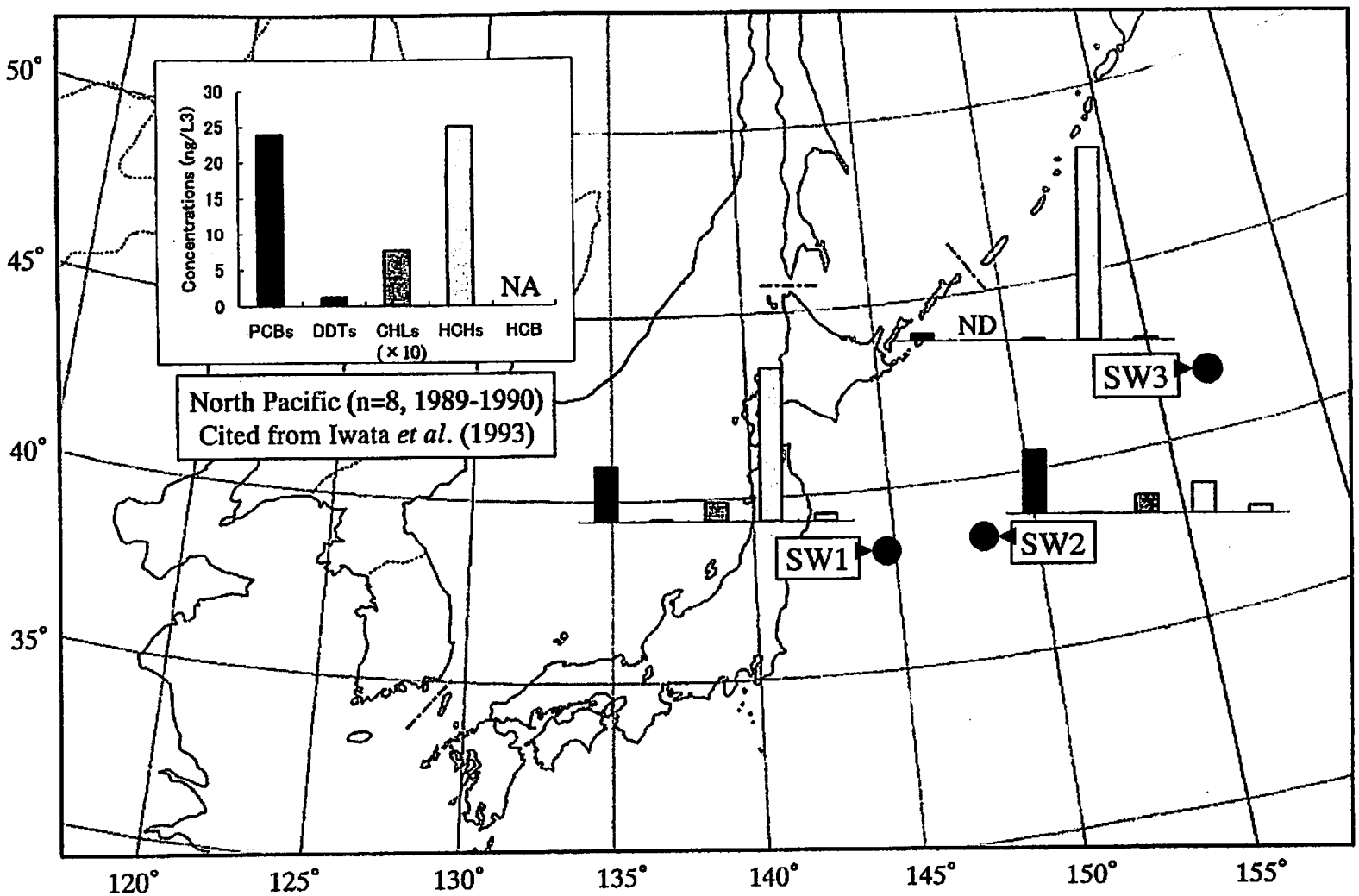
Table 1 Summary of sampling location in the 2001 JARPN II survey.

	Sampling No.	Starting date and time		latitude	longitude
Air sample	AT1	01/05/15	6:15	37-41N	142-06E
	AT2	01/05/29	6:20	35-28N	142-23E
	AT3	01/06/13	5:30	39-25N	147-47E
	AT4	01/06/28	4:30	39-57N	156-51E
Sea water sample	SW1	01/5/24	19:08	38-16N	145-02E
	SW2	01/6/13	6:00	38-02N	148-33E
	SW3	01/6/28	5:30	42-13N	157-16E



ND: Not detected, NA: Not analysis

Fig. 1 Concentrations of persistent organochlorines (pg/m^3) in air samples from North Pacific Ocean in the 2001 JARPN II. These of air samples collected by (1989-1999) are also shown (Iwata *et al.*, 1993).



ND: Not detected, NA: Not analysis

Fig. 2 Concentrations of persistent organochlorines (ng/L^3) in surface seawater samples from North Pacific Ocean in the 2001 JARPN II. These of air samples collected by (1989-1999) are also shown (Iwata *et al.*, 1993).

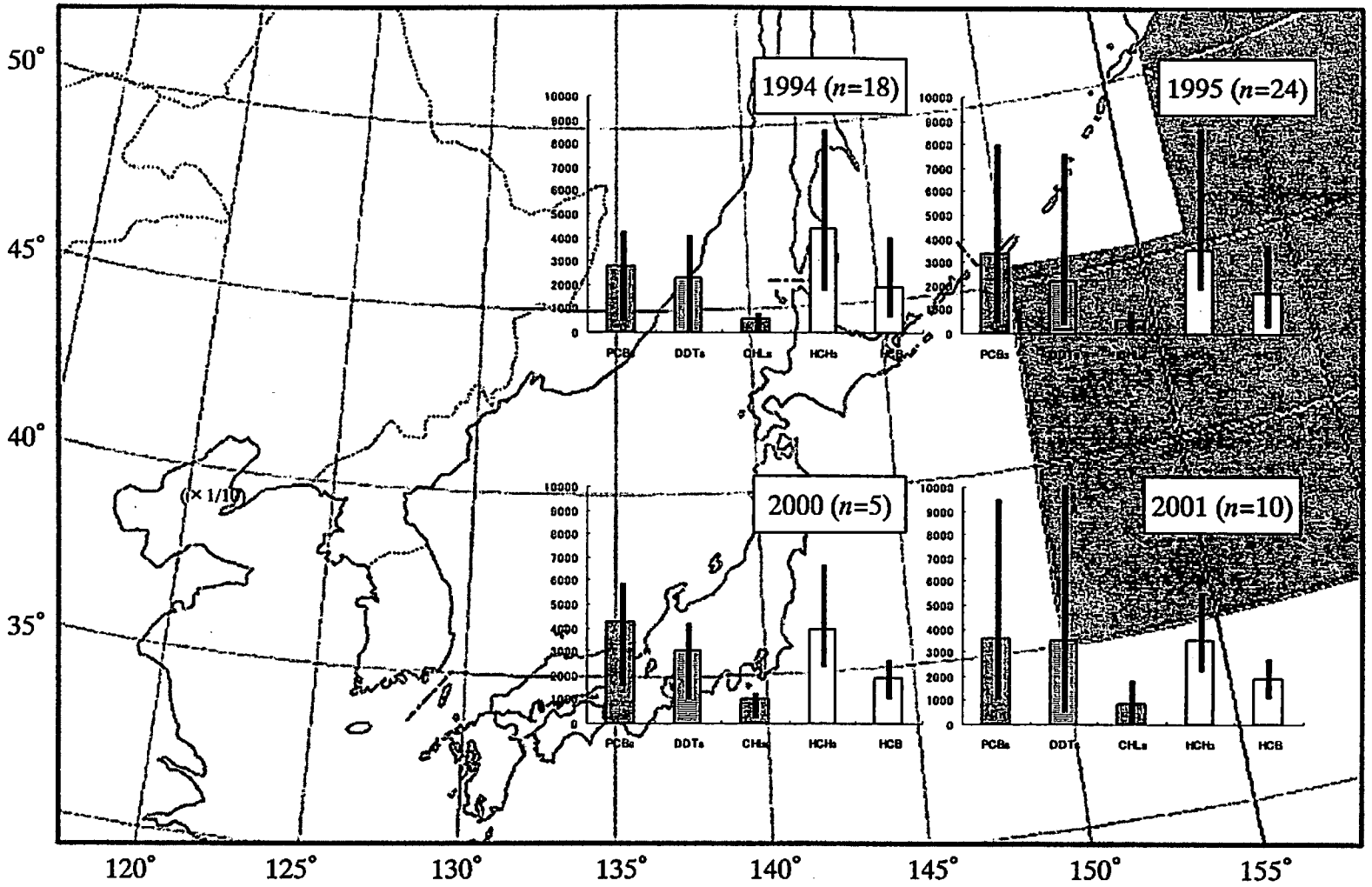


Fig. 3 Concentrations of persistent organochlorines (ng/g fat wt) in blubber of minke whales from North Pacific Ocean during 1994-2001.

Appendix 15

Preliminary results of analysis of the relationships between trace element concentrations of skin and other parameters, such as the concentrations in internal organs and the body burden, for minke whales collected from the western North Pacific during JARPN surveys.

Genta YASUNAGA*, Yoshihiro FUJISE*, Takashi KUNITO** and Shinsuke TANABE**

(*: *The Institute of Cetacean Research*, **: *Ehime University*)

ABSTRACT

A preliminary study was conducted to examine the concentration of trace elements (Mn, Cu, Zn, Se, Cd, total Hg, methyl Hg and Pb) in different tissue samples of common minke whales (*Balaenoptera acutorostrata*) including skin, liver, kidney and muscle. JARPN samples taken in sub-area 9 in 1995 and sub-area 11 in 1999 were used. One of the objectives of the study was to evaluate the effectiveness of skin biopsy samples for environmental monitoring of trace elements. Several factors were considered in the analysis: body length, sex and sampling year. Toxic element concentrations in some organs were significantly correlated with those in skin. No such correlation was found for essential elements. A linear correlation was observed in the concentration of Cd in skin and those in liver and muscle. Also a linear correlation was found in the concentration of total Hg in skin and that in kidney. Consequently concentrations of some elements in skin might be useful to monitor the levels of pollutant in internal organs of North Pacific minke whales. Such results were not found in the case of the Antarctic minke whale (*Balaenoptera bonaerensis*).

INTRODUCTION

The SWG on Environmental Concerns, at the 52nd meeting of the SC suggested that a calibration study was needed, which used tissue samples from previously harvested whales to evaluate whether biopsy samples can be used to monitor and assess contaminant levels in cetaceans (IWC, 2000). For Antarctic minke whales (*Balaenoptera bonaerensis*), our group has already detected 12 trace elements (V, Cr, Mn, Cu, Zn, Se, Rb, Sr, Cd, Cs, Ba and Hg) from skin (122 males, 39 females) and liver (17 males, 2 females) of samples collected during JARPA surveys, and assessed the effectiveness of the biopsy sample for detecting trace elements (Kunito *et al.*, 2002). Results showed significant positive correlations between liver and skin for Cr, Mn, Cu, Zn, Rb, Cd and Cs. There were also significant differences in the Cr and Cu concentrations of skin among samples from Areas III, IV and V, especially for males.

The present study attempted to reveal the relationships among the skin, liver, kidney and muscle concentrations and total burdens in western North Pacific common minke whales (*Balaenoptera acutorostrata*) sampled during JARPN surveys in 1995 (Area 9) and 1999 (Area 11), and to evaluate the effectiveness of skin biopsy samples for environmental monitoring of trace elements. Furthermore, effects of body length, sex and sampling year (area) upon estimation of trace element concentrations and total burdens of internal organs with skin biopsy are evaluated by employing a Stepwise regression analysis.

MATERIALS AND METHODS

Concentrations of Mn, Cu, Zn, Se, Cd, Hg (total and organic form) and Pb were determined for skin and internal organs (liver, kidney and muscle) samples of 15 minke whales taken from the western North Pacific during JARPN surveys in 1995 and 1999 (Table 1).

Tissue samples were dried in oven for 12 hours at 80℃ and digested in microwave using nitric acid in a PTFE (Teflon) vessel (Okamoto, 1994). Mn, Cu, Zn, Cd, Pb were measured by inductively coupled plasma-mass spectrometry (Hewlett Packard HP4500) using external standard method. Total Hg (THg) concentrations were determined by cold vapor / atomic absorption spectrometry (Shimadzu AA-680) and Se concentrations were determined by hydride generation / atomic absorption spectrometry (Shimadzu AA-680). Organic Hg (OHg) was analyzed by the method according to Thompson and Furness (1989).

Concentrations are given on dry weight basis. Accuracy and precision of the methods were confirmed using bovine liver (NIST No. 1577b) and DORM-2 (NRC) (Table 2).

The differences between sexes and sampling years were assessed by Mann-Whitney U test and the relationships between concentrations or burdens of trace elements were assessed by Spearman rank correlation (Zar, 1999). Estimation of trace element concentrations and burdens of internal tissue from skin biopsy were assessed by the stepwise analysis which is specified criteria for sequential addition and removal of the specified independent variables, as concentration of skin, sex, body length and sampling year (Zar, 1999). Then, values of trace element concentrations and burdens and body length were converted to the logarithm, and sex and sampling year were converted into dummy variables (Male: 0, Female: 1; 1995: 0, 1999:1), respectively. These statistical analysis were executed by Stat View version 4.58 (Abacus Concepts Inc.) for windows.

RESULTS

Concentrations of trace element, except for Se, in North Pacific minke whales were higher in liver or kidney and were comparatively lower in skin (Table 3). Table 4 shows the relationship between trace element concentrations of skin and other parameters. Toxic elements in some organs were found to be significantly correlated between the skin concentrations and, internal organ concentrations and body burdens. No such correlations for essential elements were found. Figs. 1-3 shows the relationships of Cd, THg, MeHg lognormal concentrations between skin and internal organs. Using the Stepwise regression analysis, liver, kidney and muscle concentrations and burdens of trace elements are examined in relationship with skin concentrations, body length and sex. From the Spearman's correlation analysis (Table 5), significant correlations were observed between the skin concentrations and these variables, as follows:

Cd: Liver (log (μg/g))=0.744 × Skin (log (μg/g)) + 4.86

Muscle (log (μg/g))=0.643 × Skin (log (μg/g)) – 0.262

THg: Kidney (log (μg/g))=0.797 × Skin (log (μg/g)) + 2.93

Muscle (log (μg/g))=0.643 × Skin (log (μg/g)) + 0.198 × Body length (log (m)) – 0.370 × Sex – 0.268 × Area – 2.86

Body burden (log(g)) = 0.634 × Skin (log (μg/g)) – 0.366 × Area + 0.741

OHg: Liver (log (μg/g))= – 0.778 × Area + 0.057

Kidney (log (μg/g))= 0.540 × Skin (log (μg/g)) – 0.460 × Area + 0.62

DISCUSSION

In general, liver has been used for heavy metal monitoring and blubber was used for organochlorine, as these tissues have shown higher accumulations (Furness, 1993; Holden, 1972; Honda *et al.*, 1987). For this reason, skin tissue is not a reasonable indicator for monitoring of trace elements. Analysis of Antarctic minke whale samples for toxic elements in the liver show similar results however, this is not the same for essential elements (Kunito *et al.*, 2002).

Simple linear correlations were observed between the concentrations of skin and the concentrations of Cd in liver and muscle and total Hg in kidney. Consequently, concentrations of some elements in skin might be useful for monitoring of the levels in the internal organs of North Pacific minke whales. However, the results of present study are not consistent with the results obtained for Antarctic minke whales. Further study is therefore required to determine the applicability of using skin samples to monitor trace elements in cetacean.

REFERENCES

Furness, R. W. 1993. Birds as monitors of pollutants. pp. 86-143. *In:* R.W. Furness and J.J.D.

Greenwood (eds.) *Birds as monitors of environmental change*. Chapman & Hall, London, UK. +356pp.

Government of Japan. 2000. Research plan for cetacean sutdies in the western North Pacific under special permit (JARPN II) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC Scientific Committee, Jun 2000 (unpublish). 68pp.

Holden, A.V. 1972. Monitoring organochlorine contamination of the marine environment by the analysis of residues in seals. pp. 266-272. *In:* M. Ruivo (ed). *Marine pollution and sea life*. FAO.

Honda, K., Yamamoto, Y., Kato, H. and Tatsukawa, R. 1987. Heavy metal accumulations and their recent changes in southern minke whales *Balaenoptera acutorostrata*. *Arch. Environ. Contam. Toxicol.* 16:209-216.

Kunito, T., Watanabe, I., Yasunaga, G., Tanabe, S. and Fujise, Y. 2002. Using trace elements in skin to discriminate the populations of minke whales in Southern Hemisphere. *Mar. Environ. Res.* 53:175-197.

Okamoto, K. 1994. Biological sample pp. 128-147. *In:* H. Kawaguchi and T. Nakahara (eds.) *Plasma source mass spectrometry*. +228pp. [In Japanese]

Thompson, D.R. and Furness, R.W. 1989. The chemical form of mercury stored in South Atlantic seabirds. *Environ. Pollut.* 60:305-317.

Zar, J.H. 1999. *Biostatistical analysis*, 4th Edn., Prentice Hall, New Jersey, USA, +663pp.

Table 1 Biological data of minke whales collected by the JARPN surveys in 1995 and 1999 .

Year	No.	Sub-area	Sex & Status	Body length	Organ weight(kg)		
				(m)	Liver	Kidney	Muscle
1995	002	9	Mature male	7.24	41.0	10.0	2140
	004	9	Mature male	6.80	53.0	10.0	2510
	011	9	Mature male	7.89	51.5	13.5	3100
	034	9	Mature male	7.96	41.0	10.2	2450
	058	9	Mature female	8.05	67.0	13.2	3090
	076	9	Mature female	8.18	47.0	12.0	3570
	083	9	Mature male	7.40	46.0	12.0	2810
	091	9	Mature male	7.53	43.0	11.0	3160
1999	051	11	Mature female	7.64	62.0	13.0	2580
	069	11	Mature female	8.06	77.0	17.0	3110
	075	11	Mature female	7.33	68.0	12.0	2340
	081	11	Mature male	7.68	77.0	15.0	2410
	085	11	Mature male	7.66	59.0	12.0	2420
	087	11	Mature male	7.65	68.0	15.1	2840
	094	11	Mature male	7.23	65.0	16.0	2290

Table 2 Concentration of trace element (μg/g dry wt) of Bovine liver and Dogfish muscle

	Bovine Liver: NIST No.1577b		Dogfish muscle: NRC DORM2	
	certify value	present study	certify value	present study
Mn	10.5±1.7	10.5	3.66±0.34	3.87
Cu	160±8	163	2.34±0.16	2.28
Zn	127±16	126	25.6±2.3	27.0
Se	0.73±0.06	0.59	1.40±0.09	1.31
Cd	0.50±0.03	0.46	0.043±0.008	0.052
Pb	0.129±0.004	0.134	0.065±0.007	0.064
T-Hg	(0.003)		4.64±0.26	4.4
Org-Hg			4.47±0.32*	4.3

*: methyl mercury

Numbers in parentheses represent noncertified value.

Table 3 Trace element concentrations (μg/g dry wt) of minke whales collected by the JARPN surveys in 1995 and 1999 .

	Liver		Kidney		Muscle		Skin	
Mn	12.3 ± 2.6	(15)	3.60 ± 0.70	(15)	0.323 ± 0.090	(15)	0.214 ± 0.055	(15)
Cu	20.1 ± 3.9	(15)	11.9 ± 1.3	(15)	1.77 ± 0.27	(15)	1.93 ± 0.46	(15)
Zn	152 ± 21	(15)	97.4 ± 20.5	(15)	28.5 ± 6.1	(15)	46.6 ± 4.1	(15)
Se	6.3 ± 1.4	(15)	5.9 ± 1.2	(15)	0.59 ± 0.10	(15)	20 ± 23	(15)
Cd	10.3 ± 7.2	(15)	32.2 ± 28.8	(15)	0.072 ± 0.129	(15)	0.029 ± 0.026	(15)
Pb	0.048 ± 0.042	(15)	0.044 ± 0.020	(15)	0.022 ± 0.028	(15)	0.034 ± 0.027	(15)
T-Hg	2.4 ± 1.3	(15)	3.9 ± 2.4	(15)	0.79 ± 0.30	(15)	0.28 ± 0.10	(15)
O-Hg	0.79 ± 0.40	(15)	0.52 ± 0.24	(15)	0.50 ± 0.20	(15)	0.16 ± 0.04	(12)

Numbers in parentheses represent sample size.

Table 4 Spearman's rank correlation coefficient of trace elements between skin, and internal organs and body burden in minke whales.

	n		Mn	Cu	Zn	Se	Cd	Pb	THg	OHg
NP minke whale	15 (10male, 5female)	Liver/Skin	0.086	-0.007	-0.232	0.200	0.629*	-0.018	0.446	0.555**
		Kidney/Skin	0.132	0.054	0.186	0.379	0.486	0.307	0.668**	0.808**
		Muscle/Skin	0.243	0.032	0.125	0.086	0.536*	0.100	0.825**	0.409
		Body burden/Skin		-0.150			0.504		0.754**	0.456
Antarctic minke whale (1)	19 (17male, 2female)	Liver/Skin	0.718**	0.654**	0.519**	-0.416	0.607*		-0.209	

*, ** and *** indicate significance at the 5, 1, and 0.1% level, respectively.

(1): cited from Kunito *et al.* (in press)

Table 5 Stepwise regression analysis of variables related to trace element concentrations of internal tissues in minke whales of JARPN.

Cd	Liver (Log (μg/g))		Muscle (Log (μg/g))	
	F	RC	F	RC
Skin (Log (μ g/g))	16.1	0.744	9.16	0.643
Body length (Log (m))	2.59	ns	1.01	ns
Sex	2.81	ns	0.164	ns
Sub- area	0.497	ns	0.765	ns
Intercept	48.7	4.86	0.072	- 0.262
p	**		**	

T- Hg	Kidney (Log (μg/g))		Muscle (Log (μg/g))		Burden (Log (g))	
	F	RC	F	RC	F	RC
Skin (Log (μ g/g))	22.7	0.797	51.4	0.673	16.426	0.634
Body length (Log (m))	0.599	ns	5.40	0.198	2.758	ns
Sex	1.84	ns	18.3	- 0.370	0.918	ns
Sub- area	0.363	ns	7.91	- 0.268	5.466	- 0.366
Intercept	56.5	2.93	3.08	- 2.86	9.767	0.741
p	***		***		***	

O- Hg	Liver (Log (μg/g))		Kidney (Log (μg/g))	
	F	RC	F	RC
Skin (Log (μ g/g))	2.79	ns	10.3	0.540
Body length (Log (m))	<0.001	ns	0.101	ns
Sex	0.007	ns	0.334	ns
Sub- area	19.9	- 0.778	7.510	- 0.460
Intercept	0.147	0.057	3.3	0.62
p	***		***	

RC: Regression Coefficient., ns: not selected, *:p<0.05, **: p<0.01, ***: p<0.001

Appendix 16

Oceanographic conditions in the Kuroshio-Oyashio Inter-frontal zone in August 2000 and around June 2001

Denzo Inagake and Kazuyuki Uehara

National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu, Shizuoka 424-8633 Japan

ABSTRACT

Hydrographic observations with CTD/XCTD were carried out during the feasibility study of the Japanese Whale Research Program under special permit in the western North Pacific-phase II (JARPN II) in August 2000 and May-July 2001 in the eastern waters of Japan. In the area, there are a lot of fronts and water masses. The Kuroshio Extension northern limit at the first crest was 36° N in August 2000 and 37° 40'N around June 2001. A few Kuroshio warm-core rings were observed within the area. The southern limits of the first and second Oyashio Intrusions were located at approximately the mean location of its fluctuation. While the Kuroshio water was more dominant in 2001 than in 2000, there are less differences between the two years except for the seasonal changes. The oceanographic conditions could be monitored in the full-scale JARPN II hereafter with the present level of research efforts and the information from the Tohoku National Fisheries Research Institute (TNFRI).

INTRODUCTION

The feasibility study of the Japanese Whale Research Program under special permit in the western North Pacific-phase II (JARPN II) was operated in the eastern waters of Japan in August to mid-September 2000 and mid-May to early August 2001. In this area, there are a lot of fronts and water masses. The Kuroshio, which is one of the strongest west-boundary currents of subtropical gyre, flows northward from the offshore area of Philippine to the waters off Japan with warm high-salinity water. The Oyashio flows southward along the Kuril Islands with cold low-salinity water. The Kuroshio and the Oyashio flows eastward from the Japan coastal area, and the area between the Kuroshio and Oyashio east off Japan was usually called the Kuroshio-Oyashio Inter-frontal zone or perturbed area. Oceanographic conditions in the research area of JARPN II are described comparing the surveys in 2000 (JARPNII-2000) and 2001 (JARPNII-2001). Also some discussions are made for the hydrographic observations in the full-scale JARPN II hereafter.

METHODS

Hydrographic observations with a conductivity-temperature-depth profiler (CTD; Neil Brown Mark ⅢB) and an expendable CTD (XCTD) were carried out from 2nd to 31st August 2000 using *Shunyo Maru* and *Kyoshin Maru* No. 2, respectively. Hydrographic observations with a CTD (SBE 9plus) were carried out from 16th May to 10th July 2001 using *Torishima*. Fig. 1 shows the oceanographic stations in 2000 and 2001. Salinity compensation for CTD data was done using water sampling data at three CTD stations in each year.

The oceanographic conditions were presented by the Tohoku National Fisheries Research Institute (TNFRI), who used quasi-real-time data from several cooperative organizations and prefectures, that was Fisheries Agency, Meteorological Agency, Hydrographic Department and Fisheries Experiment Stations, etc. TNFRI published temperature maps and schematic hydrographic maps using World Wide Web (http://ss.myg.affrc.go.jp/kaiyo/temp/temp.html). Oceanic fronts and water masses are usually detected by subsurface temperature map, because they are obscure in sea surface temperature distributions in warming seasons and the Oyashio water spreads into the subsurface layer. The Kuroshio Extension is defined by the 14℃ isotherm at the depth of 200m (Kawai, 1969). The Kuroshio warm-core rings and cold rings are defined by closed isothermal lines on a 200 m temperature map. The warm water spreading from Kuroshio Extension is defined by temperature more than 10℃ at the depth of 100 m . The Tsugaru

warm water is defined by an oceanic front in a 100 m temperature map. The first and the second Oyashio Intrusions are defined by temperature lass than 5℃ at the depth of 100 m (Murakami, 1994).

OCEANOGRAPHIC CONDITIONS IN 2000 AND 2001

Figure 2 shows Temperature-Salinity (T-S) diagrams using CTD and XCTD data in August 2000 (left panel) and using CTD data in May to July 2001 (right panel). Water masses in the research area have characteristics of warm high-salinity water (the Kuroshio water in the right read part of Fig. 2), cold low-salinity water (the Oyashio water in the lower blue part of Fig. 2) and the mixed water of the Kuroshio and Oyashio water. The T-S points were distributed in these water masses characterized by the Kuroshio water to the Oyashio water in both of two years. The Kuroshio water mass was observed in only two stations during JARPNII-2000, but in twelve stations during JARPNII-2001. This increase in the number of stations indicates that the Kuroshio water was more dominant in 2001 than in 2000. The low-salinity Intermediate waters (North Pacific Intermediate Water) were observed in the mid-layer under the depth of 300 m of the Kuroshio area. The low-salinity water less than 34 psu shows that the Oyashio water mass spread into the mid-layer of the Kuroshio water directly. These phenomena were observed more typically at JARPNII-2001 than JARPN-2000.

Figures 3 and 4 show the 200 m depth temperature map and the schematic hydrographic map in August 2000 and in June 2001, respectively, presented by TNFRI. The Kuroshio Extension northern limit at the first crest, which fluctuated from 33.2° N to 40.0° N in resent 47 years, was 36° N in August 2000 (upper panel in Fig. 3) and 37° 40'N in June 2001 (upper panel in Fig. 4). A few Kuroshio warm-core rings were observed in the research area in both years. The east limit of the Tsugaru water in JARPN-2001 was more east than that in JARPN-2000. The southern limit of the first Oyashio Intrusion was located at 39° 20'N and 142° 30'E in JARPN-2001 (blue area in lower panel of Fig. 4), which was approximately same in JARPNII-2000 period and approximately the mean location of its fluctuation from 35.4° N to 42.5° N in resent 37 years. The southern limit of the second Oyashio Intrusion in 2000 and 2001 was also approximately in the mean location. Red diamond, green triangle, light blue star and blue square on the lower panel in Figures 3 and 4 denote CTD stations in the Kuroshio area, warm area (100 m temperature was over 10℃ and 200 m temperature was less than 14℃), cold area (100 m temperature was over 5℃ and less than 10℃) and the Oyashio area, respectively. In comparison with Fig. 3 and Fig. 4, the Oyashio area was not so different, but the Kuroshio area was wider in Fig. 4 than in Fig. 3. Thus the Kuroshio water was dominant in JARPNII-2001.

Figures 5 and 6 show the vertical temperature sections along several N-S sections in 2000 and 2001, respectively. Southern part of each section corresponded with the Kuroshio area that was indicated by a typical slope of sharp thermocline. The Kuroshio front at the first crest in JARPNII-2001 lied at more northern area (north of 36° 30'N along 142-143° E and 144-145° E) than in JARPNII-2000 when the Kuroshio Extension flowed at south of 36° N along 144-146° E. The Kuroshio warm-core ring was indicated by the deeper thermocline structure like a bowl shape. In the northern area, there was the Oyashio water shown by the cold water less than 5℃ in the upper layer shallower than 200 m depth. At the layer deeper than 300 meter, cold water less than 3℃ was observed to the north of the Kuroshio front. It indicated that the pure Oyashio water exerted a substantial influence on the intermediate water of the Kuroshio. In summary, the Kuroshio water was more dominant in JARPNII-2001 than in 2000, but there are less differences between the two years except for the seasonal changes.

SOME DISCUSSIONS FOR THE FULL-SCALE JARPN II

As above-mentioned, the hydrographic conditions in the research area were analyzed sufficiently in the two-year feasibility study of JARPN II. The yearly and seasonal changes could be monitored in the full-scale JARPN II hereafter if the current level of hydrographic observations is continued and the information is available from the Tohoku National Fisheries Research Institute (TNFRI). Also the Geographic Information Systems (GIS) technique is inevitable to combine and analyze the information on oceanographic conditions, preys and cetaceans.

REFERENCES

Kawai, H. (1969): Statistical estimation of isotherms indicative of the Kuroshio axis, *Deep-Sea Res.*, **16**, 109-115.

Murakami, M. (1994): On long-term variations in hydrographic conditions in the Tohoku area, *Bull. Tohoku Natl. Fish. Res. Inst.*, No. 56, 47-56 (in Japanese with English abstract).

Inagake, D. and K. Uehara (2001): Oceanographic conditions in the Kuroshio-Oyashio Inter-frontal zone in August 2000, Appendix II in Progress report of the Feasibility Study of the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPN II) in 2000, IWC/SC/53/O10, 49-53.

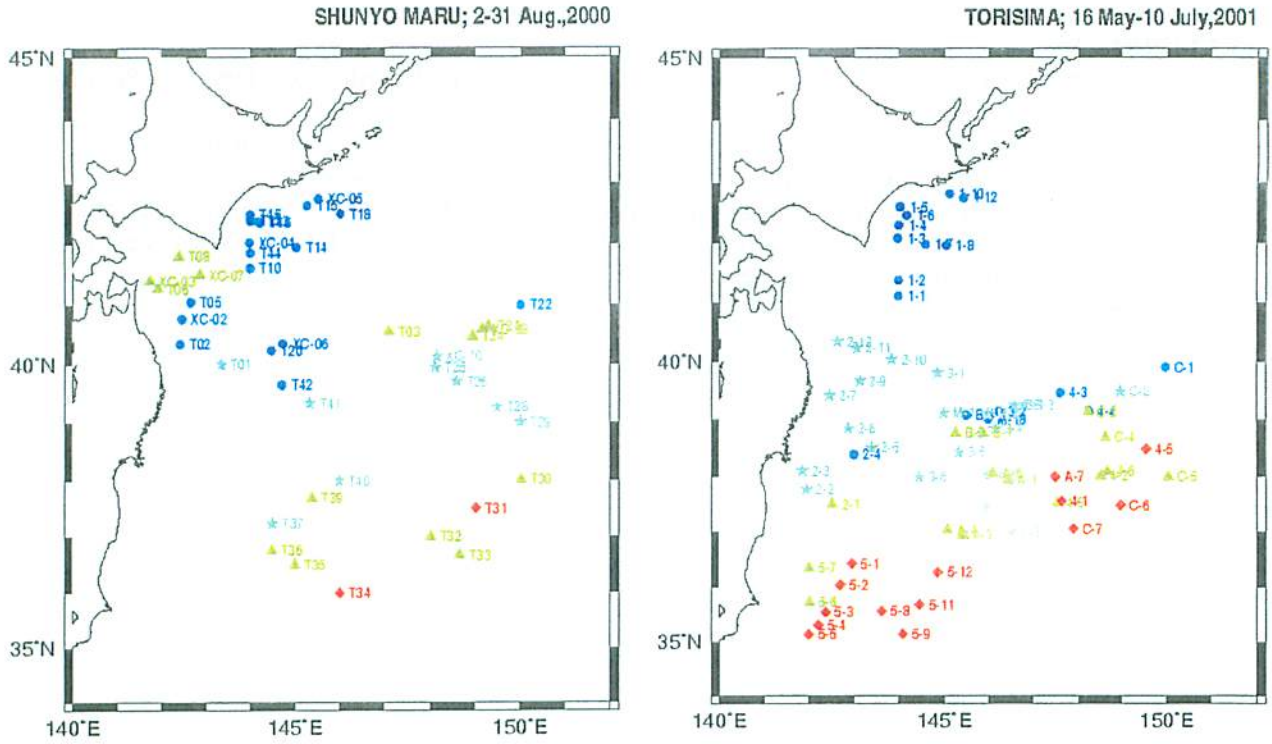


Fig. 1. Station maps in August 2000 (left panel) and in May-July 2001 (right panel). Red diamond, green triangle, light blue star and blue square denote CTD or XCTD stations in the Kuroshio area (200 m temperature was over than 14℃), warm area (100 m temperature was over 10℃ and 200 m temperature was less than 14℃), cold area (100 m temperature was over 5℃ and less than 10℃) and the Oyashio area (100 m temperature was less than 5℃), respectively

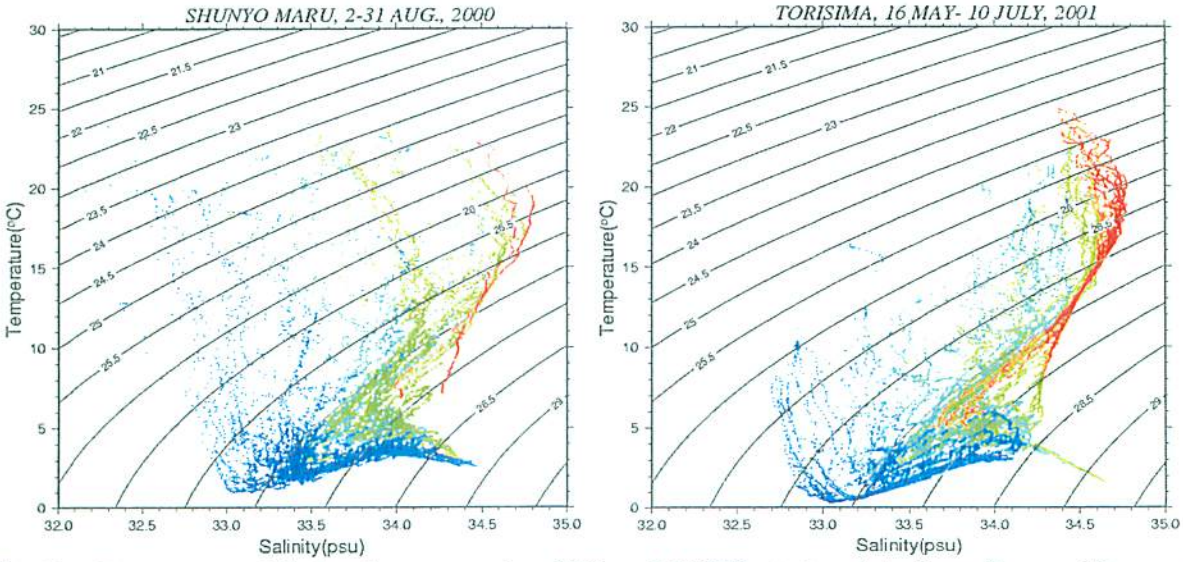


Fig. 2. Temperature-Salinity diagrams using CTD and XCTD station data from *Shunyo Maru* and *Kyoshin Maru* No. 2 in August 2000 (left panel) and CTD station data from *Torishima.* from May to July 2001 (right panel). Each thin line in this figure denotes a density line of sigma-t. Red, green, light blue and blue points corresponded to the Kuroshio area, warm area, cold area and the Oyashio area, respectively.

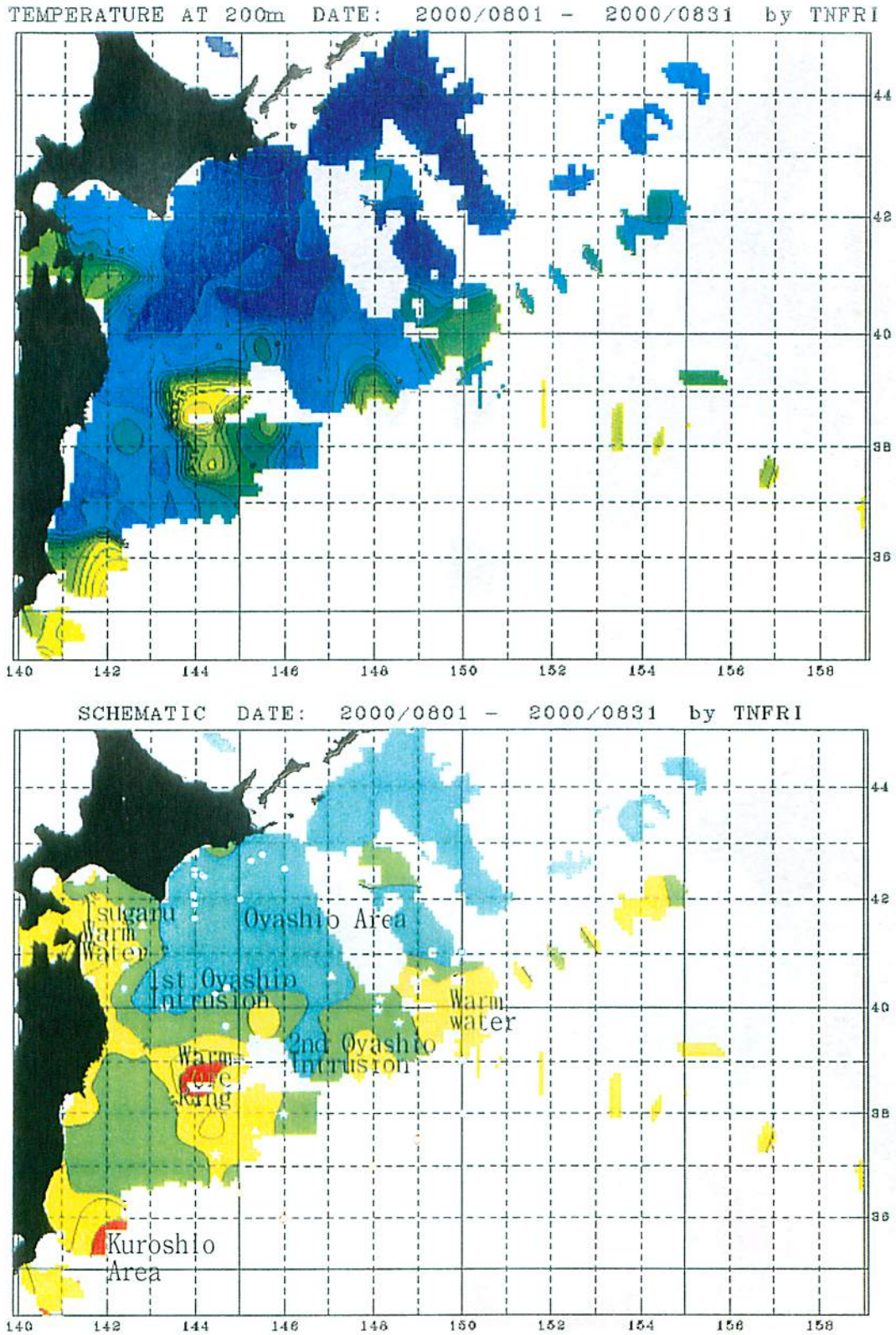


Fig. 3. 200 m temperature map (upper panel) and schematic hydrographic map (lower panel) in August 2000 (presented by the Tohoku National Research Institute). Red diamond, green triangle, light blue star and blue square on the lower panel denote CTD and XCTD stations observed from *R/V Shunyo Maru* and *Kyoshin Maru* No. 2. in the Kuroshio area, warm area, cold area and the Oyashio area, respectively. In the lower panel, blue, yellow and red area show distributions of the Oyashio, the warm water spreading from the Kuroshio Extension and the Kuroshio Extension, respectively. The red area around 38 ° 30'N, 144 ° E in the lower panel shows the Kuroshio warm-core ring.

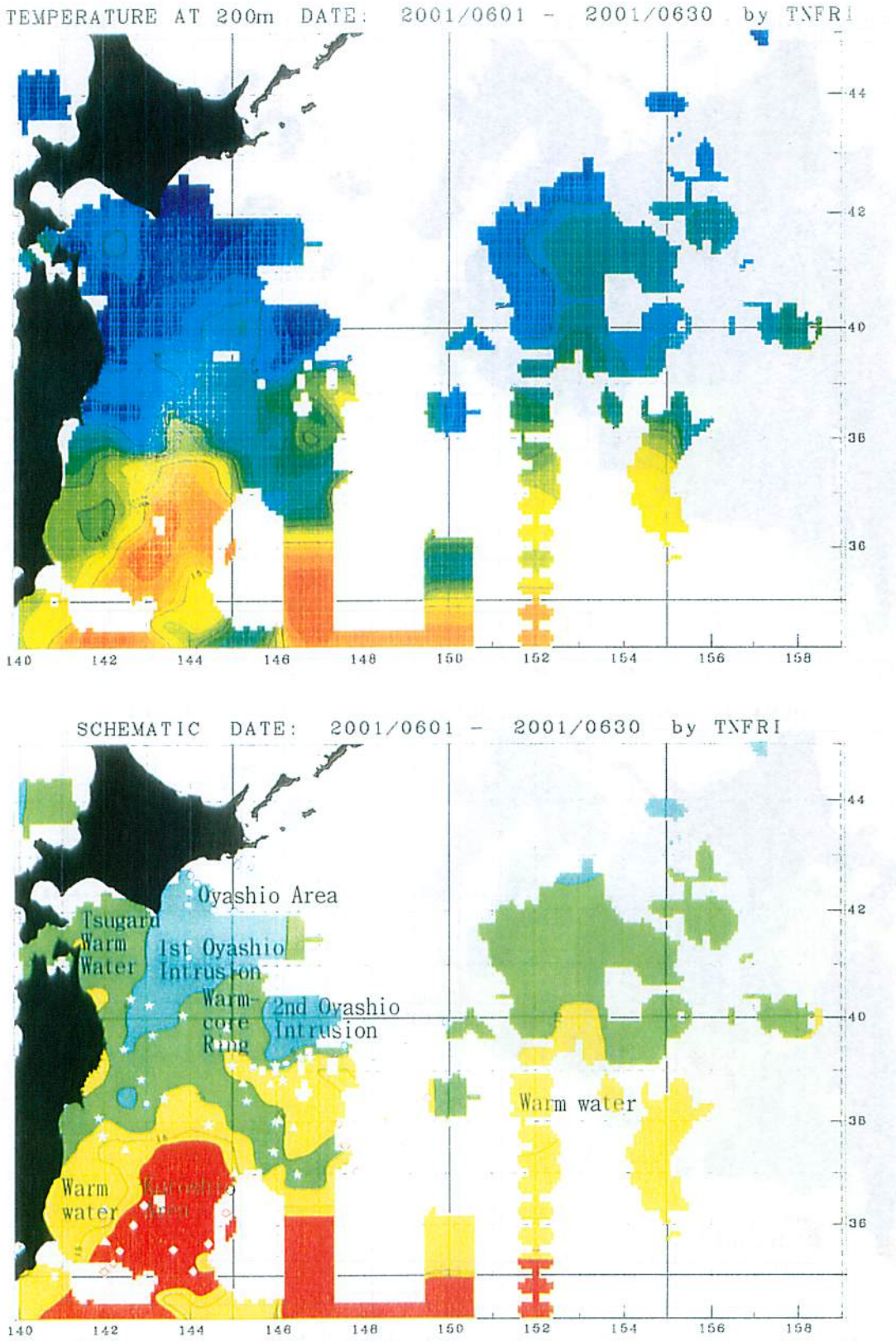


Fig. 4. Same as Fig. 3, but for June 2001. Red diamond, green triangle, light blue star and blue square on the lower panel denote CTD stations observed from *Torishima.* in the Kuroshio area, warm area, cold area and the Oyashio area, respectively. In the lower panel, blue, yellow and red area show distributions of the Oyashio, the warm water spreading from the Kuroshio Extension and the Kuroshio Extension, respectively.

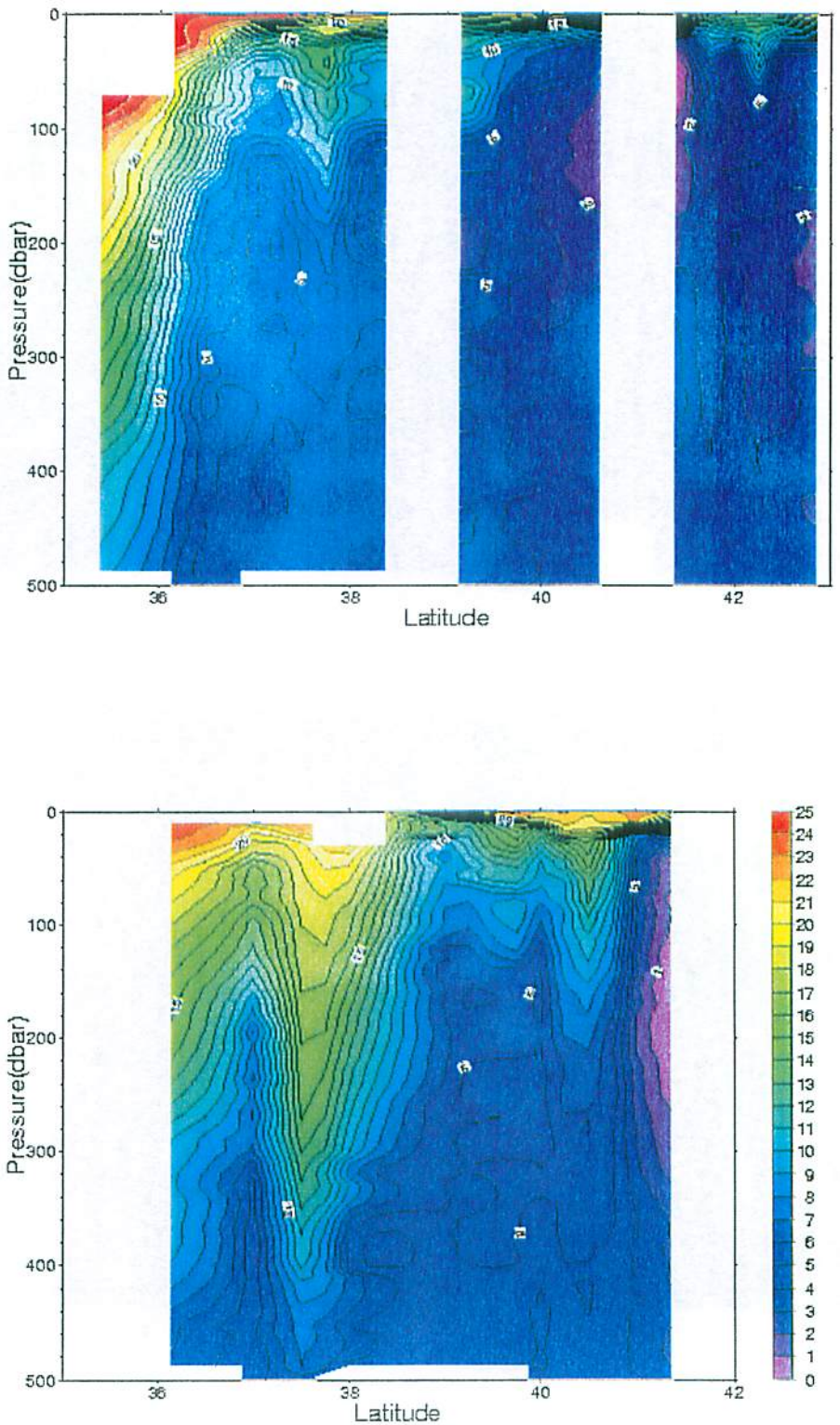


Fig. 5. Temperature sections along 144-146 ° E (upper panel) and 148-150 ° E (lower panel), observed from *Shunyo Maru* and *Kyoshin Maru* No. 2 in August 2000.

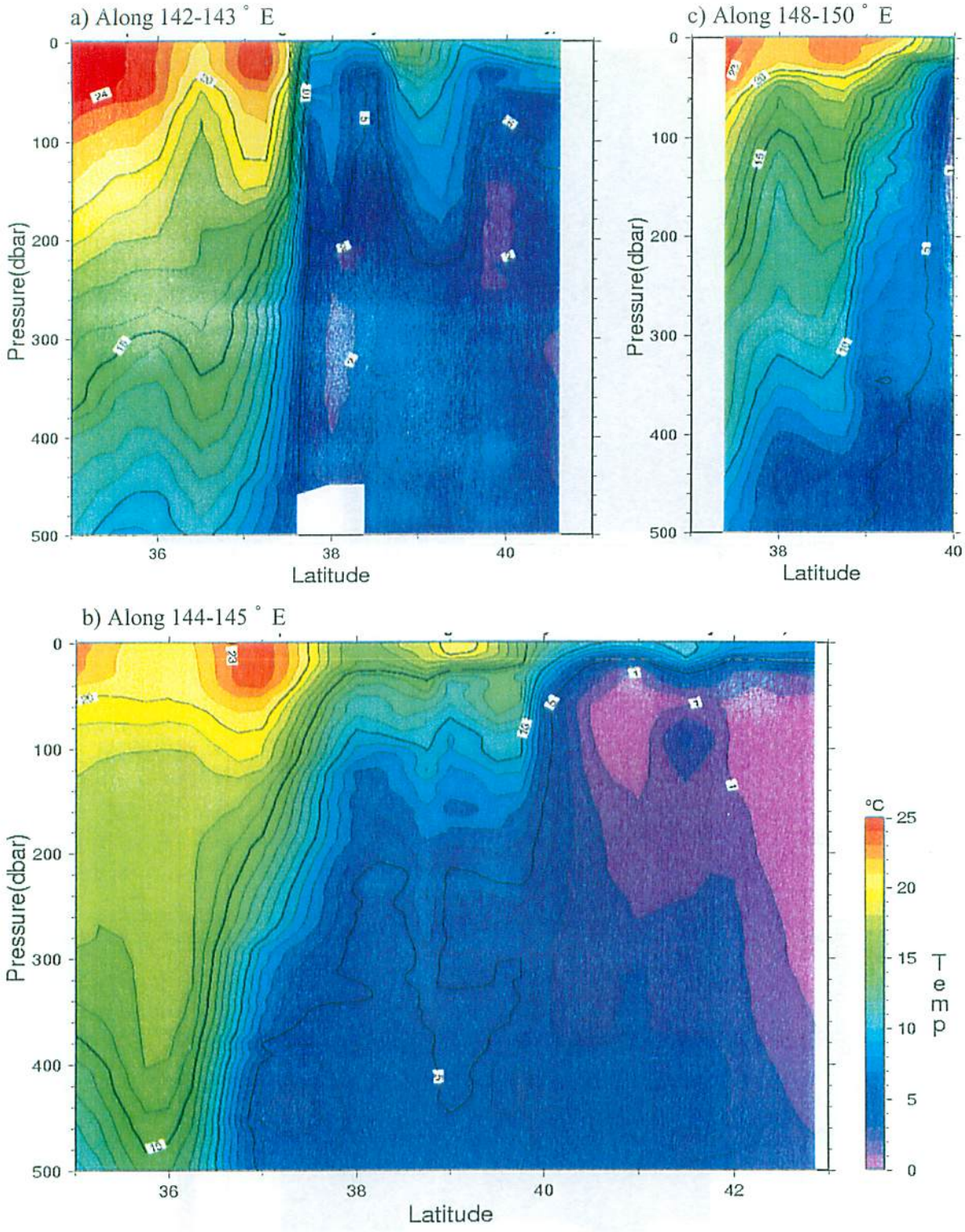


Fig. 6. Temperature sections along 142 °-143 ° E (upper left panel), 144 °-145 ° E (lower panel) and 148-150 ° E (upper right panel), observed from *Torishima.* from May to July 2001.