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RESEARCH PLAN FOR CETACEAN STUDIES IN THE WESTERN NORTH PACIFIC UNDER SPECIAL PERMIT (JARPN II) (FEASIBILITY STUDY PLAN FOR 2000 AND 2001)

THE GOVERNMENT OF JAPAN

ABSTRACT

The Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN) was conducted between 1994-1999. JARPN had two main objectives: a) population structure and b) feeding ecology of minke whales in the western North Pacific. The second objective was added in 1996 as a feasibility study. At the JARPN review meeting held in February 2000, while a considerable amount of data and information and interesting results were presented, some scientific issues remain unresolved. To follow up these issues, it is proposed that JARPN be continued and developed to a second phase: JARPN II. The priority in this second phase will be on feeding ecology, involving the studies on prey consumption by cetaceans, prey preference of cetaceans and ecosystem model. Bryde's and sperm whales will be included as part of this research as well as Baird's beaked and short-finned pilot whales and Dall's porpoises, which are caught by the commercial fishery. The second objective is on stock structure. The stock structure of minke whales in the eastern and north sides of Japan will be investigated to clarify some pendent issues from the JARPN review meeting. Also samples obtained from the Bryde's and sperm whales will be used for studying the stock structure in these species. The third objective is on environmental effects on cetaceans and marine ecosystem such as chemical pollution. The research area is set in sub-areas 7, 8 and 9. In the feeding ecology study, the sighting and sampling surveys of whales and the survey of prey species will be conducted concurrently. A two-year feasibility study is planned for years 2000 and 2001. A total of 100 minke whales (effectively O Stock and putative W Stock), 50 Bryde's whales (Western North Pacific Stock) and 10 sperm whales (Western Division Stock) will be sampled in each year. These whale species are selected because they are likely major components of the large whale biomass in the region. Also because their populations are relatively abundant and in good condition. The research methods will be the same in the second year in principle, but these might be adjusted based on the data obtained in the first year. The results of the two-year feasibility study will be submitted to the IWC/SC and other organizations, and the Government of Japan may construct a future research plan on feeding ecology of cetaceans based on the results obtained through the feasibility study and on comments by members of IWC/SC and other organizations.

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I. INTRODUCTION

Although paragraph 10(e) of the IWC Schedule stipulates that by 1990 at the latest the Commission will undertake a comprehensive assessment of the effects of the moratorium of commercial whaling and consider modification of the moratorium and the establishment of other catch limits, the moratorium is still in force without being reviewed based upon the best scientific advice. The Government of Japan ceased the large-type whaling for sperm whales (Physeter macrocephalus) and Bryde's whales (Balaenoptera edeni), and the small-type coastal whaling for minke whales (Balaenoptera acutorostrata) in the North Pacific in 1988.

After the introduction of the moratorium, the IWC/SC started the comprebensive assessment (CA) of whale species beginning by the order of importance and quantity of data. The CA for minke whales and Bryde's whales in the western North Pacific was completed in 1991 and 1996, respectively. A steering group had been set up in 1998 to discuss and plan the start of the CA for the North Pacific sperm whales. At present the Implementation Simulation Trials (IST) are being conducted to apply the Revised Management Procedure (RMP) for the cases of minke and Bryde's whales in the western North Pacific. The main issue in these IST is the stock structure and mixing rates.

In 1994 the Japanese Whale Research Program under Special Permit in the Northwestern Part of the North Pacific (JARPN) was initiated to address the issues of the stock structure and mixing rates of minke wbales, as requested for the IST (Government of Japan, 1994). Three objectives were established for JARPN: to clarify whether or not W Stock exists in offshore areas of the North Pacific, the mixing rate of the bypothesized W Stock with O Stock (the Okhotsk Sea-the east coast of Japan) and the validity of O sub-stock scenario. Clarifying further when and to what extent J Stock whales mix in sub-areas 7 and 11 is also important as far as the ISTs are concerned. Feeding ecology of minke whales was added as a new objective in 1996, as a feasibility study (Government of Japan, 1996). Six JARPN surveys were conducted in each year between 1994 and 1999 and a total of 498 minke whales were sampled (Fujise, 2000). Sampling covered sub-areas 7, 8, 9 and 11 and nearly half of the year between the middle of May and early September.

In 1996 an IWC/SC working group reviewed the new information relevant to IST for North Pacific minke whales. The new information came mainly from the JARPN surveys conducted in 1994 and 1995 in sub-area 9. Based on the new information the working group dropped the O sub-stock scenario, however there was no consensus within the group whether the new information was enough to drop the W Stock hypothesis. An IWC/SC workshop was held in Tokyo in February 2000 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. The workshop agreed that, in the light of the results of 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. One of the recommendations of the workshop was to obtain further genetic samples from sub-areas 12, 9 and possibly sub-area 8.

While noting that the investigations under JARPN were only a feasibility study, the workshop considered the study of the feeding ecology to be successful. The results showed that most of minke whales pursued single prey species aggregations and the main prey species changed seasonally and geographically, for example, anchovy in May/June and saury in July/August. These are the main target species for the Japanese fisheries. The estimated prey consumption by minke whales was comparable to that of the commercial fisheries. 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.

As mentioned above, although most of the scientific evidence presented at the JARPN review meeting did not support the existence of the W Stock, a mtDNA analysis suggested the possibility of additional stock structure in part of sub-area 9 in some years. To clarify this situation further investigation is requested. In addition, the workshop agreed that it is of the utmost importance for future ecological studies to expand survey grounds and to obtain an improved understanding of the relevant prey species. Therefore, it is proposed that JARPN be continued to follow up these issues and be developed into the second phase: JARPN II. The priority research in JARPN II will be on the feeding ecology. Apart the minke whale, the Bryde's and sperm whales will be added to the feeding ecology study, as these species are relatively abundant and almost certainly play an important role in the ecosystem. The Baird's beaked whales (Berardius bairdii), short-finned pilot whales (Globicephala macrorhynchus) and the Dall's porpoise, (Phocoenoides dalli), are also included as samples of these three species are available from the commercial fisheries.

A two-year feasibility study is planned because there is limited information from the prey species surveys and little information on the feeding ecology of Bryde's and sperm whales. The research area is set off the coast of Tohoku and southern Hokkaido, which is Japan's richest fishing grounds and therefore provides an ideal area to study the interactions between cetaceans and fisheries. The results of the two-year feasibility study will be submitted to the IWC/SC, PICES, ICES, NAMMCO and other organizations. The Government of Japan would then construct a future research plan on feeding ecology of cetaceans based on the results obtained through the feasibility study and comments received.

II. BACKGROUND

For the fisheries management Japan has been traditionally depending upon input control measures such as limited entry licensing system. In 1997, however, Japan introduced its first Total Allowable Catch (TAC) system, thereby establishing a unique system of the combination of input and output control fisheries management measures. According to the White Paper issued by the Government of Japan (1999), while the fisheries have provided 40% of animal protein with a variety of fish products, the recent level of fisheries resources and catches have decreased. The catches by Japanese fisheries were drastically shrank from 12,785 thousand tons 1988 to 6,684 thousand tons in 1998. Last year, therefore, the Fisheries Agency announced the principle for the fundamental policy on fisheries and its action program to implement the policy. In the principle, the first priority is given to science-based management and sustainable utilization of fisheries resources within Japan's EEZ. To aid the recovery of the resources, investigations should be carried out taking into account the management and sustainable utilization of whole ecosystem including marine mammals.

The principle of multi-species management has been discussed by many international organizations including the FAO. In the 1995 Kyoto Declaration adopted by the International Conference for the Sustainable Contribution of Fisheries to the Food Security (the Kyoto Conference, jointly held by Japan and FAO, 1995), it was noted that the effectiveness of multi-species management should be studied and harvesting at multi-trophic levels should be considered (Government of Japan, 1995). The Indian Ocean Tuna Commission (IOTC), recognizing the importance of the ecosystem approach to fisheries management, encouraged its Scientific Committee to carry out research on the predation by marine mammals and sharks on tunas caught on longlines at its fourth session held at Kyoto in December 1999. This decision was made on the basis of many reports of the damages caused by the marine mammal predation in tuna longline fisheries especially in developing countries. The North Pacific Marine Science Organization (PICES) also set up a working group on food consumption by marine mammals and seabirds in 1995 which noted that there still exists shortage of quantitative data on the ecosystem, especially feeding ecology of top predators (PICES, 1999). The Fourth Annual Conference of the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea (Pusan, Republic of Korea, November 1999) decided to include a study on the ecosystem approach in its 2000 work plan, focusing on the prey/predator relationship between Walleye Pollock and marine mammals. The FAO Conference of Fisheries Ministers (Rome, March 1999) and the FAO Committee of Fisheries (COFI, Rome February 1999) also recognized the importance of the multi-species management approach for the sustainable utilization of fisheries resources. The competition between top predators and fisheries was discussed also at the 51st IWC meeting, when the estimated prey consumption by cetaceans worldwide was reported as 300 to 500 million metric tons, multiple times larger than the world fisheries production (Tamura and Ohsumi, 1999).

In the North Atlantic, the feeding ecology of top predators has already been studied. According to the Norwegian feeding ecology research conducted between 1992 and 1994, the prey species consumed by minke whales change conspicuously according to area, season and year, and minke whales have flexible feeding patterns to match the local abundance of prey species (Haug *et al.*, 1995a). Further, it was suggested from the concurrent prey species surveys that there existed higher preference to herring (*Clupea harengus*) and capelin (*Mallotus villotus*) by minke whales. By inputting these data into MULTSPEC model, future forecasting is possible (Bogstad *et al.*, 1997). For example, it was shown that, when minke whales increase, important fish resources such as cod decrease by predation, resulting in serious consequences for fisheries targeting these species.

As is well known (e.g. IWC, 1990), the identification of stocks and their geographical (and temporal) boundaries is fundamental to the management of exploited and protected species. This identification is necessary to properly estimate abundance, set catch limits, and interpret catch statistics and life-history parameters. Such information is important for the implementation of the IWC's Revised Management Procedure. The IWC Scientific Committee has supported and encouraged discussions on this issue across the formation of a special Working Group on Stock Definition (IWC, 1999).

Another issue is environmental concern and whales. In the IWC/SC, the question of the effects of environmental changes on whales are addressed as following: (1) global warming, (2) ozone depletion, (3) pollution, (4) direct (intentional and incidental mortality) effects of fisheries and indirect (ecological ramification) effects of fisheries, (5) noise and (6) other human activities (e.g. tourism, coastal development) (IWC, 1993). The importance of this subject is reflected in the IWC's creation of two working groups, one on chemical pollution and whales in 1995 and the other on climate changes and whales in 1996.

Organochlorines (OCs) such as PCBs, DDTs and HCHs are generally used in land-base, then move to the coastal and pelagic waters by atmospheric transportation. Although the contamination levels of OCs in some marine animals such as fur seals have decreased in the Northern Hemisphere (Tanabe *et al.*, 1994), it thought that a small percentage of the PCBs products still reaching the ocean and then contamination by PCBs are still continued at least in the marine environment (Reijnders, 1996; Tateya *et al.*, 1988). The monitoring of these and other contaminants in the marine environment through the examination of biological tissues of marine mammals is of fundamental importance.

In the North Pacific, about 20 % of mature male minke whales sampled during the JARPN surveys presented anomalous testis (Fujise *et al.*, 1996; 1997; 2000; Ishikawa *et al.*, 1997; Zenitani *et al.*, 1999). The cause of these anomalies could not be determined and the relationship between the anomaly and the pollutants was also unknown. However, it is clear that additional efforts are needed to investigate the rate of occurrence and the cause of the anomaly. Also the IWC noted that physical processes affect the body condition and abundance of whales through availability of food, and the need of such research was emphasized (IWC, 1997)

III. OBJECTIVES OF THE RESEARCH

The overall goal of the research is 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 is important to gather the information on resources and to merge it as a whole ecosystem. In this research special attention will be paid to the ecosystem surrounding cetaceans, and the data and materials related to cetaceans, prey species and oceanographic conditions will be collected. The cetacean species to be sampled under special permit are minke, Bryde's and sperm whales. These species are found in abundance (Appendix 1) and could readily be subject to sustainable harvesting. Baird's beaked whales, short-finned pilot whales and Dall's porpoises, which are commercially taken in the coastal area, are also examined in the project using commercial samples.

1. Feeding ecology and ecosystem studies

The priority research will be on the feeding ecology and ecosystem studies, including both prey consumption and prey preference of cetaceans, as well as assessment of nature how cetaceans use their habitats through feeding activities.

Baleen whales, as well known, feed on relatively low trophic level organisms such as krill and small schooling fishes, while toothed whales feed on relatively high one such as squids and larger sized fishes, thus they occupy different ecological niches in marine ecosystem and such two types of group should be considered separately for choosing samples species.

Most important issues for choosing sample species are their abundance and biomass, but biomass rather important from the view of ecosystem studies. For baleen whale components, as given in Appendix 1, minke and Bryde's whales are the primary baleen whale component in the western North Pacific region. Their biomass is over 146,000 tons and 298,000 tons, respectively in summer. These two species are highly dominant, more than any other baleen whales. Among toothed whales, sperm whales are overwhelmingly dominate as being 3,228,000 tons. The following components are short-finned pilot whales as 138,000 tons, Baird's beaked whales are also important especially in sub-area 7 (27,000 ton).

Ecological niches are obviously another important issue for choosing sample species. Both minke and Bryde's whales are main components and feed on plankton and small-schooling fishes (Appendix 2). Details of the prey species and their fisheries are shown in Appendix 3. Comparison between the two baleen whale species should be examined for clarification of species-specific nature of feeding habits of baleen whales in the same region. For bottom feeders, both sperm and Baird's beaked whales are typical deep diving predators mainly feed on bathyal squids and clarification of their feeding habits and food consumption are also important to investigate interaction between surface marine ecosystem and bottom ecosystem. Toothed whales have also feeding habits as surface feeders on pelagic fishes and squids. Dall's porpoises are typical surface feeders, which are most abundant toothed whale as being over 554,000 animals while biomass is not so high. Short-finned pilot whales have similar nature of feeding on pelagic squids.

In addition, further comparison on nature of feeding between the two species within same type of feeder, such as minke vs. Bryde's whales or sperm vs. Baird's beaked whales, may give some solutions how cetacean use their habitats through feeding activities, which is important one for better understanding of marine ecosystem studies.

As a conclusion, sampling should be prioritized according the two issues discussed above, biomass (or abundance) and ecological niches, and we concluded that the following species should be examined in this project:

1) Plankton and small schooling fish feeder: Minke and Bryde's whales by research take.

2) Bottom feeder: Sperm whales by research take and Baird's beaked whales by commercial harvests.

3) Pelagic squids and fishes feeder: Short-finned pilot whales and Dall's porpoises by commercial harvests.

For Baird's beaked whales, short-finned pilot whales and Dall's porpoises, it has merits we can have scientific samples through on-going commercial fisheries.

(1) Prey consumption by cetaceans

Many papers have reported on the prey species of cetaceans in the western North Pacific. However, quantitative data on prey consumption are insufficient. Past analyses were based on commercial catches and whalers usually lost the stomach by cutting abdominal cavity and then it was difficult to measure the weight of the stomach contents.

Minke whales feed on swarming zoo-plankton and schooling fish. There are geographical, seasonal and yearly changes of prey species in the western North Pacific. In the Pacific side, Japanese anchovy (*Engraulis japonicus*) was the most important prey species in May and June, while Pacific saury (*Cololabis saira*) was the most important one in July and August (Tamura *et al.*, 1998; Tamura and Fujise, 2000a). Krill was the most important prey species in September. Walleye pollock (*Theragra chalcogramma*) was also an important prey species during June and September in coastal waters. In the southern Okhotsk Sea, krill was the most important prey species in July and August. These changes in the prey species probably reflect the changes in the availability of prey species in these areas. Daily food consumption rate was estimated as 1.8 – 5.7 % of body weight. These values are similar to the estimates of eastern North Atlantic minke whales and the Antarctic minke whale.

Bryde's whales feed on krill and schooling fish. Off the Pacific coast of Japan, they feed on krill, Japanese anchovy and chub mackerel (*Scomber japonicus*). In the waters around Bonin Islands, they fed on krill and lantern fish. In the East China Sea, they fed mainly on Japanese pilchard (*Sadinops melanostictus*), Japanese anchovy and horse mackerel (*Trachurus japonicus*).

Sperm whales feed on squids and fishes. The most important squid species in Tohoku-Hokkaido area are *Histioteuthis dolfleini*, *Octopoteuthis* sp., *Moroteuthis robusta* and *Ommastrephes bartrami*. In Tohoku-Hokkaido area rockfishes occupy 14%, cods 30% and Pacific saury, Japanese pilchard and sharks 14 %, respectively. There are not quantitative data on the stomach contents for sperm whales in the western North Pacific

Baird's beaked whales mainly feed on benthic cods such as Macrouridae and Moridae, and cephalopods. Baird's beaked whales mainly feed on bathyal squids in the northern Japan, and on bottom fishes in the central Japan.

Short-finned pilot whales northern form mainly feed on ommastrephid squids and octopus in the northern Pacific coast.

Dall's porpoises were studied in almost all their distribution area including Sea of Japan, Sea of Okhotsk, Bering Sea, and northern North Pacific. Generally, they feed on smaller fishes and pelagic squids. Most of the prey items are mesopelagic micronekton in the North Pacific and Bering Sea, but limited to the fishes and squids that perform diurnal vertical migration to shallower waters at night. In contrast to the North Pacific and Bering Sea, epipelagic fishes such as Japanese pilchard and Japanese anchovy are a part of important food in the Sea of Japan and the Sea of Okhotsk, as well as benthos which are alternatively utilized when epipelagic prey are less. Estimation of the daily prey consumption rate was 5.0 % of body weight (Ohizumi, 1998).

As mentioned above, quantitative data on stomach contents of these cetaceans are not sufficient for estimating prey consumption in these species. Prey consumption by cetaceans is the main part of the research. Data obtained for minke whales will be analyzed together with those already obtained in JARPN surveys. Data obtained for Bryde's whale will be analyzed in the same manner as minke whale. Data obtained for sperm whale, short-finned pilot whale and Dall's porpoise will be analyzed for prey species, prey consumption and so on.

(2) Prey preference of cetaceans

As minke whales are opportunistic feeders, the prey species changes temporally and geographically. Known prey species in the western North Pacific are Japanese pilchard, chub mackerel, walleye pollock, Pacific herring, sand lance (*Ammodytes personatus*), squid and so on (Kasamatsu and Tanaka, 1992; Tamura and Fujise, 2000a). In the JARPN surveys sixteen prey species, consisting of one copepod, four euphausiids, one squid and 10 fishes, were identified.

As mentioned above, prey species of Bryde's whales off the Pacific coast of Japan have been reported as krill, Japanese anchovy and chub mackerel (Nemoto, 1959) and for sperm whale four species of squid and rock fishes, cods, Pacific saury, Japanese pilchard and sharks have been reported (Kawakami, 1980). The biology, stock structure and fisheries of these main prey species are described in Appendix 3. However, no useful data was reported until now in especially information on prey preference for these cetaceans.

Prey preference of cetaceans, which is a key parameter in most ecosystem models, is a challenging objective. The concurrent prey species survey is designed mainly for minke whales and Bryde's whales in the two-year feasibility study.

(3) Ecosystem model

An ecosystem model suitable to the western North Pacific will be developed based on the models such as ECOPATH and MULTSPEC. These two models are preferred and being investigated for initial work (see Appendix 4).

The ECOPATH model has 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. ECOPATH need to postulate an equilibrium of biomass. Therefore we will make use of this model to evaluate the relative importance of predator species and to know the distinction between keystone predators and trivial ones at the first stage. After the trials, Ecosim model and Ecospace model will be 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.

The MULTSPEC model is achieving some success in the Norwegian aquatic ecosystem. The model integrates the dynamic of each fish and marine mammal. Like ECOPATH there are some difficulties to include many species and complicated food web. 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 and describe dynamic change including various uncertainties and predict future interactions among whales and fisheries.

The trial of our development of ecosystem or multi-species management models begins with the application of the ECOPATH model and then the MULTSPEC-type model. The combination of merits of both models will be investigated. The ECOPATH model will find out the keystone species and encourage the simplification of entries. On the other hand, the MULTSPEC model will be developed for including many other species. The final model would show the interaction among multi-species and the relation between fisheries and top predators. Also it will able to predict the dynamics change and gives us reasonable advises for the strategy and tactics for multi-species management.

2. Stock structure

(1) Minke whale

The main objective of the JARPN was to investigate the possibility of additional structure (i.e. W Stock) in the eastern side of Japan. The results obtained by different approaches that used JARPA data and information for the period 1994-1999 were reviewed and discussed in a JARPN review Workshop in February 2000. While most of the genetic and other biological markers showed no firm evidence for the occurrence of additional structure in the eastern side of Japan, a mtDNA analysis suggested certain degree of genetic heterogeneity in a part of sub-area 9 in a specific year. Based on this result the Workshop could not discard the occurrence of W Stock in offshore areas, at least in some years. Then the occurrence of the W Stock in offshore areas of the western North Pacific should be confirmed and if so, the extent of its spatial and temporal occurrence should be investigated. There are no data available from JARPN for sub-area 12 or portions of sub-areas 7, 8 and 9 in the Russian EEZ.

Another important issue for the IST of this species is the estimation of the mixing rate between O and J Stocks in the coastal area of Japan. While there are good evidence of mixing in sub-area 11 in part of the year, no firm evidence for the occurrence of J Stock animals in sub-area 7 exist. Then the possible occurrence of J Stock animals in this sub-area should be investigated and if so, the mixing rate between O and J Stocks in sub-area 7 should be estimated.

Following the discussions and conclusions of the JARPN review meeting, this objective is 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. 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 will be estimated in sub-area 7. These are the main components related to this objective.

(2) Bryde's whale

The CA for this species in the North Pacific was completed by the IWC/SC in 1996. On the basis of genetic and other biological marker information the Committee defined five stocks in the North Pacific being one of them the Western North Pacific Stock. The eastern boundary for this stock was set at 150°W and the southern boundary at 2°S. In subsequent SC meetings these boundaries have been slightly modified (see Annex D, appendix 14 of IWC, 1999). In 1998 the Committee agree that there should be two sub-areas (sub-areas 1 and 2) in this stock area divided at 180° which would allow the testing of two alternative stock hypothesis for IST (IWC, 1999). 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). 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). Then sampling of biological material useful for studies of genetic structure should be carried out in these parts.

(3) Sperm whale

The IWC/SC has conducted preliminary discussion to start the CA for the North Pacific sperm whale. Information on stock structure of the species will be important for the CA and the attainment of samples for such purposes is necessary.

3. Environmental effects on cetaceans and marine ecosystem

(1) Chemical pollution and their effect on cetaceans and marine ecosystem

It is known that differences in the accumulation levels of organochlorines such as PCBs and DDTs are observed between baleen whales and toothed whales. These differences reflect the fact that their prey species are in different trophic levels and/or contaminated level, in addition to the physiological difference themselves. In this research plan, it is planned to monitor for several types of whales, which have different feeding habitat (i.e. plankton and small schooling fish feeder, and bottom feeder). At the same time, monitoring of chemical pollution in other marine organisms will be conducted as well. Feasibility study for constructing a comprehensive monitoring and assessment system for the marine ecosystem in the western North Pacific will be examined as well as the monitoring of pollution in each biota. In this program, it is also planned to monitor the pollution of seawater and air. This information was not available after the 1980s. These comprehensive monitoring will contribute to conservation of marine ecosystem.

(2) Other effects on cetaceans and marine ecosystem
In this program, sighting records are collected for all cetaceans, at least for all large whales during the sighting activities. These observations involve whale species such as right and blue whales, which present low abundance as well the recording of abundant species such as minke, Bryde's and sperm whales.

At the same time, oceanographic observations using XCTD, CTD, EPCS and echo sounder will be made concurrently during the survey. Information on oceanographic condition in the research area will be collected during the research activities.

IV. RESEARCH METHODS AND ITEMS

The research methods used in the first year will be continued in the second year in principle, but those might be adjusted in the second year based on the data obtained in the first year. Finally the research methods will be determined by taking the due consideration of the results of the feasibility study.

1. Research design

(1) Research area
The whole research area is sub-areas 7, 8 and 9, and, if possible, sub-areas 12 and 13. The research area is the Western Subarctic Gyre region in the North Pacific (Fig. 1; Favorite *et al.*, 1976). The Western Subarctic Gyre region is known as an area of high production capacity. The Oyashio, which is the Western Boundary Current of the gyre, flows into the sea east of Honshu and sustains the high productivity there.

Feeding ecology study will be mainly conducted in sub-areas 7 and 8 in the first year, because the concurrent prey survey can be conducted in these sub-areas due to the availability of research vessel (Fig. 2). For the objective of stock structure of minke whales, the research areas to be covered are sub-areas 12, 9 (and possibly 8) and 13. Sub-area 9 (and possibly 8) will be surveyed in the first year. If permission to enter the Russian EEZ is obtained from the Russian Government, priority will be given to sub-area 12.

(2) Research duration and period
A two-year feasibility research is for the feeding ecology study. The research will be conducted in summer (July-September) in the first year and in spring (April-June) and/or early summer in the second year.

(3) Research on cetaceans
Research on whales consists of sighting and sampling surveys. In the sighting survey, a dedicated sighting survey vessel, the Kyoshin-Maru No.2, will cover the entire research area to collect the data on the distribution and other information of whales, and conduct oceanographic observations along the survey lines. In the sampling survey, the Nisshin-Maru research fleet will operate (Fig. 2).

No selection will be made as to sex and size in the sampling. The sampled whales are measured in the same way as in the JARPN. Stomach contents are measured following the Norwegian procedure regarding number, weight and body size by prey species (Haug et al., 1995b). For fully digested prey, hard tissues (otoliths for fishes and beaks for squid) are used for species identification and body size estimation.

(4) Research on prey species
The research on prey species will be closely integrated with the research on whales so that whales and fish are sampled as near to simultaneously as possible in both space and time. The survey of prey species will be conducted by a trawler-type research vessel of the Fisheries Agency, the *Shunyo-Maru*. The survey by the *Shunyo-Maru* consists of two two-week cruises. The research will be supplemented by the dedicated sighting survey vessel, *Kyoshin-Maru No.2,* which is equipped with the echo integrator. Distribution and population size of prey species by depth range is estimated using echo integrator. Also two observers will be on board the *Shunyo-Maru* to collect the data on the distribution of whales.

Responses on fish finders are identified to the species using mid-water trawl, drift-nets and jigging. The catch will be sorted by species and weighed. At each operation about 100 individuals of the main species will be selected at random and measured to nearest cm. Also 10 individuals will be sampled for biological measurement including stomach content. Frozen samples of main prey species will be used to analyze the energy density and to extract hard tissues for species identification and body size estimation.

2. Prey consumption by cetaceans
The amount of prey consumption by cetaceans per day is estimated through two methods: one is the indirect method based on standard metabolism and the other is the direct method based on the temporal changes of the weigbt of stomacb contents in a day. For the former method, physiological parameters will be obtained for the time being from the past studies (e.g. Lockyer, 1981; Folkow et al., 2000; Tamura and Fujise, 2000b). The energy density in prey will be estimated from the literature and samples collected during the research. With respect to the information needed for the latter method, evacuation rate from the stomach will be for the time being obtained in reference to Bushuev (1986) and other studies (e.g. Tamura et al., 1997; Tamura and Fujise, 2000b). Seasonal consumption of each prey species will be estimated from consumption per day, composition of prey species and the number of wbales in the area.

3. Prey preference of cetaceans
Prey preference will be estimated by comparing the prey composition in the stomach of whales and the prey composition in the environment estimated by the echo-integrator and/or trawl catches. Two indices will be used to express the prey preference; the relative frequency of occurrence by number and the individual number index (Lindstrøm et al., 1998).

4. Stock structure and mixing rates
(1) Minke whale
In sub-area 9 (and possibly sub-area 8), the stock structure of minke whales will be investigated using the same methods used under the JARPN. The Okhotsk Sea and/or portions of sub-areas 7, 8 and 9 in the Russian EEZ will be covered if permission is obtained from the Russian Government. Then samples and data for genetics and other biological markers will be collected from each whale sampled. Genetic analyses will be based on mtDNA, nuclear DNA (microsatellite) and allozyme. In sub-area 7, the mixing rate between O and J Stocks will be estimated using the markers mentioned above. If the putative W Stock exist in offshore areas, the mixing rate between O and W Stocks will be examined using genetic markers

(2) Bryde's whale and sperm whales

For Bryde's whales, stock structure will be examined using genetic markers, such as mtDNA, microsatellite and allozymes as well as other biological markers and then samples for conducting such analyses will be collected. For sperm whales, tissue samples will be collected for the genetic markers indicated above as well for other biological markers.

5. Effect of chemical pollution on cetaceans
In order to examine the effect of pollutants on whales, the following two items are considered.

(1) Accumulation levels of pollutants in cetaceans.
Tissue samples will be collected from blubber, liver, kidney muscle and other tissues and blood from each whale sampled and from some prey species taken from stomach contents of the whales and by the trawling survey. These tissues will be analyzed for pollutants such as organochlorines (e.g. PCBs, DDTs, HCHs, HCB, CHLs, Dioxins, co-PCBs), and heavy metals (e.g. Hg, Cd and Pb). Furthermore, the contaminant levels of lower-trophic organisms such as krill and other zoo-plankton, and sea water and air will be analyzed in the same way.

(2) Examination of the health condition of cetaceans
This item includes the external observation of body and the examination of occurrence of anomaly in internal organs and tissues as well the chemical examination for blood and other tissue (i.e. liver) for sex hormone, enzyme induction, immune system if possible.

6. Other effects on cetaceans and marine ecosystem
In addition to sighting records for whales, photo-ID, observation of whale behavior, especially feeding behavior will be also recorded, if possible.

Oceanographic observations are examined by using XCTD, CTD, EPCS and echo sounder will also be made concurrently during the survey. Information on oceanographic condition in the research area is planned to collect during the research activities using these instrumental. It is also used for satellite information. This information will contribute to the feeding ecology and environmental studies.

V. TARGET CETACEAN SPECIES AND SAMPLE SIZE

For the two-year feasibility study, the following species and sample size are planned for each year: 100 minke whales, 50 Bryde's whale and 10 sperm whales. The necessary sample sizes were calculated mainly from and for the feeding ecology study and supplemented with the genetic and pollution studies.

For feeding ecology study the necessary sample sizes were calculated for estimating their prey consumption with good precision as in the North Atlantic minke whales (Government of Norway, 1992; Appendix 5). In the case of minke whales, the data from sub-area 7 were divided into two seasons: spring and summer. Two type of data were used for the calculation; number of whales with each prey species (krill, Pacific saury and Japanese anchovy), and average stomach contents weight with its standard deviation. To get CV=0.2 for consumption of all dominant prey species, 201 minke whales are necessary. Furthermore, it is calculated that 72 in spring and 129 in summer are necessary.

In the case of Bryde's whales, for which limited data are available, data from the past pelagic fishery were applied to the number of whales with each prey species; that is, krill and fishes (unidentified). As the quantitative data on the stomach contents weight are not available, data of minke whales were used. For CV=0.2, it is calculated that 48 for krill (dominant prey species) are necessary to estimate the consumption (Appendix 5). However, these result are calculated based on several assumptions as the data of the actual prey species and stomach contents weight of Bryde's whales are not available.

In the genetic studies, the necessary sample size will generally depend on the degree of genetic differentiation between putative stocks and on the resolution of the genetic technique to detect such differentiation. Then the sample size should be determined on a case by case basis. However, several workshops have recommended a similar sample size to that proposed here. For example the Workshop on the Genetic Analysis of Cetacean Population 'recommends sample sized of 20-50 from each population are desirable and that theses should be taken throughout the geological range' (Hoelzel, 1991). More recently the Special Meeting on the Comprehensive Assessment of Right Whales also suggested that 'samples should be collected from a minimum of 20-50 individuals' (IWC, 1999).

On the light of the pollution study, the group in Texel meeting which was convened by IWC/SC proposed the follows: "it is clear that sample sizes will probably need to be at least 50 in each cell where the cell will vary by the important variables (e.g. age and sex) as indicated in the table. The total sample needed to collect sufficient animals in each cell will depend on a number of sampling selectivity factors (e.g. are juveniles more likely to be by-caught and do hunters select for larger individuals?) and of course any sex/age segregation in distribution." (Aguilar *et al.*, 1999). Comparing this sample size and those of the present research plan (100 minke, 50 Bryde's and 10 sperm whales), probably these sample sizes will not be adequate to examine fully all parts of the effect of pollutants on cetaceans. However, as the first step of the pollution study, contaminant levels of the cetaceans could be obtained by using these preliminary samples size. In the case of the minke and Bryde's whales pollutant burden could be examined considering temporal and space variation (and effect of pollutant on the whale will also examined if possible). The adequate sample sizes for the pollution study will be determined after these examinations.

VI. EFFECTS ON THE RESOURCES

The effects on the whale stocks sampled under special permit are examined in Appendix 6. For minke and Bryde's whales, the effects of the proposed catch are assessed by using the standard HITTER method (Butterworth, 1996).

For minke whales, two O Stock scenarios are used: 1) sub-areas 7+8+9+11+12 are O Stock, and 2) sub-areas 7+8+11+12 (40% in sub-area 12) are O Stock. One W Stock scenario case is used: western part of sub-area 9 and sub-area 12 (60%) are W Stock. These scenarios are based on the results of the JARPN surveys. The effects of the catch on the stock are assessed from the stock trend in the case of catch number at 100. From the results of HITTER calculation, it can be concluded that effect on the minke whale stock is negligible. Details of the calculations are shown in Appendix 6.

Bryde's whales will be sampled from the Western North Pacific Stock. Because the proposed sampling area is far from the coastal region of southwest Japan, in which the East China Sea Stock extends (Yoshida *et al.*, 1997; Pastene *et al.*, 1997) and also far from oceanic islands, it is unlikely that Bryde's whales from other stocks will be taken. Two stock scenarios are used: whole area and sub-area 1 according to the recent IST. The effects of the catch (50) on the stock are assessed in the same way as in the minke whale. From the results of HITTER calculation, it can be concluded that effect on the Bryde's whale stock is negligible. Details of the calculations are shown in Appendix 6.

Sperm whales will be sampled from the Western Division Stock. While no calculation was made for the sperm whales, the sample size is so small that is obviously below critical level to affect the stock.

VII. RESEARCH VESSELS, RESEARCH ORGANIZATIONS AND PARTICIPANTS

1. Research vessels

Sighting and sampling surveys on whales will be conducted with a dedicated sighting vessel, the *Kyoshin-Maru No.2*, and with the *Nisshin-Maru* research fleet composed of the research base (*Nisshin Maru*) and three sampling vessels (the *Kyo-Maru No.1*, the *Toshi-Maru No.25* and the *Yushin-Maru*). Research on prey species will be mainly conducted by a trawler-type research vessel of the Fisheries Agency, the *Shunyo-Maru*.

2. Main research organizations

(1) National Research Institute of Far Seas Fisheries (NRIFSF),
National Research Institute of Fisheries Science (NRIFS)
(2) The Institute of Cetacean Research (ICR)
(3) Other research institutions

3. Participation of foreign scientists

Participation of foreign scientists, especially those from neighboring countries, is welcome, insofar as their qualifications meet the requirements set by the Government of Japan. These requirements are the same as those for JARPN.

VIII. NEED FOR THE RESEARCH AND THE USE OF NON-LETHAL METHODS

1. Objectives and non-lethal methods

The objectives of the research cannot be attained by means of non-lethal research methods for practical and scientific reasons as follow.

Among baleen whales, minke whales are opportunistic feeders and their prey composition shows drastic changes reflecting the distribution pattern and level of abundance of prey species (Kasamatsu and Tanaka, 1992). From the commercial whaling period, only qualitative data on stomach contents are available for all whale species. The research on excrement and the rate of breathing does not give very reliable results on the prey composition in the stomach (e.g. Smith and Whitehead, 2000). Prey preference can be studied only by using the lethal method, in which whales are caught and their stomach contents are examined in parallel with the concurrent research on prey species. Further, data on body condition, especially fat, cannot be obtained by means of non-lethal methods. Quantitative research on stomach contents of minke whales was also conducted in JARPN, but there are limited data within the EEZ. Further no concurrent research on prey species was conducted. In this research, the whale and prey surveys will be closely integrated so that whales and fish are sampled as near to simultaneously as possible in both space and time.

The methods proposed for studying stock structure are the same as in the JARPN, i.e. genetic and non-genetic analyses. Non-genetic approaches require lethal method. DNA-based genetic analyses can be conducted using biopsy samples, however, biopsy sampling is difficult to conduct for minke whales, especially in the open sea due to their quick and fast movement. Further, DNA-based genetic analyses are complemented with the analyses of other biological data such as morphometrics and conception dates, which only can be obtained using lethal methods. Skin samples are not useful for allozyme analysis.

Lethal method is considered to be the most suitable approach for a rapid assessment of the effects of environmental pollution. It allows quantitative determination of the accumulation of chemical pollutants through analysis of the tissues from whale body and direct assessment of those effects through observation of viscera and tissues. In addition, the interpretation of the level of contaminant should be made by taking into consideration other biological information such as the reproductive status and age. Especially, age information is important factor to examine the contamination levels, because these pollutant are accumulated with age. Usually lethal methods provide a more comprehensive and faster approach to this issue as compared with non-lethal method such as biopsy sampling.

2. Objectives and contribution to rational management of cetaceans, and methodology

The information on feeding ecology is essential to understand the role of cetaceans in the ecosystem. Especially the information on the competition between cetaceans and fisheries will contribute to the science-based management of whales as well to the management of fisheries resources in the future.

To clarify whether or not the W Stock exists in offshore areas is an important matter for the North Pacific minke whale RMP trials. If W Stock exist then the estimation of the mixing between O and W Stocks in sub-areas 9 (and possibly 8) and 12 will be important information for the management of minke whales. Also, clarification of the annual changes of mixing (if any) of O and J Stocks in sub-area 7 as well in sub-areas 11 and 12 will be useful for the management of minke whales. For Bryde's whales, the information on abundance and distribution, especially in the area near Japan will improve the IST for this species. SC agreed that the available data did not provided evidence of sub-stock structure in offshore form Bryde's whales in the western North Pacific. Some members concerned that sub-area 1 is very large and that there is limited information for some parts of it. In the case of sperm whale, a preliminary discussion for stating the CA in the North Pacific was carried out in 1998. The attainment of biological information such as growth rate and maturity around the coast of Japan will improve the CA of this species in the North Pacific.

The effect of the pollution on whales can be monitored by measuring the accumulated amount of pollutants such as organic chlorine compound and heavy metals as well the observation of abnormalities in viscera and tissues.

The research on stomach contents is conducted with the Norwegian method, which is a method recognized worldwide with respect to marine mammals. At the same time, the research on prey species is conducted with the same level of precision as for the fisheries management within Japan's EEZ.

3. Sample size, age and sex of cetaceans

The proposed number of minke whales and Bryde's whales to be sampled is necessary to estimate the prey consumption with appropriate accuracy. The calculation of sample size is based on the data obtained from JARPN surveys and past commercial whaling (Appendix 5). Furthermore, these proposed numbers for minke and Bryde's whales are necessary for the studies on stock structure and pollution. The proposed number for sperm whales is subject to change in the second year of the program in the light of results from the first year.

The numbers for the three whale species are small and below the level which would affect the stocks (Appendix 6). During the sampling no selection of size, age or sex will be made.

4. Killing methods

All the sampling will be carried out in a quick and effective manner by means of explosive harpoons. When whales are not killed instantly with the primary killing method, an appropriate secondary killing method will be chosen according to the whale species and whale condition. For minke whales, a large caliber rifle will be used in principle as a secondary killing method. For Bryde's and sperm whales, appropriate quick and efficient methods such as large caliber rifle and second explosive harpoon will be used as secondary killing method, if necessary.

IX. OTHER MATTERS TO BE CONSIDERED

1. Processing of cetaceans sampled

All the whales sampled will be processed in accordance with Article VIII (2) of the International Convention for the Regulation of Whaling. Tissue samples will be taken from all whales sampled and the DNA data will be registered for market control (individual identification).

2. Reports to the IWC/SC

A report on the research will be submitted to the next meeting of IWC/SC and to other organizations. Also, a report on the two-year feasibility research on feeding ecology of whales will be submitted to IWC/SC.

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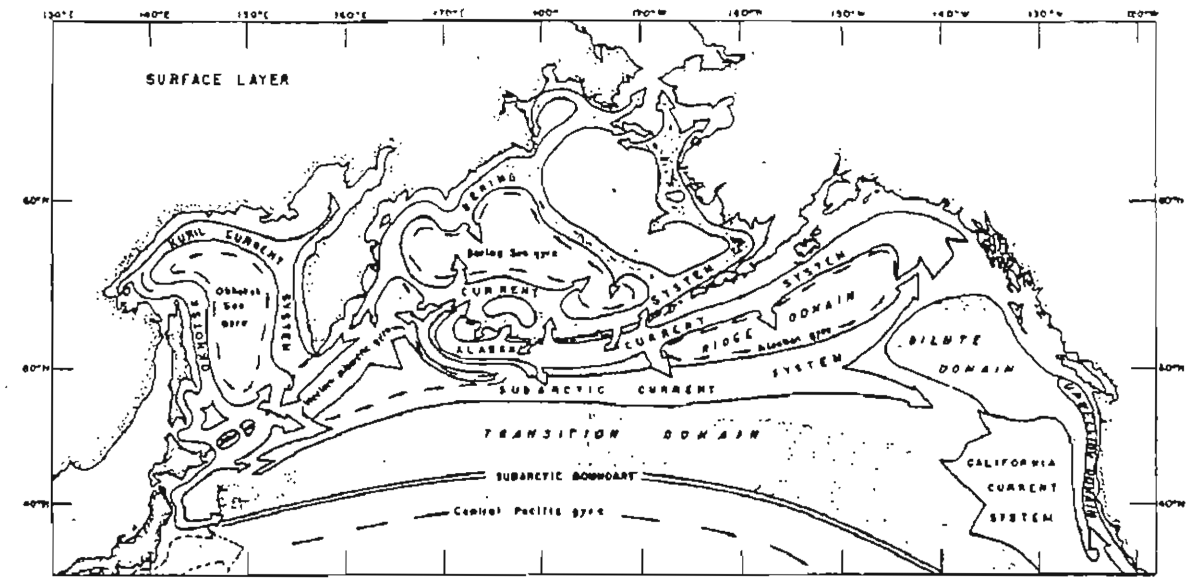

Figure 1. A schematic illustration of the oceanographic conditions in the North Pacific (Favorite *et al.*, 1976).

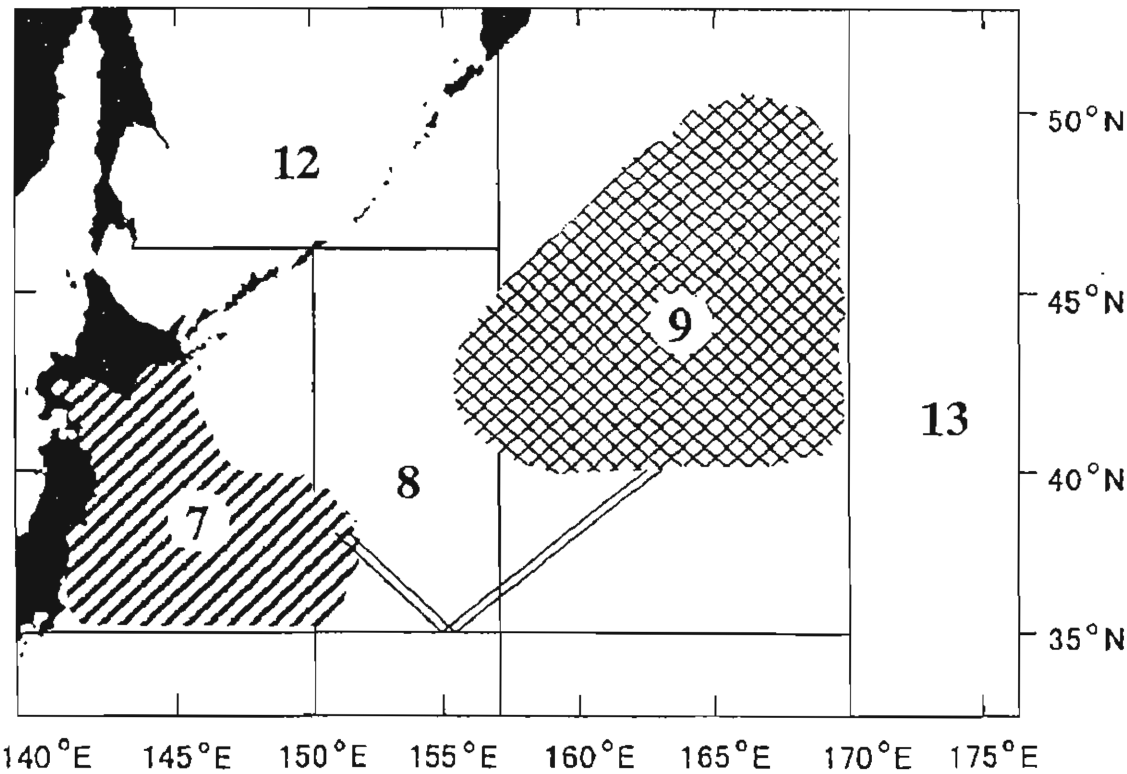

Fig. 2. The research area for feasibility study of JARPN II in 2000. [hatched] : the sampling of whales and prey study will be conducted, ═ : sampling will be conducted, [cross-hatched] : sampling of minke whale will be conducted for stock structure.

Appendix 1.

Abundance and biomass of major cetaceans occurring in the western North Pacific particularly in sub-area 7, and biological aspects of cetacean species to be sampled by JARPNII

1. Abundance and biomass of major cetaceans in the western North Pacific.

Current knowledge of abundance of cetaceans in the western North Pacific is summed up from the published or submitted documents to the IWC/SC (Table 1). From May to July, there is no available estimate. In some species, there is also no available estimates of abundance from August to September. Multiplying the abundance by the mean body weight of both matured males and females, biomass in tonnage is estimated. In the baleen whales, minke and Bryde's whales occupy large biomass ignoring no estimate in fin, sei and blue whales. However biomass of the last three species seem to be not so large because the number of sightings were not many. In the toothed whales, sperm whales has the largest biomass because of large abundance and heavy weight.

In the sub-area 7, which is considered to be the main research area for the JARPN II, the abundance of all species found in the area was estimated by season using the usual line transect method (Table 1). The data used are obtained from the dedicated sighting surveys from 1983 to 1996. The mean school size and the number of sightings per unit transect length are estimated from the data in the sub-area, but the effective search half width was estimated from the all sightings in the North Pacific because of small number of sightings in the sub-area 7 in some species. The biomass of the species preferring to inhabit the cold waters like Dall's porpoises and minke whales, became small with the progress of season. On the other hand, for the species inhabiting the warm waters like Bryde's whales, it became larger. Entirely minke whales, sperm whales, short-finned pilot whales, Baird's beaked whales, bottlenose dolphins and Pacific white-sided dolphins have large bio-mass in the sub-area

2. Biological information of three species planned to take under special permit.

2.1 North Pacific minke whale, Balaenoptera acutorostrata (Lacépède 1804)

2.1.1 Distribution and abundance

Minke whales are well known as one of most cosmopolitan cetacean species and widely distributed from the tropics to the ice edges in both hemispheres all over the world's oceans. As in other balaenopterids, they are known to seasonally shift their habitats in accordance with their life cycle moving to higher latitudes for feeding in summer and to lower latitudes for breeding in winter. Although they can be seen offshore as well, minke whales are often seen in coastal and inshore areas.

Almost every summer since the early 1980's Japan (National Research Institute of Far Seas Fisheries) has conducted systematic whale sighting surveys incorporating line transect theory in the western North Pacific and adjacent waters for obtaining population estimates (Kato, 1996; Miyashita *et al.*, 1995; Miyashita and Kato, 1999). Through these survey cruises information on the Okhotsk Sea – West Pacific minke whale Stock have been accumulated. Additional information has also been made available through the Japanese Research Program under the Special Permit in the North Western Pacific (JARPN) which has been conducted in accordance with Article VIII of the International Convention for the Regulation of Whaling (ICRW) since 1994 (Fujise *et al.*, 1995, 1996, 1997; Ishikawa *et al.*, 1997; Miyashita and Fujise, 1996, *Zenitani et al.*, 1999).

Minke whales of this stock are considered to be in lower latitudes (at least lower than 30°N) in the Northwestern Pacific in winter for breeding. According to Hatanaka and Miyashita (1997) they appear in early summer in waters off Pacific northern Japan and move northward during several months, subsequently they penetrate into the Okhotsk Sea. They also occur in waters off the west coast of Kamchatka Peninsula, Kurile islands and Hokkaido in summer, and genetic and morphological evidence suggests they spread west to 170°E (Pastene *et al.*, 1999). It is also known there is sexual and reproductive segregation as: immature individuals dominate in waters of the Pacific coast of northern Japan in early summer whereas pregnant females dominate in the Okhotsk Sea and mature males in waters off eastern Hokkaido in late-summer (Kato, 1992).

For abundance, Buckland *et al.* (1992), using sighting data from these cruises, estimated the population abundance for this stock to be 25,049 animals (95%CL., 13,700 – 36,600). This estimate was accepted by the Scientific Committee of IWC at its Comprehensive Assessment (CA) on the North Pacific minke whales. However, it is important to note that this abundance estimate is likely an underestimate because it was assumed that the probability of detection on the track line [g(0)] = 1. This leads to an underestimate of the abundance.

2.1.2 Stock structure

Comprehensive assessment by the SC on North Pacific minke whales indicated there are two genetically different stocks in western North Pacific: the Okhotsk Sea - West Pacific stock and Sea of Japan - Yellow Sea - East China Sea stock (IWC, 1992). The two stocks can be identified by difference in genetic aspects (e.g. Goto and Pastene, 1999) and in conception dates (Kato, 1992; Best and Kato, 1992). There are some discussions on plausibility of putative W-stock among the scientific committee, these are given in items I and II of the main text.

The Okhotsk Sea - West Pacific stock occurs west of 170°E in the western North Pacific based on genetic evidence (Goto and Pastene, 1999) while the western boundary of this stock is still being examined by experts. They are seen in waters north of 35°N in summer. According to Hatanaka and Miyashita (1997) the minke whales appear off the Sanriku coast as well as offshore waters there in early summer and they migrate to north during summer. Finally they enter into the Okhotsk Sea and spread there in mid-summer (Fig.1).

The Sea of Japan - Yellow Sea - East China Sea stock is believed to distribute in those waters. However, it has been reported that some of them penetrate into the southern parts of Okhotsk Sea in early Summer (Wada, 1991; Kato, 1992; Goto and Pastene, 1997) also in mid-summer (Goto and Pastene, 1997).

Further information was presented to the IWC/SC workshop for JARPN review, and it will be available in the 52nd IWC/SC annual meeting in Adelaide, Australia in June 2000.

2.1.3 Biological parameters

Minke whales (Okhotsk Sea – West Pacific stock) breed in mid-winter (January – February; Kato, 1992) and believed somewhere in lower latitudes in the western North Pacific. After 10.5 to 11 months gestation, the females give birth of a calf (litter size 1.005) at about 2.6m (Kato, 1994). Calving interval is estimated to be 1.2 years (Kato, 1992) but it is little known about suckling, but it seems to last about four months from analogy of Southern Hemisphere minke whale stocks and calves wean at about 4m in body length (Kato, 1994). Males attain sexual maturity at 6.3 m and females at 7.1 m (Kato, 1992). Age at sexual maturity is not available due to lower earplug age readabilities, but it seems to be about 6 to 8 years from analogy of southern Hemisphere stocks in which enough age data are available. Asymptotic lengths are 7.5m and 8.0m for males and females respectively (Kato, 1992). Although there is no estimate by empirical data on natural mortality rate (M) for this stock, Kato (1992) estimated 0.11 by incorporating Ohsumi' formula on M to maximum life span or maximum body length (Ohsumi, 1979).

For assessment purpose, the SC agreed to use following biological parameters at the CA of North Pacific Minke whales:

Item	value
Age at first parturition	8 years (50%), 13 years (95%)
Age at recruitment	3 years (50%), 6 years (95%)
Natural mortality rate (M)	0.09

2.2. Western North Pacific Bryde's whales, *Balaenoptera edeni* (Anderson, 1878)

2.2.1 Distribution and abundance

Although there is a general pattern of migration towards to the equator in winter and to the higher latitudes in summer, Bryde's whales are seen in tropical and warm temperate waters throughout the year, in which the surface temperature is above 16.4° (Ohsumi, 1977a).

The western North Pacific stock for which we now propose to survey, distributes in temperate and tropical zone in western region of the North Pacific as being through waters off the Pacific coasts of Japan, Taiwan and Philippine to 150°W, northern limits approximately corresponds to southern margin of the sub-arctic boundary at about 40°N and the southern limits extends about 2°S in the Southern Hemisphere (IWC, 1996; Shimada and Miyashita, 1996). Kishiro found northward migration of this stock in summer by discovery tagging data (Kishiro, 1996).

Shimada and Miyashita (1995) presented population estimate of the western North Pacific Bryde's whales based on the sighting surveys made in August and September from 1988 to 1994. During a total of 60,000 n. miles of searching effort 348 schools (512 animals) of primary sightings were seen, and they estimated abundance to be 23,751 animals (CV=0.20) using the program DISTANCE developed by Laake *et al.*, (1994). They assumed the probability of detection on the track line g(0)=1, which probably results in a negative bias and no searching effort in some parts of the stock distribution also led to negative bias (IWC, 1996a).

In the 1996 IWC/SC annual meeting Shimada and Miyashita (1996) further presented new analyses incorporating new data from more area between 0° and 22°30' covered by the 1995 survey, and the resultant estimates of abundance was 25,640 (CV=0.20). However this estimate also present negatively bias because they still adopted g(0)= 1 and no searching effort was made in some parts off Philippine (IWC, 1996b).

For other stocks of Bryde's whales in the North Pacific, most recent estimates are as follows: Shimada and Miyashita (1995) estimated abundance in the East China Sea (the East China Sea stock) as 105 individuals (CV=2.79) and Kishiro *et al.*, (1996) estimated abundance in coastal waters of Kochi, southwest Japan, to be 58 individuals (CV=0.58). Both of studies were based on the sighting survey based on line transect methodology. Regarding the Eastern Tropical stock, Wade and Gerrodette (1993) estimated the abundance to be 13,000 individuals (CV=0.202) using line-transect methodology.

2.2.2 Stock structure

For management purpose, Bryde's whales in the western parts of the North Pacific have been divided into three stocks (IWC, 1996): the western North Pacific stock inhabiting offshore waters; the East China Sea stock including coastal waters off Kochi; and the Solomon Island /Southeast Asia consisting Philippine waters and Gulf of Thailand.

As examined by genetic study, the East China Sea stock extends Pacific side of Southern Japan such as waters off Kochi but they do not extend distribution beyond the Kuroshio current and it is limited to the west side of the Current (Kato *et al.*, 1996, Yoshida *et al.*, 1997; Yoshida and Kato, 1999) as in Fig. 2.

As to the western North Pacific stock, Pastene *et al.* (1998) found no statistically significant evidence of deviations from genetic uniformity over geographical localities within this stock using mtDNA sequencing analysis.

2.2.3 Biological parameters of the western North Pacific Bryde's whales

Based on foetus length distribution, both calving and mating are seasonally diffuse, but peak is still in winter (Omura, 1962; Ohsumi, 1977; Kato and Yoshioka, 1995). It is little known about localities of breeding ground but it must be somewhere in lower latitudes.

After about 11 months of gestation, the females give birth of a calf at about 4.0m (Ohsumi, 1995), and mean calving interval is about two years from analogy of (unbiased) apparent pregnancy rate of 0.6 by Kato and Yoshioka (1995). It is little known about suckling, but it seems to last about half year as in other Balaenopterids, and calves wean at about 7m in body length (Ohsumi, 1995).

Kato and Yoshioka (1995) estimated biological parameters for the Western North Pacific stock taking account of bias due to operation and difference in regulation of whaling, they estimated males attained sexual maturity at 11 – 11.4 m and females at 11.6 – 11.8m and physical maturity at 13.0m and 13.5m for males and females respectively, and as to age at sexual maturity, Ohsumi (1977) estimated to be about 7 – 10 years for both sexes.

Although there is no estimate by empirical data on natural mortality rate (M) for this stock, IWC (1988) once used M= 0.07 ~ 0.08 for assessment purpose. Maximum life span may be at around 60 years. For assessment purpose, the SC agreed to use the following biological parameters at the CA of North Pacific Bryde's whales (IWC, 1997):

Item	value
Age at first parturition	8 years (50%)
Age at recruitment	5years for coastal operation, 8 years for pelagic operation
Natural mortality rate (M)	0.07

2.3 Western North Pacific Sperm whales, *Physeter macrocephalus* Linnaeus, 1758.

2.3.1 Distribution and abundance

Sperm whales range throughout all deep oceans of the world from the equator to the edge of the polar pack ice. It is well known that only mature males range into the higher latitude. In the western North Pacific, they range north into the deeper portions of the South China Sea, the East China Sea, the Sea of Japan (Rice, 1989). Females regularly range north only about as the Transitional Domain, which lies just north of the Subarctic Boundary. There is a general northward shift in summer and southward in winter. The distribution limits during the winter, and the limits of females and younger males during the summer, correspond approximately with the 15°C sea surface isotherm.

In western parts of North Pacific, sperm whales frequently occur in waters off Sanriku to Kurile coasts, where known continental slope or edge of trench occur and in pelagic zone of middle latitudes around 30°N (Kato, 1995; Fig. 3).

Kato and Miyashita (1998) estimated population abundance of sperm whales to be 102,112 (CV= 0.155) in west of 180° under assumption of g(0) = .32 (CV= .11) and they also noted an encounter rate increasing at 11% per annum from 1987 to 1996.

2.3.2 Stock structure

The current management of the sperm whale population by the IWC is based on the assumption of two stocks in the entire North Pacific, i.e. the western stock and the eastern stock divided by at 180° in north of 50°N, at 160°W in 40° – 50°N and at 150°W in south of 40°N, which has been adopted since the 1977 season (IWC, 1979). Recently and based on the several information like whaling operation data, movement of marked whales and whale sighting, two latitudinal segregating sperm whale stocks is assumed in the western North Pacific (Kasuya and Miyashita, 1988).

2.3.3 Biological parameters

Sperm whales are well known as socialized cetaceans such as having polygenous mating system, segregation of schools by sex and growth stage. Best (1968) summarized social structure of sperm whales as follows: main unit of sperm whale population is mixed school consisting of 16 mature females, 5 juveniles and 3 calves; juveniles leave the mixed school and males subsequently organize small-bachelor school consisting of 15 animals with other juvenile males from other mixed school or join to the existing small-bachelor school while much uncertain in juvenile females; small bachelors subsequently organize or join to middle-bachelor school (usually 5 – 6 males) and they finally become an independent solitary bull. It is believed that a bull join to the mixed school to mate with females in estrous after intro-sexual fighting with other independent bulls, but length of stay is very short time, probably few days.

Sperm whales are generally believed principally breed in winter in lower latitudes. Pregnant females give birth of a single calf at about 4m after 15 – 16 gestation period with five year calving interval in average (Ohsumi, 1965; Best, 1968). Suckling is believed to last about two years, but its length is tend to be longer in older mother (Best, 1968). Females attain sexual maturity at 8 to 10 years and at 8.6 m (Ohsumi, 1968; Best, 1968). On the other hand, for males, sexual maturity can be interpreted as social independence (so called social maturity) from specialized nature of breeding strategy of this species, and it is considered to attain such sexual maturity at about 13.7 - 14.0m or 25 years (IWC, 1983; Best, 1968; Kato, 1995).

Sperm whales have distinctive sexual dimorphism in size as males reach 16 m (40years) at full growth stage while females at 11m in average (Best, 1970; Ohsumi, 1977). Kasuya (1991) reported both of body length at sexual maturity and maximum body length increased with decreasing population level in late 1960s-early 1970s to late 1970s in the North Pacific. Maximum life span is about 75 years for both sexes (Ohsumi, 1979) and natural mortality rate is consider to be 0.102 (IWC, 1983).

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Table 1. Abundance and biomass of cetacean in the western North Pacific.
For the western North Pacific, the data of the published or submitted documents to
The figure in area 7 is estimated from the sighting data from 1983 to 1996.
+ means the downward estimate because of the presence of unsurveyed area.

	Western North Pacific			Area 7	
	Abundance	Ref.	Biomass(t)	Abundance	Biomass(t)
May-July					
Minke whale	-		-	6,396	37,418
Bryde's whale	-		-	80	1,084
Sei whale	-		-	0	0
Fin whale	-		-	7	279
Blue whale	-		-	0	0
Northern right whale	-		-	0	0
Humpback whale	-		-	0	0
Sperm whale	-		-	688	21,770
Bottlenose dolphin	-		-	4,344	1,392
Pantropical spotted dolphin	-		-	17,562	2,090
Striped dolphin	-		-	46,168	6,787
Common dolphins	-		-	30,551	2,154
Pacific white-sided dolphin	-		-	233,376	21,004
Northern right whale dolphin	-		-	0	0
Risso's dolphin	-		-	40,898	12,699
Killer whale	-		-	1,344	6,300
Dall's porpoise	-		-	167,989	17,639
Short-finned pilot whale	-		-	9,879	15,313
Baird's beaked whale	-		-	3,405	33,855
Other beaked whales	-		-	26,525	27,878
August-September					
Minke whale	25,000+	1	146,250+	2,470	14,450
Bryde's whale	22,000	2	298,100	144	1,949
Sei whale	-		-	11	193
Fin whale	-		-	0	0
Blue whale	-		-	0	0
Northern right whale	900	3	51,750	0	0
Humpback whale	1000	4	70,000	0	0
Sperm whale	102,000	5	3,228,300	442	13,976
Bottlenose dolphin	168,000	6	53,844	77,043	24,692
Pantropical spotted dolphin	438,000	6	52,122	899	107
Striped dolphin	570,000	6	83,790	580	85
Common dolphins	-		-	42,855	3,021
Pacific white-sided dolphin	366,000	7	33,120	192,818	17,354
Northern right whale dolphin	100,000	7	11,300	0	0
Risso's dolphin	83,000	6	25,772	18,806	5,839
Killer whale	-		-	662	3,103
Dall's porpoise	554000+	8	58170+	69,546	7,302
Short-finned pilot whale	89,000	9	137,950	24,403	37,825
Baird's beaked whale	5,000	10	49,715	2,677	26,622
Other beaked whales	-		-	13,455	14,142

1: Buckland et al.(1992), 2:Shimada and Miyashita (1996), 3:Miyashita and Kato (2000),
4: Darling (1991), 5: Kato and Miyashita (1998), 6: Miyashita (1993a), 7: Miyashita (199
8: Miyashita (1991), 9: Miyashita (1988), 10: Miyashita and Kato (1995)

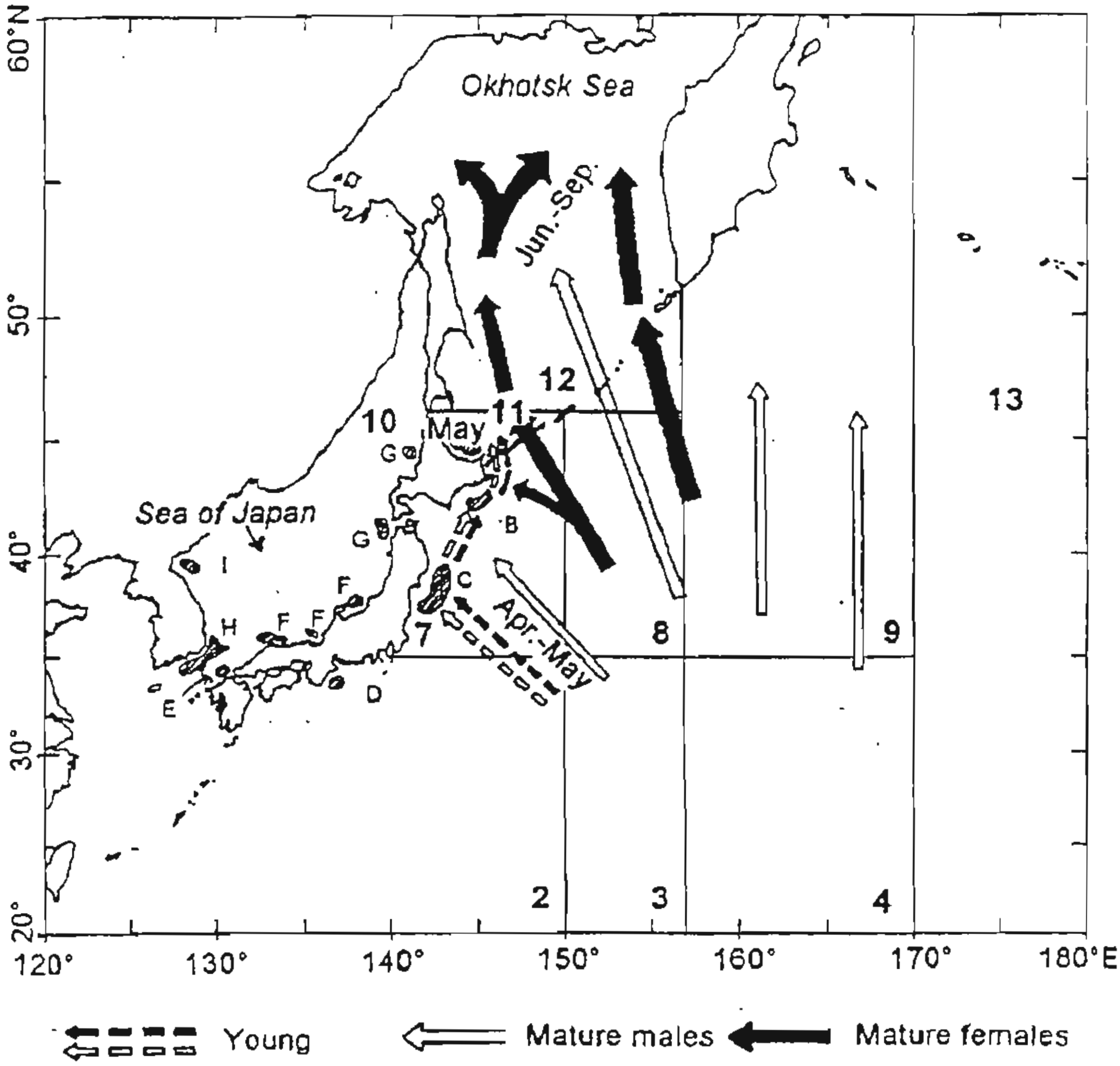

Fig.1. Possible migration routes of Okhotsk-West Pacific stock of minke whales in western North Pacific. After Hatanaka and Miyashita (1997).

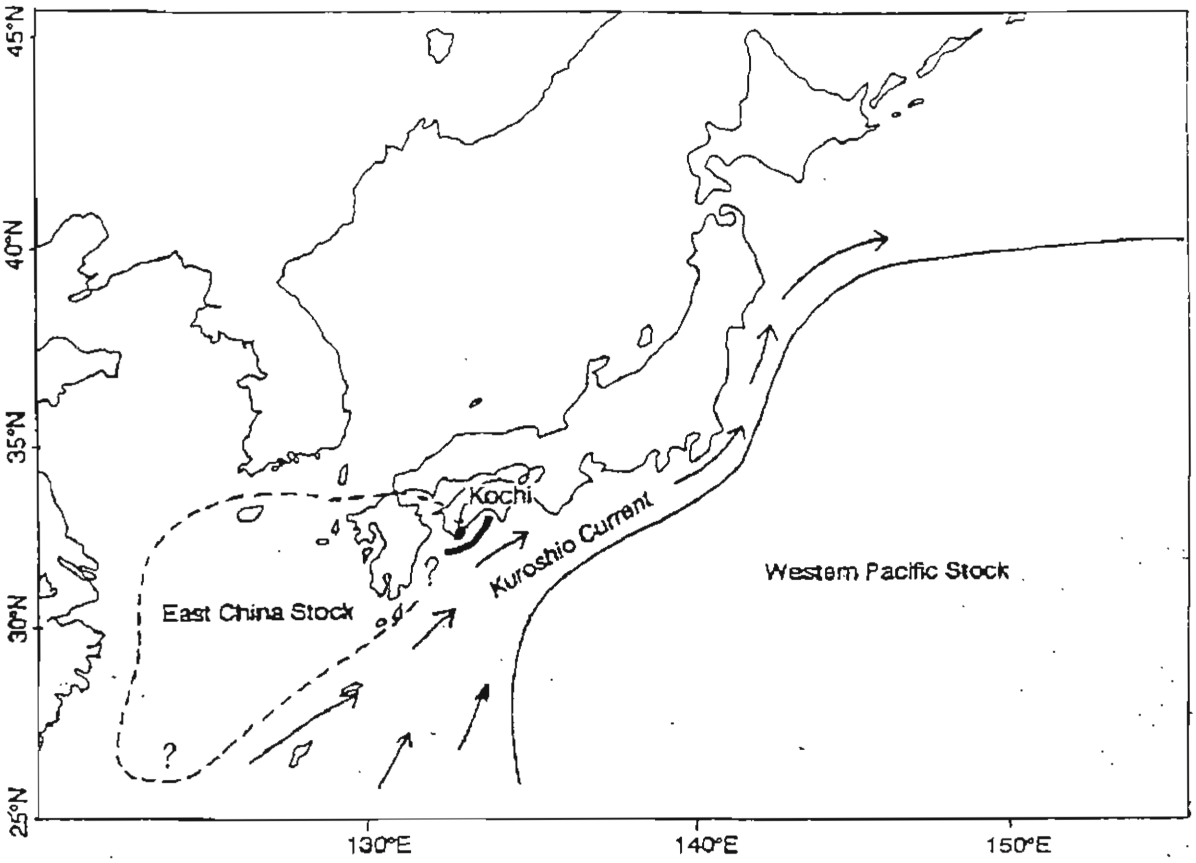

Fig. 2. Schematic illustration of stock separation of Bryde's whales around Japan between western North Pacific stock and East China Sea stock. After IWC (1996).

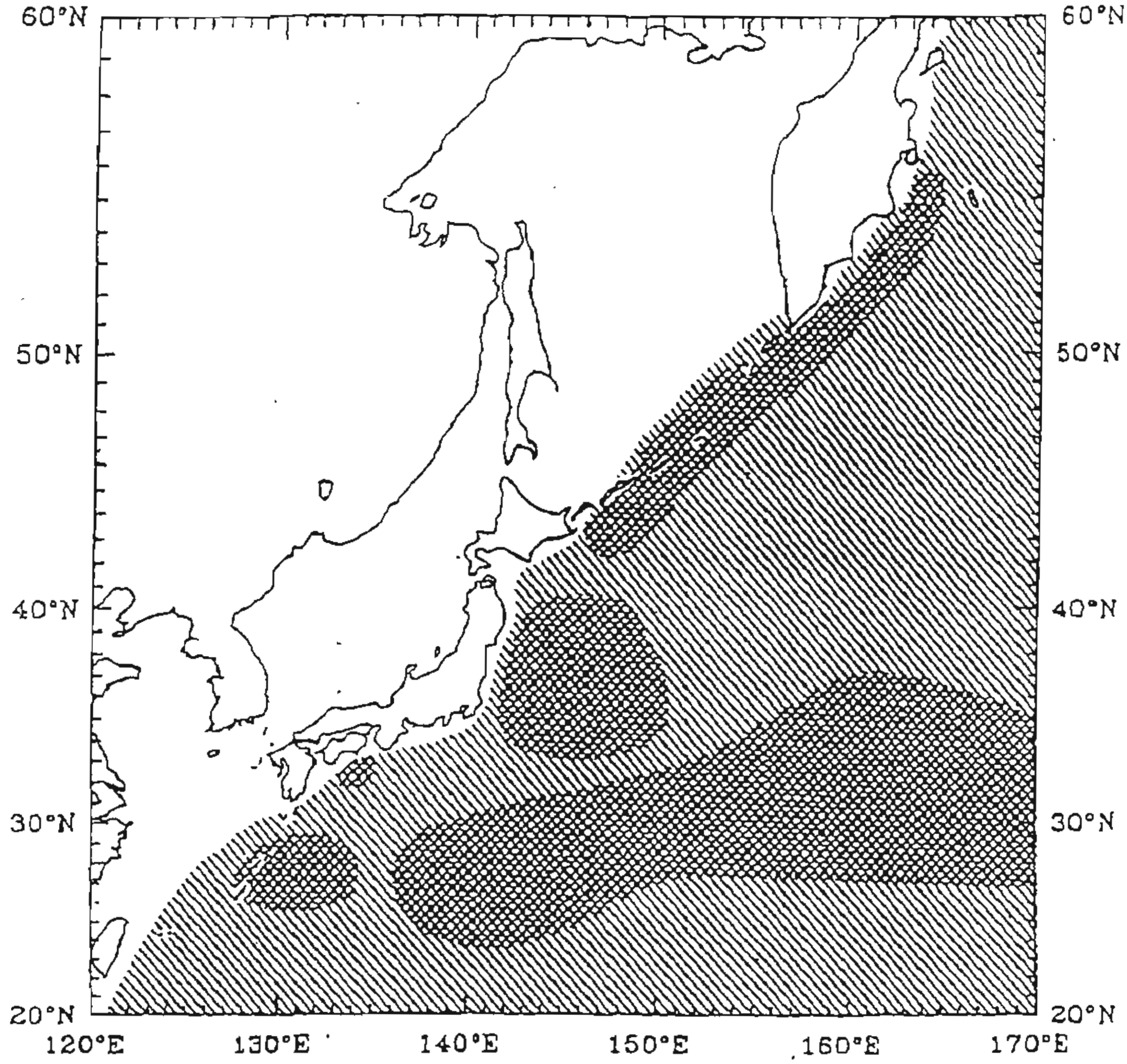

Fig.3. Distribution of sperm whales in western North Pacific, double hatched represents high-density area. After Kato (1995).

Appendix 2.

Prey species of six cetacean species distributed in the western North Pacific

INTRODUCTION

Three kinds of cetacean fisheries were or are carried out in the western North Pacific by Japan. They are the large-type whaling, small-type whaling and dolphin fishery. They are all coastal fisheries, and the Japanese pelagic whaling was prohibited by Japanese law to operate in the waters to protect coastal whaling (Ohsumi, 1972).

The whale species targeted by the large-type whaling were the sperm whale and some baleen whales species, except the minke whale. The small-type whaling aims to take minke whale, which is now prohibited to take by the IWC, and large or middle sized toothed whales, except the sperm whale. The method of dolphin fishery is by the hand harpoon, and the target cetacean species in Dall's porpoise.

In the case of the large-type and almost small-type whaling, abdominal cavity of a whale caught was breached to keep the freshness of the carcass during the pulling it by a catcher boat to a land station from 1960's. It was difficult to examine the stomach contents, because the whalers usually cut the stomach in breaking the abdominal cavity.

The whaling grounds of large-type whaling was limited within about 150-200 n. miles from land stations that were distributed along the coasts of Sanriku-Hokkaido to keep the freshness of the whales caught till the reach to a station by catcher boat. The whaling ground of the small-type whaling is limited within about 60 n. miles from the coast, because the size of the catcher boat is small to operate in the open sea. The dolphin fishery has the same situation as the small-type whaling. Furthermore, the whaling ground of Japanese pelagic whaling was established east of 157°E by law. Therefore, there has been large blank area of knowledge on the prey species of whales in the planned research area except on the minke whale on which feeding study has been conducted by the JARPN.

This paper introduces briefly on the past feeding ecology studies of six cetaceans, which will be objects of the planned research.

Minke whale Balaenoptera acutorostrata

Omura and Sakiura (1956) surveyed the prey species of minke whales, which were caught by the small-type whaling in 1953 and 1954. Japanese anchovy (*Engraulis japonicus*), Japanese pilchard (*Sardinops melanostictus*), Chub mackerel (*Scomber japonicus*), walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), Pacific herring (*Clupea pallasi*), krill, copepods and squids were found from the stomachs. Kasamatsu and Tanaka (1992) reported that there were geographical, seasonal and yearly changes in prey species of minke whales in the western North Pacific, and these cbanges in the prey species of minke whales probably reflect the changes in the availability of prey species in these areas. For example in Pacific coast of Hokkaido, the change of prey species 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.

Tamura and Fujise (2000a, b, c) reported the results of the feeding ecology studies of minke whales sampled in the western North Pacific from May to September through 1994 - 1999 JARPN surveys. Results showed geographical, seasonal and yearly changes of prey species of minke whales in the western North Pacific. In the Pacific side, Japanese anchovy was the most important prey species in May and June, while Pacific saury (*Cololabis saira*) was the most important one in July and August. Krill was the most important prey species in September. Walleye pollock was also a important prey species during June and September in coastal waters, over the continental shelf. In the southern Okhotsk Sea, krill was the most important prey species in July and August.

These changes in the prey species of minke whales probably reflect to changes in the availability of prey species in these areas. The western North Pacific minke whale was confirmed as of the swallowing type. They feed on swarming zooplankton and schooling fish. There was little diurnal change of feeding activity of western North Pacific minke whale. Estimates of the daily prey consumption rate obtained by the method-1 and 2 were 1.8 – 5.7 % of body weight. These values were similar to the estimates of eastern North Atlantic minke whales and the Antarctic minke whale. Total consumption of krill, Japanese anchovy, Pacific saury and walleye pollock by minke whales in Pacific side of Japan during August and September were $2.1 - 4.0\times10^4$ tons, $0.4 - 0.6\times10^4$ tons, $2.8 - 6.2\times10^4$ tons and $0.3 - 0.4\times10^4$ tons, respectively. Total consumption of krill by minke whales in southern Okhotsk Sea during August and September were $1.4 - 2.2\times10^4$ tons by two methods.

Bryde's whale Balaenoptera edeni

This species was classified as sei whale in the 1950s in Japan, then the prey species were described for both whale species pooled (Nemoto, 1959). In addition, feeding studies of Bryde's whales, which were caught by Japanese coastal whaling, became difficult from the 1960s because of cutting belly of whale carcass in Japanese coastal whaling. Therefore, the present knowledge on the prey species and feeding of the Bryde's whales is not enough in the research area. Nemoto (1959) reported a review of prey species of baleen whales in the world. In the Sanriku Coast of Japan, Bryde's whales fed on krill, Japanese anchovy and Chub mackerel. In the Pacific coast of Japan, they fed on krill and

Japanese anchovy. In the waters around Bonin Islands, They fed on krill and lantern fish. In West Kyushu, they fed mainly on Japanese pilchard, 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 feed on euphausiids (89 %) and fishes (11 %). The feeding type of Bryde's whale was considered the euphausiids feeder and fish feeder. However, there is no quantitative studies on food consumption of the Bryde's whales in the North Pacific.

Sperm whale Physeter macrocephalus

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.

According to Kawakami (1980), 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 %. Kawakami (1980) lists these fish species.

Squids were most dominant in the stomach contents of sperm whales, and Kawakami (1980) listed the species. The most important prey species in Sanriku-Hokkaido area are *Histioteuthis dolfleini*, *Octopoteuthis* sp., *Moroteuthis robusta* and *Ommastrephes bartrami*.

Baird's beaked whale *Berardius bairdii*

Dietary studies of Baird's beaked whale are limited to the Pacific and Okhotsk coastal waters off Japan. Nishiwaki and Oguro (1971) examined 701 stomachs of the Baird's beaked whale, and reported that bottom fishes is the main prey item around the Boso peninsula in central Japan, and bathyal squids are the main prey from Tohoku to Hokkaido area in northern Japan. Walker and Mead (1988) observed benthic cods, Macrouridae and Moridae, as well as some cephalopods in the stomach contents taken around Boso peninsula.

Short-finned pilot whale Globicephala macrorhynchus

The knowledge about feeding habits of Short-finned pilot whale northern form is very limited. Only one study is available, in which 19 pilot whales from the Tohoku area were examined. This species mainly fed on ommastrephid squids in 1982, but octopus was an important prey in 1983 (Kubodera and Miyazaki, 1993).

Dall's porpoise Phocoenoides dalli

Stomach contents of Dall's porpoises were studied from 475 stomachs collected in almost all the distribution area including Sea of Japan, Sea of Okhotsk, Bering Sea, and northern North Pacific (Ohizumi *et al.*, 1999; Ohizumi *et al.*, in press). Generally, they feed on smaller fishes and pelagic squids. Dall's porpoises in the pelagic area of Northern North Pacific feed mainly on myctophid fishes. In the Bering Sea, they feed on gonatid squids as well as myctophid fishes. The local prey faunas strongly characterize stomach contents and the prey selectivity is not obvious. Most of the prey items are mesopelagic micronekton, but limited to the fishes and squids that perform diurnal vertical migration to inhabit shallower waters at night (Ohizumi *et al.* 1999). In contrast to the prey items in the North Pacific and Bering Sea, epipelagic fishes such as Japanese pilchard and Japanese anchovy are a part of important prey in the Sea of Japan and Sea of Okhotsk, but the importance of such epipelagic fishes depends on its abundance. Recent population decline of Japanese pilchard caused distinct prey shift in Dall's porpoises to benthic prey such as walleye pollock and *Berryteuthis magister* (Ohizumi *et al.* in press). Estimates of the daily prey consumption rate was 5.0 % of body weight (Ohizumi, 1998).

COMPETITION OVER PREY SPECIES AMONG SIX WHALES

Fig. 1 shows a schematic illustration on food web involving six cetaceans in the western North Pacific. Baleen whales, especially Balaenopterid whales, use common prey species, and they compete with each other. For example, Bryde's whale competes with minke whale through prey species such as krill, Japanese anchovy and Chub mackerel. Sei whale and fin whale compete with minke whales through prey species such as Pacific saury, Chub mackerel, Japanese pilchard and krill.

There are also competitions between cetaceans and fishes. For example, Bryde's whales compete with skipjack tunas for Japanese anchovy. They move together to chase Japanese anchovy. Furthermore, most cetaceans compete with mankind, because they feed on fishes taken by commercial fisheries.

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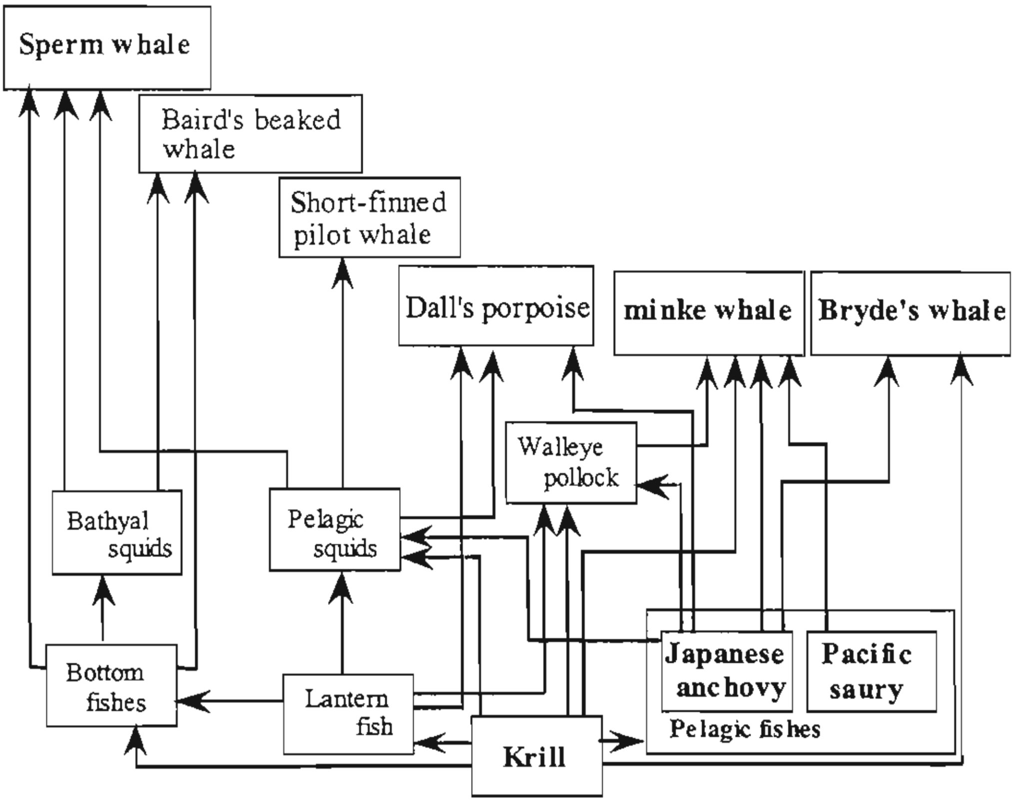

Fig. 1. Schematic illustration on food web around major cetaceans in the western North Pacific.

Appendix 3.

Prey species of cetaceans and fisheries.

The western North Pacific is Japan's richest fishing ground, where the interaction between cetaceans and fisheries is likely to be important and needs to be better quantified. In this area, the pelagic fish resources have shown drastic fluctuations in a process so-called species replacement. The most abundant species has changed in the order of Japanese pilchard, saury, chub mackerel, Japanese pilchard again and Japanese anchovy recently for the past 100 years (Wada and Matsuda, 1993). Especially, the catch of Japanese pilchard was more than 4 million tons in the late 1980s but decreased to 0.3 million tons in recent years. The decrease of Japanese pilchard could have some effect on cetacean populations.

The biology, stock structure and fisheries of nine main prey species of cetaceans are summarized in Table 1. Some of these main prey species are short-lived. Also the average age of commercial catches has decreased in some prey species, mainly due to the increased fishing efforts. This means that availability of prey species to minke whales will be unstable. The fishing grounds and seasonal distribution of the main prey species are shown in Fig. 1. The distributions of these prey species are overlapped with the target cetacean species especially in spring and summer.

The above-mentioned information was collected from the various published and unpublished sources with the help of the people for the stock assessment of fisheries resources within Japan's EEZ.

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Table 1. The summary of the biology, stock structure and fisheries of the main nine prey species of cetaceans in the western North Pacific.

Species	Japanese anchovy	Pacific saury	Krill
Scientific Name	*Engraulis japonicus*	*Cololabis saira*	*Euphausia pacifica*
Stock	Honsyu Pacific stock	Western North Pacific stock (westward from 165° E)	North Pacific stock
Distribution/ Migration (see Figures)	Adults distributed even eastwards to 160° E at high level of abundance, and only in coastal area at low level of abundance. Move northwards in summer.	Distributed in sub-tropical and temperate zones in the Pacific (20~55° N). Sea of Japan and southern Sea of Okhotsk. Move northwards in summerand southwards in in late-autumn	Widely distributed in sub-arctic waters in North Pacific, occuring from Bering Sea to mid-Honsyu. High density is found off Sanriku and other 3 areas in the North Pacific.
Age/Growth	Life span is 3 years. Maximum length is 15cm. 11cm at one and 14cm at two years old.	Life span is 1.5 years, maxim length is 40cm. 24-29cm at 0.5 year old and 30cm at one.	Life span is estimated to be 2 years. Maximum length is 20mm. Aging materials is not decided.
Maturation/ Spawning	Mature at one year old. Spawn from February to November, and in mid- and northern Honsyu at high level of abundance.	Mature at 20cm. Spawn in autumn/spring in northern Honsyu, in winter in mid-Honsyu/Kuroshio area.	Main spawning season is April-June off Sanriku and October off east Hokkaido. Fecundity is 100 egg/female.
Natural mortarity	Change with life stages and 1.0 for adults.	Natural mortarity is around 1.85 based on the life span.	Not known.
Feeding	Zoo- and phyto-plankton feeder. Young fish feed on zoo-plankton such as copepod and adults on phyto-plankton.	Zoo-plankton feeder. Also feed on krill and anchovy.	Phyto-plankton feeder.
Stock biomass	100-200 thousand tons in 1978-87 and 500-850 thousand tons after 1991.	1,100-4,600 thousand tons in 1992-95.	2,000 thousand tons off Sanriku.
Fisheries/ Catches	Fished by purse seins in coastal areas. Recruited partially at 0 years old. Catches in recent years are 100-200 thousand ton.	Fished by dip nets in coastal/offshore areas (occasionally far offshore to 150° E). Catches in recent years are 140-300 thousand ton.	Fishing grounds formed in relation to southward shift of Oyashio Current. Fished by small trawls, and by scoop nets targeting to floating swarms. Catches in recent years are 40-110 thousand ton.
Consumption by cetaceans	4-6 thousand tons by minke whales during August and September (Tamura and Fujise, 2000).	28-62 thousand tons by minke whales during August and September (Tamura and Fujise, 2000).	21-40 thousand tons by minke whales during August and September (Tamura and Fujise, 2000).
Importance in ecosystem model	Important prey for minke whales, Bryde's whales and requisite to ecosystem model.	Important prey for minke whales, Bryde's whales and requisite to ecosystem model.	Important prey for minke whales, Bryde's whales/fishes and requisite to ecosystem model.

Table 1. Continued.

Species	Japanese pilchard	Chub mackerel	walleye pollock
Scientific Name	*Sardinops melanostictus*	*Scomber japonicus*	*Theragra chalcogramma*
Stock	Pacific stock	Pacific stock	Pacific stock
Distribution/ Migration (see Figures)	Distributed range varys in accordance with the level of abundance. Spawn off mid-Honsyu and move northwards to Sanriku/eastern Hokkaido for feeding in summer/autumn.	Spawn near Izu Is. in winter/spring, move northwards to northern Honsyu for feeding in summer/autumn and move southwards to mid-Honsyu for wintering.	Spawn in coastal areas centering Hunka Bay, Hokkaido. Distributed from northern Honsyu to southern Kurile Is. Young fish distributed southwards in coastal Sanriku.
Age/Growth	Life span is more than 7 years. Maximum length is 24cm. Few more than 5 years old and grow faster at low level of abundance.	Life span is more than 7 years. Maximum length is 43cm. Few more than 4 years old and grow faster at low level of abundance.	Life span is more than 8 years. Maximum length is 60cm. Few more than 5 years old at low level of abundance.
Maturation/ Spawning	Mature at 1-2(3-4) years old at low(high) level of abundance. Main spawning season is March-May in recent years.	Mature at 2(3) years old at low(high) level of abundance. Main spawning season is April-July in recent years.	Mature for the first time at 3 and fully at 5 years old.
Natural mortarity	Estimated from the life span, natural mortarity is 0.4.	Natural mortarity is 0.4 based on the life span.,	Natural mortarity is 0.25.
Feeding	Zoo- and phyto-plankton feeder. Young fish feed on zoo-plankton such as copepod and adults on phyto-plankton.	Feed on zoo-plankton such as copepod, krill and small fish (bristlemouth, Japanese anchovy et al.).	Feed mainly on krill. Also feed on zoo-plankton such as copepod, small shrimp, squid and small fish.
Stock biomass	Decreased from 37,000 thousand tons in 1988 to 300 thousand tons in recent years.	Decreased from 6,400 thousand tons in 1977 to 500 thousand tons in recent years.	Increased to 800-900 thousand tons during the years since 1989.
Fisheries/ Catches	Fished by purse seins in coastal areas. Recruited partially at 0 years old. Catches decreased from 4,000 thousand tons in mid-1980's to 100-150 thousand tons in recent years.	Fished by purse seins off Sankiku and scoop nets in Izu Is. areas. Catches decreased from 1,300 thousand tons in 1978 to 90-150 thousand tons in recent years.	Fished by off-shore bottom trawls, gill nets and set nets in September-March. Catches in recent years are 120-150 thousand ton.
Consumption by whales	Lower consumption due to the low level of abundance in recent years.	Lower consumption due to the low level of abundance in recent years.	Prey of cetaceans in coastal areas
Importance in ecosystem model	Less important at present. Requisite to ecosystem model in analyzing data in the past.	Less important at present. Requisite to ecosystem model in analyzing data in the past.	Consumer of a pariety of animals, prey of whales and target of fisheries. Potentially important to coastal part of ecosystem model.

Table 1. Continued.

Species	Common squid	Flying squid	Lantern fishes
Scientific Name	*Todarodes pacificus*	*Ommastrephes bartramii*	(Myctophidae)
Stock	Pacific stock	Western Pacific stock (mainly winter-spring spawner)	(Subarctic-transitional and subtropical-tropical species)
Distribution/ Migration (see Figures)	Spawn mainly south west of Kyusyu. With growth, migrate northwards to Sanriku, eastern Hokkaido and centeral Kurile Is. Begin southwards migration in mid-summer.	Spawn at 20°-30°S in North Pacific. Migrate northwards with growth. Females attain northern limit in October, then move southwards. Males occur more southern area than females.	Widely distributed in North Pacific. Little information on seasonal migration. Almost all species undertake diel vertical migration; at depths between 300-700m during daytime and up to depths betwee 0-200m at night.
Age/Growth	Life span is one yea. Maximum mantle length is 30cm. 15cm at 6 months old.	Life span is one yea. Maximum mantle length is 40 cm. 30cm at 6 months old, and 50cm for females and 43cm for males at 10 months old.	Life span is 3-7 years for subarctic-transitional species, and 1-3 years for subtropical-tropical species. Maximum length is 3-20cm by species.
Maturation/ Spawning	Males (females) mature at 8-9 (10) months old and die after spawning.	Both males and females mature 9 months old and females die after spawning.	Not known
Natural mortarity	Natural mortarity is 0.114-0.422 per 10 days in the Sea of Japan	Natural mortarity is less than 0.07 (Murata and Shimadu, 1982)	Not known
Feeding	Feed on fishes (lantern fish, anchovy, mackerel, Alaska pollack et al.) and krill. Also cannibalistic.	Larvae feed on crustaceans. Young squids and adults eat fishes (lantern fish, Japanese pilchard, saury et al.) and squid.	Crustacean zoo-plankton feeder. Also feed on fish larva and small-sized squid.
Stock biomass	Probably between 1,300-2,300 thousand ton. Difficult to estimate as annual species with several seasonal coholts.	Several estimates avairable but some of them are lower than catches of the years.	At least 10,000 thousand tons order in the North Pacific.
Fisheries/ Catches	Fished by jiging. Also trawls in Sanriku area and set nets. Catches peaked to 400-500 thousand tons in late 1960's and are 80-230 thousand tons in recent years.	Fished by drift nets in 1978-92 and jigging before/after the period. Fishing grounds are in northward intrusions of warm waters. Catches in recent years are 50-70 thousand ton. More taken by China/Korea.	No direct fisheries.
Consumption by whales.	Prey of cetaceans	Prey of toothed whales such as sperm whales and pinnipeds.	Dominant prey of smaller odontcetes such as Dall's porpoise
Importance in ecosystem model	Consumer of krill/fish, prey of fish/cetaceans and target of fisheries. Important to ecosystem model.	In the ocean dominant nekton and key species conecting micro-nekton and top predators. Potentially important to oceanic part of ecosystem model.	One of the most dominant micro-nekton and key species in the oceanic ecosystem, conecting zoo-plankton and predators such as tunas, cod, squid, and marine mammals.

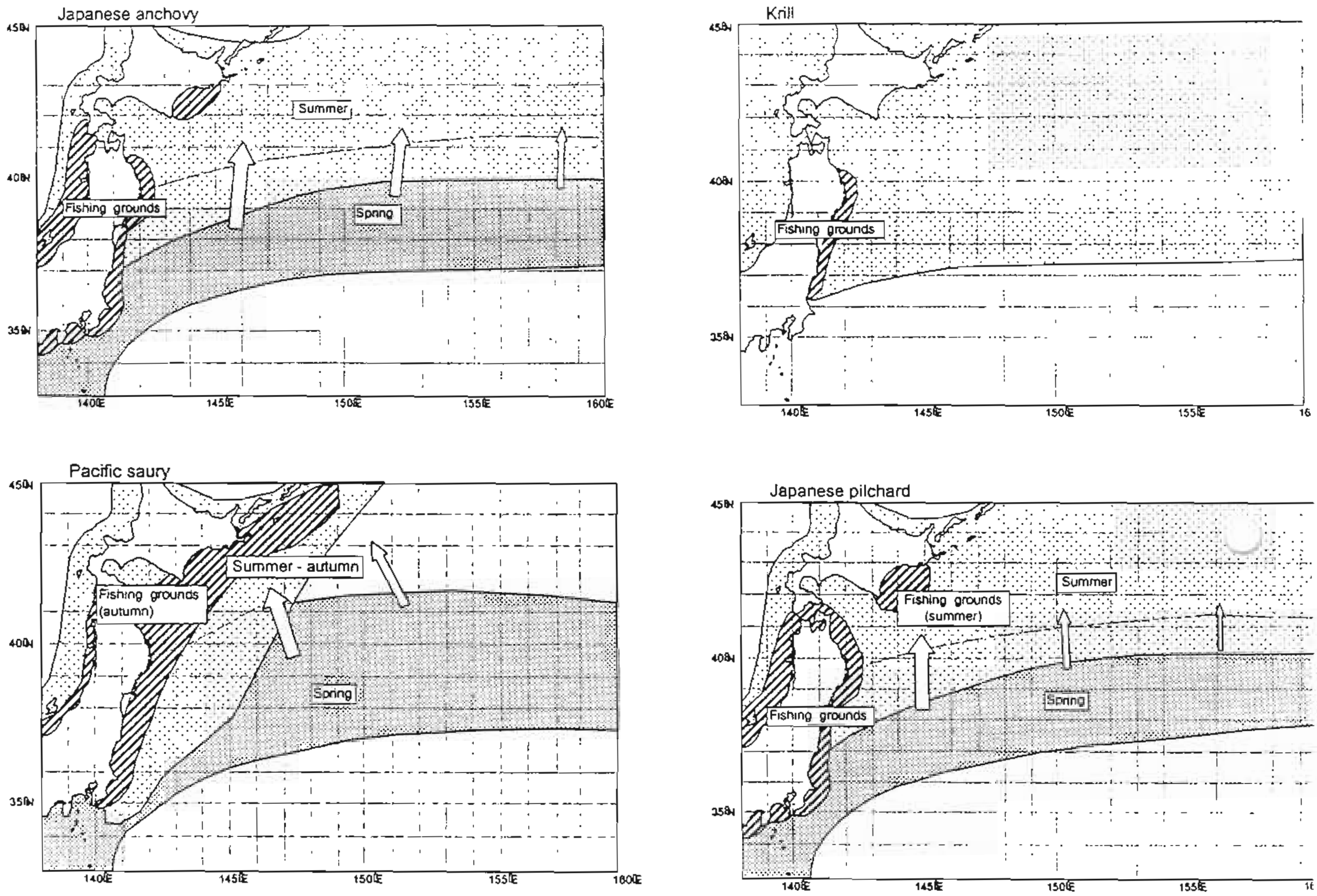

Fig. 1. The fishing grounds and seasonal distribution of the main prey species of cetaceans in the western North Pacific.

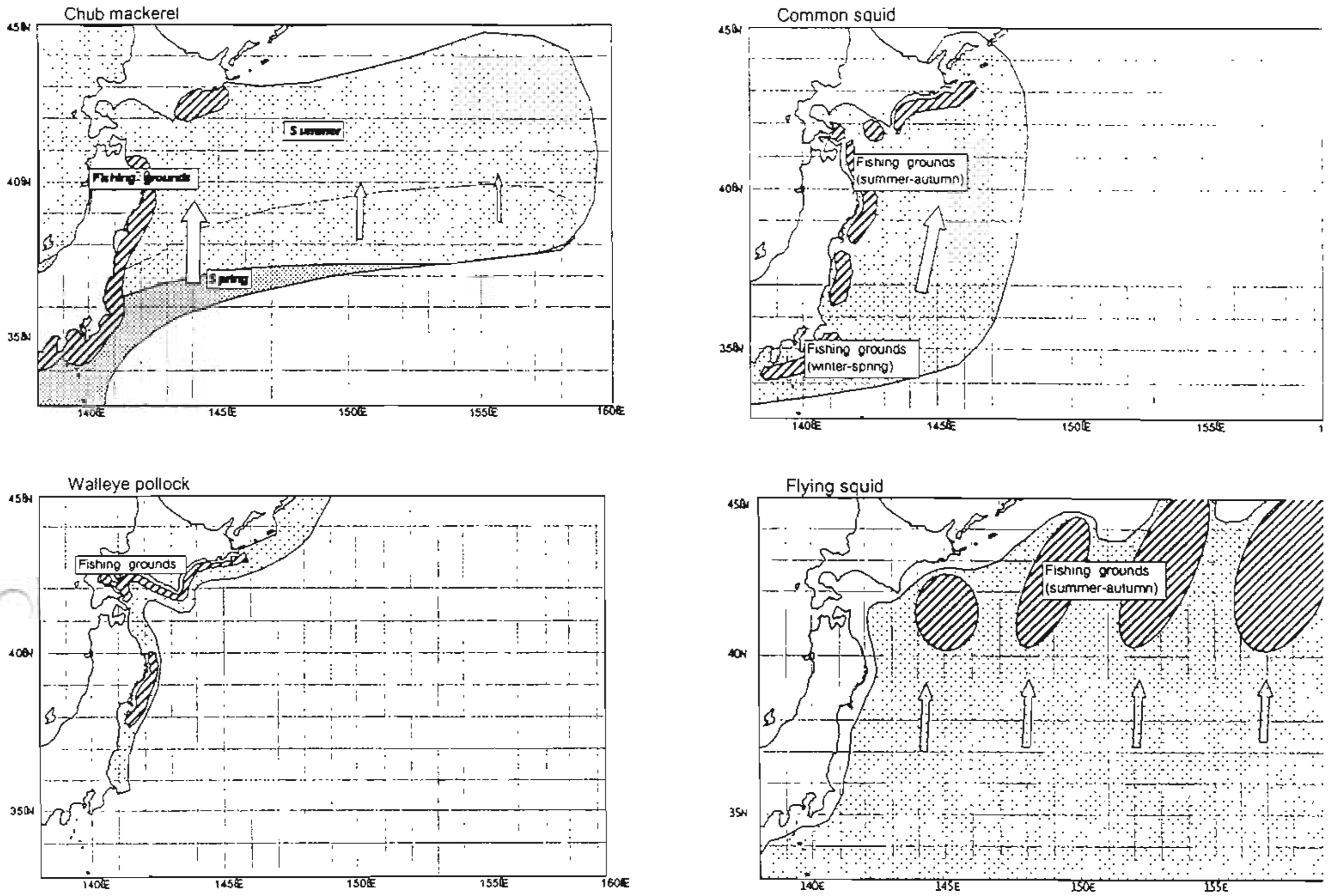

Fig. 1. Continued.

Appendix 4.
The description on basic models for an ecosystem
in the western North Pacific

Two models are introduced below. One is the ECOPATH model and the other is the MULTSPEC model. These will lay the foundation of our ecosystem modeling. We intend to run ECOPATH II program for aquatic data in the western North Pacific in the first place. The result of the test run may bring us knowledge of key species and important parameters. At the second stage, the MULTSPEC type model may be developed based upon the result of ECOPATH test run because the model like MULTSPEC includes effectively the time series data collected from fisheries and scientific surveys. ECOPATH provides a basis for initial analyses, but cannot be used to provide management guidance because of its equilibrium nature. The key reason to advance further to the MULTSPEC approach (and possibly also the ECOSIM extension of ECOPATH) is to be able to project resource abundance into the future under different harvesting policies, so as to provide a basis for multi-species management recommendations that do take account of biological interactions between the different species in the ecosystem.

ECOPATH MODEL

ECOPATH II is a micro-computer software for describing mass-balance in an ecosystem. It includes three main routines. The first is for balancing the flow in a steady-state ecosystem from estimation of a missing parameter for all groups in the system. The second is for estimating network flow indices and the last is deriving additional indices in relation to ecological theory. The program is developed to be able to present the result by graphical method. Test run for the western North Pacific will show the importance of interactions among multi-species and enable us to discriminate keystone predators.

1. The Basic Equations

Basically, the approach is to model an ecosystem using a set of simultaneous linear equations, that is

$$\text{Production} - \text{Predation} - \text{Non Predation losses} - \text{Harvest} - \text{Migration} = 0.$$

This means the system is on the steady state, *i.e.* under the equilibrium.
The above equation can be expressed as

$$P_i - B_i\, M2_i - P_i(1 - EE_i) - EX_i = 0$$

P_i: the production of group i
B_i: the biomass of group i
$M2_i$: predation mortality of group i
EE_i: the Ecotrophic Efficiency of group i
$(1 - EE_i)$: the "other mortality"
EX_i: the Export of group i.

This equation can be re-expressed as

$$B_i \cdot PB_i \cdot EE_i - \Sigma B_j \cdot QB_j \cdot DC_{ji} - EX_i = 0$$

PB_i: the production/biomass ratio
QB_i: the consumption/biomass ratio
DC_{ji}: the fraction of prey (i) in the average diet of predator (j)

This system of simultaneous linear equations can be solved using standard matrix algebra. If the determinant of a matrix is zero, it has no ordinary inverse. However, a generalized inverse can be found in most cases. If the set of equations has more equations than unknowns, and the equations are not consistent with each others, the generalized inverse method provides least squares estimates. On the other hand, if the system has more unknowns than equations, an answer that is consistent with the data will still be output. However, it will not be a unique answer.

B_i,PB_i,QB_i and EE_i are allowed to remain unknown parameters, *i.e.* they can be estimated. However, EX_i and DC_{ji} have to be always given for all groups. Generally only one of the parameters B_i, PB_i, QB_i or EE_i may be unknown. In special cases, QB_i may be unknown in addition to one of the other parameters.

2. Network Analysis

ECOPATH II links concepts developed by theoretical ecology. They are ascendancy, trophic level, trophic aggregation and omnivory index etc.

Ascendency is a measure of the average mutual information in a system, scaled by system throughput, and is derived from information theory.

Detritus and primary producers have a trophic level equal to 1. Besides them, the trophic level of other groups is defined as

$$TL = 1 + \sum_{j=1}^{n} DC_{ij} TL_j$$

DC_{ij}: the proportion of prey (j) in the diet of species (j)
TL_j: the trophic level of prey (j)
n: the number of groups in the system.

In addition to the routine for calculation of fractional trophic levels, a routine is included in ECOPATH II, which aggregates the entire system into discrete trophic levels. The trophic aggregation produces as its main result calculated estimates of trophic transfer efficiencies by trophic levels.

Omnivory index describes the feeding behavior of the consumer groups. The omnivory index (OI) is calculated at the variance of the trophic levels of a predator's prey as

$$OI_i = \sum_{j=1}^{n} (TL_j - TL) DC_{ij} .$$

If a predator has only one prey, its omnivory index equal 0. A large omnivory index indicates that the trophic positions of a predator's preys are variable.

3. Ecosim Model

Ecosim is a simulation model built including dynamic effects of changes into the set of linear equations used to construct an ECOPATH model. It represents dynamic change for each biomass (B) with a differential equation of the below form:

dB/dt = Food Consumption – Predatory losses – Non-predatory losses – Harvest

The consumption and loss rates are predicted over time as functions of prey and predator biomasses.

Ecosim requires very few additional parameters over the parameters in ECOPATH. An additional parameter describes the maximum production/biomass ratio allowed for any of the groups. If fishery or predation increases, the production/biomass ratio will also increase for a given group, and the parameter sets the bounds for how much it can increase relatively.

Ecosim includes equilibrium analysis for predicting the impact of changes in fishing patterns on yield and biomass of all ecosystem components, and a routine for estimation of stock-recruitment relationships.

MULTSPEC MODEL

The MULTSPEC model is an area, age and length structured multispecies simulation model for the species krill, Japanese anchovy, Pacific saury, and minke whale in the Pacific Ocean (Figure 1). The model shown in Figure 1 is thought to be the simplest. In the future, Japanese pilchard, Chub mackerel, common squid, walleye pollock, skipjack tuna, Bryde's whale, Dall's porpoise and sperm whale etc. are going to be added into the model.

For all species, migration between areas is implemented using migration matrices which are variable by month, and for fish by age group, but constant from year to year :

$$N_{s,t+1,a} = M_{s,t,a} N_{s,t,a} \qquad (1)$$

where s is stock, t is time, a is age, m is number of areas, $N_{s,t,a}$ is an m-dimensional vector, containing the number of fish of stock s at time t of age a for each area, and $M_{s,t,a}$ is an m by m migration matrix, where matrix elements m_{ij} indicate the proportion of the stock s in area i at time t which migrate to area j during this time step.

Each fish and marine mammals have the following equations in relation to maturation, growth, reproduction and feeding level. First of all, notation used in this appendix is defined :

0. Notation :

p : predator species
s : sex
a : age (years)
A : area
m : month
N : number of krill and fish (millions) and mammals
W : individual weight
B : biomass (thousand tons)
T : temperature (℃)
P_i's : parameters in relation to plankton
K_i's : parameters in relation to krill
AN_i's : parameters in relation to Japanese anchovy
SA_i's : parameters in relation to Pacific saury
MI_i's : parameters in relation to sea mammals

1. Temperature

The coastal temperature of the Pacific of Japan is known in detail until 1996. For the time being, future temperature is determined to be same as that in 1996

2. Plankton

The plankton supply for krill, Japanese anchovy, Pacific saury is given by the following function :

$$F(A,t) = P_1(A)e^{-4\ln 2\frac{(P_2(A)-t)^2}{P_3(A)}} \qquad (2)$$

where F is the plankton abundance in grams dry weight per square meter, t is time (month number (1-12)), $P_1(A)$ is the maximum plankton abundance in area A, $P_2(A)$ is the time for the maximum plankton abundance in area A, $P_3(A)$ is square of duration of the time period when the plankton abundance exceeds half the maximum abundance in area A.

3. Krill

Proportion of maturing stock is calculated as:

$$m(l) = \frac{1}{1 + e^{4K_1(K_2 - l)}} \qquad (3)$$

m(l) is proportion of stock maturing at length *l*, K_1 is change in maturation with length when $l = K_2$, K_2 is krill length at 50% maturity, referred to as "length-at-maturity".

Feeding level :

$$f(\phi) = \frac{\phi}{K_3 + \phi} \qquad (4)$$

where ϕ is relative food abundance (plankton biomass divided by krill biomass), and K_3 is the value of ϕ when a krill consumes half of maximum.

Individual growth :

$$\frac{dl}{dt} = K_4 l^{K_5} f(\phi)(K_6 T + K_7) \qquad (5)$$

$$\frac{dW}{dt} = K_8 W^{K_9} (f(\phi) - K_{10})(K_{11} T + K_{12}) \qquad (6)$$

Spawning stock biomass – recruitment relationship :

$$R(B) = \frac{K_{13} B}{K_{14} + B} \qquad (7)$$

where R is recruitment-at-age 0, B is spawning stock biomass, K_{13} is maximum recruitment, and K_{15} is the value of B giving half of maximum recruitment.

4. Japanese anchovy

Proportion of maturing stock is calculated as:

$$m(l) = \frac{1}{1 + e^{4AN_1(AN_2 - l)}} \qquad (8)$$

m(l) is proportion of stock maturing at length *l*, AN_1 is change in maturation with length when $l = AN_2$, AN_2 is fish length at 50% maturity, referred to as "length-at-maturity".

Feeding level :

$$f(\phi) = \frac{\phi}{AN_3 + \phi} \qquad (9)$$

where ϕ is relative food abundance (plankton biomass divided by Japanese anchovy biomass), and AN_3 is the value of ϕ when a sardine consumes half of maximum.

Individual growth :

$$\frac{dl}{dt} = AN_4 l^{AN_5} f(\phi)(AN_6 T + AN_7) \qquad (10)$$

$$\frac{dW}{dt} = AN_8 W^{AN_9} (f(\phi) - AN_{10})(AN_{11} T + AN_{12}) \qquad (11)$$

Spawning stock biomass – recruitment relationship :

$$R(B) = \frac{AN_{13} B}{AN_{14} + B} \qquad (12)$$

where R is recruitment-at-age 0, B is spawning stock biomass, AN_{13} is maximum recruitment, and AN_{15} is the value of B giving half of maximum recruitment.

5. Pacific saury

Proportion of maturing stock is calculated as:

$$m(l) = \frac{1}{1 + e^{4SA_1(SA_2 - l)}} \qquad (13)$$

$m(l)$ is proportion of stock maturing at length l, SA_1 is change in maturation with length when $l = SA_2$, SA_2 is fish length at 50% maturity, referred to as "length-at-maturity".

Feeding level :

$$f(\phi) = \frac{\phi(L,A)}{SA_3 + \phi(L,A)} \qquad (14)$$

where SA_3 is the value of the relative food abundance when a Pacific saury eats half of maximum consumption,

$$\phi(L,A) = \sum_{prey,l} \phi(prey,l,L,A) + \phi(plankton,L,A)$$

$$\phi(prey,l,L,A) = S(prey,l,L)N(prey,l,A)W(prey,l,A) / N(saury,L,A)W(saury,L,A)$$

$$\phi(plankton,A,m) = S(plankton,L)F(A,m)areasize(A) / N(saury,L,A)W(saury,L,A)$$

S(prey, l, L) is suitability of prey of length l as food for Pacific saury of length L,

N(prey, l, A) is number of prey group l in area A

W(prey, l, A) is individual weight of prey group l in area A, and

S(plankton, L) is suitability of plankton as food for Pacific saury of length L

and: *areasize(A)* : size of area A

The amount of prey (sardine, krill) of length l eaten per unit time by a Pacific saury of length L is given by

$$R_{saury}(prey,l,L,A) = H_{saury} f(\phi(L,A)) \frac{\phi(prey,l,L,A)}{\phi(L,A)} \qquad (15)$$

H_{saury} : maximum food uptake

Individual growth :

$$\frac{dl}{dt} = SA_4 l^{SA_5} f(\phi)(SA_6 T + SA_7) \qquad (16)$$

$$\frac{dW}{dt} = SA_8 W^{SA_9} (f(\phi) - SA_{10})(SA_{11} T + SA_{12}) \qquad (17)$$

Spawning stock biomass – recruitment relationship :

$$R(B) = \frac{SA_{13} B}{SA_{14} + B} \qquad (18)$$

where R is recruitment-at-age 0, B is spawning stock biomass, SA_{13} is maximum recruitment, and SA_{15} is the value of B giving half of maximum recruitment.

7. Minke whale

In the following equations, stocks of minke whale are denoted by the index p.

Recruitment :

The number of 0-year olds of sex s recruited to the stock p is given as:

$$N_{p,A,s,0} = \frac{1}{2} \sum_{a=1}^{t_{max}} R_{p,a} N_{p,A,females,a} \qquad (25)$$

$R_{p,a}$:reproductivity for females age a of stock p

Maturity :

Knife-edge maturity at specific age is applied.

Length at age :

A von Bertalanffy growth curve is used:

$$l_{a,s} = Ml_1(1-e^{Ml_2(a+Ml_3)}) \quad (26)$$

Length-Weight relationship :

$$W(l) = M_4 l^{Ml_5} \quad (27)$$

The normal energy requirement (J) of a predator p in month m is set to :

$$E_{p,s,a,m} = P_{p,m} W_{p,s,a} \Delta t \quad (28)$$

where $P_{p,m}$ is average rate of energy consumption of the species p in month m (W/kg), and Δt is number of seconds in month m

The consumption is distributed over the various prey populations, including exogenous "other food", in proportion to the mass density of the prey weighted by its suitability for the predator. Provided that the time step is sufficiently short, the consumption of each prey will be small compared to prey stock size, and we set the consumption C from a predator p on prey species i in an area to :

$$C_{p,s,a,m,i} = E_{p,s,a,m} \frac{S_{p,i} B_i}{\sum_j \eta_j S_{p,j} B_j} \quad (29)$$

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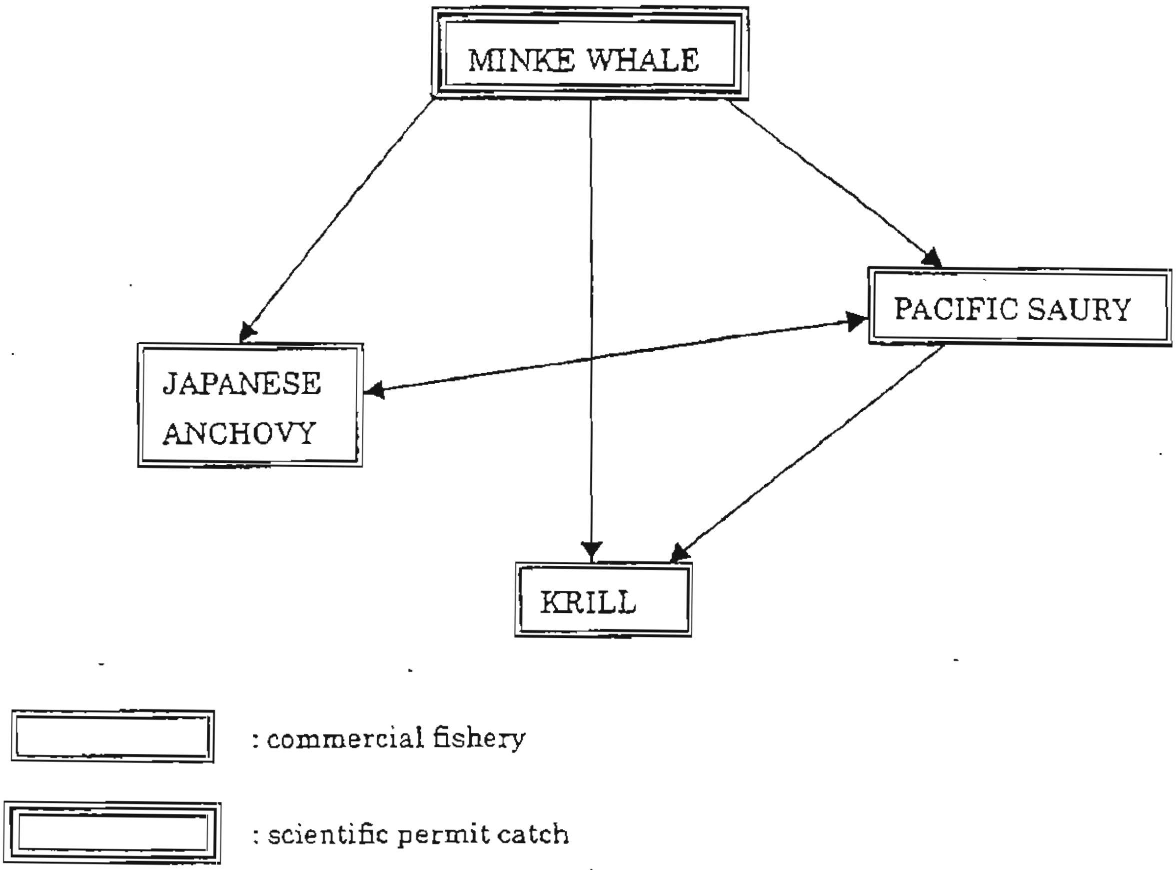

Fig.1 Modeled interactions in MULTSPEC in the western North Pacific (the simplest case).

Appendix 5.

Sample size of minke and Bryde's whales necessary for statistical examinations of consumption on various prey items

INTRODUCTION

It is known that the dominant prey species of minke whale (*Balaenoptera acutorostrata*) is different by seasons, year and area. Kasamatsu and Tanaka (1992) reported the change of dominant prey species of minke whales from Chub mackerel (*Scomber japonicus*) to Japanese pilchard (*Sardinops melanostictus*) off the Pacific coast of Hokkaido in 1977. Tamura and Fujise (2000a) reported the change of minke whales prey from Japanese pilchard to Pacific saury (*Cololabis saira*) off the Pacific coast of Hokkaido. These changes corresponded with a change of the dominant species taken by commercial fisheries in the same area. Minke whales, which consume zooplankton and schooling pelagic fish in the western North Pacific, are opportunistic feeders with a broad diet and with flexible feeding habits to reflect changes in the abundance of available prey species in this area. Tamura and Fujise (2000b) showed there was little diurnal change of feeding activity in the western North Pacific minke whale. Furthermore Tamura and Fujise (2000c) estimated that the daily food consumption rate obtained by the method-1 (estimation from diurnal change in stomach content weight) and method-2 (estimation from field metabolism) were 1.8 – 5.7 % of body weight, respectively. These values were similar to the estimates of eastern North Atlantic minke whales and the Antarctic.

Bryde's whales (*Balaenoptera edeni*) also consume zooplankton and schooling pelagic fish in the western North Pacific. They are opportunistic feeders with a broad diet and with flexible feeding habits to reflect changes in the abundance of available prey species in this area (Nemoto, 1959). However, it is unknown whether or not the dominant prey species of Bryde's whale differ by seasons, year and area. Furthermore, there is no quantitative study of food consumption for the Bryde's whales in the North Pacific.

In this paper we firstly examined whether prey species of minke whales are different by seasons and areas on the basis of JARPN survey data. Secondly, we estimated the sample size of minke whale necessary for estimating the amount of food consumption at an appropriate level of statistical precision. Thirdly, we estimated the sample size of Bryde's whale for estimating the amount of food consumption at an appropriate level of statistical precision in the same way as calculated for minke whale, using data of commercial whaling and some assumptions.

MATERIALS AND METHODS

The dominant prey species of minke whales by seasons and sub-areas

Occurrence of dominant prey species of minke whales by seasons and sub-area is shown in Table 1. To make simple the problem, we considered sub-area 7. In the spring (April – June), Japanese anchovy was the dominant prey species, occurring in 90.0 – 95.7 % of the stomach contents examined in the sub-area 7. But, in summer (July – September), Pacific saury and krill were the dominant prey species, occurring in 50.0 – 100.0 % of the stomach contents examined in the sub-area 7. These results demonstrate the seasonal and areal change of prey species.

For the next step, we examined whether the occurrence of dominant prey species changed by seasons and sub-area using statistical methods. We divided the research season into two terms: the spring and summer. Then, we examined whether there was any difference on dominant prey species by these terms using the data from sub-areas 7, 8 and 9.

Next we compared whether there was any difference on dominant prey species among sub-areas 7, 8 and 9 where JARPN survey were carried out in these spring and summer seasons. We employed χ^2 method for statistical analysis. Mean weight and *S.D.* of stomach contents is given using the data of minke whale taken by JARPN surveys.

The dominant prey species of Bryde's whales

Occurrence of dominant prey species of Bryde's whales is shown in Table 1. Nemoto (1959) reported the dominant prey species of Bryde's whales as krill, Japanese anchovy and Chub mackerel in Sanriku Coast of Japan. Nemoto and Kawamura (1977) reported that krill and fishes were the dominant prey species, occurring in 88.9 % and 11.1 %, respectively in the central North Pacific.
Mean weight and *S.D.* of stomach contents is given using the data of minke whale taken by JARPN surveys.

Sample size of minke whale and Bryde's whale necessary for statistical examinations

To calculate necessary sample size of minke whale and Bryde's whale, we used the data of the stomach contents on commercial whaling, the JARPN survey and the following formulas (The Government of Norway, 1992: SC/44/NAB18).

Consider I types of prey indexed $i = 1, \cdots, I$; J sampling seasons indexed $j = 1, \cdots, J$.
Set n ($n = n_1 + \cdots + n_J$) for the total sample size of a year.

To focus on a particular period, let for a randomly sampled whale:

X = amount of food in forestomach

T = a type of food

For simplicity, we assume that no forestomach contents is mixed type, so that T is a single species:

(1) $P(T=i) = P_i; i=1, \ldots I$

Then, from the amount of forestomach contents, we calculate the mean and the variance:

(2) $E(X|T=i) = \mu_i$

(3) $Var(X|T=i) = \sigma_i^2$

If n numbers of whales are sampled in the season, N_i of these will have prey type i in their forestomachs. Let the quantities be $X_{i1}, \cdots, X_{iNi}$, then μ_i and σ_i are estimated:

(4) $\hat{P}_i = N_i/n$

(5) $\hat{\mu}_i = 1/N_i \sum_{K=1}^{Ni} X_{ik}$

Then, the estimated mean amount of prey type i in forestomach of a random whale is

(6) $\hat{P}_i \hat{\mu}_i = 1/n \sum_{K=1}^{Ni} X_{ik}$

If W numbers of whales are in the area over the season, the estimated consumption of prey type i is

(7) $\bar{C}_i = W \hat{P}_i \hat{\mu}_i$

For simplicity, we disregard uncertainly in W. Then, the mean and variance of C_i is

(8) $E(\bar{C}_i) = W P_i \mu_i$

(9) $Var(\bar{C}_i) = W^2 \frac{1}{n} P_i (\sigma_i^2 + (1-P_i)\mu_i^2)$

Similarly, the estimated total consumption of prey type i in season j is

(10) $\overline{C}_{ij} = W_j \hat{P}_{ij} \hat{\mu}_{ij}$

The total consumption of prey type i over all sampling seasons is

(11) $T\hat{C}_i = \sum_j \overline{C}_{ij}$

By independence between feeding seasons of minke whales, the mean and variance of TC_i is

(12) $E(T\hat{C}_i) = \sum_{j=1}^{J} W_j P_{ij} \mu_{ij}$

(13) $Var(T\hat{C}_i) = \sum_{j=1}^{J} W_j^2 \frac{1}{n_j} P_{ij}(\sigma_{ij}^2 + (1 - P_{ij}) \mu_{ij}^2)$

Therefore, the coefficient of variance of TC_i is

(14) $c.v.^2 (T\hat{C}_i) = \frac{1}{n} [\sum_{j=1}^{J} \Pi_j^{-1} W_j^2 P_{ij}(\sigma_{ij}^2 + (1 - P_{ij}) \mu_{ij}^2)][\sum_{j=1}^{J} W_j P_{ij} \mu_{ij}]^{-2}$

$= \frac{1}{n} C_i^2$

where

(15) $\Pi_j = W_j / \sum_{j=1}^{J} W_k$

(16) $W_j = W_j \sqrt{\sum_{i=1}^{I} P_{ij} (\sigma_{ij}^2 + (1 - P_{ij}) \mu_{ij}^2)}$

To determine n, the criterion is to choose n as small as possible.

(17) $n \geqq c_i^2 / \alpha^2 \quad i = 1, \cdots, I$

A value of

$\alpha = 0.2$

seems to be a reasonable choice to achieve a level of precision appropriate for inputs to ECOPATH and MULTSPEC models so that they provide reliable results.

Sample size n is determined by solving inequality (17), then the way to allocate n to sampling seasons so as to minimize the variance of TC_t is determined and n_j's are

(18) $n_j = n\Pi_j \quad (j=1,\cdots,J)$

RESULTS AND DISCUSSION

The dominant prey species of minke whales by seasons and sub-areas

An examination of the dominant prey species by seasons is shown in Table 2. In sub-areas 7, 8 and 9, the dominant prey species were significantly different between the spring and the summer ($p < 0.0001$). An examination of the differences in dominant prey species by sub-areas is shown in Table 3. In the spring and summer, the differences of dominant prey species among sub-areas 7E, 8 and 9 were insignificant ($p = 0.14$, $p = 0.92$), but among sub-areas 7W, 7E, 8 and 9, these differences were significantly different ($p < 0.05$, $p < 0.0001$). However, between sub-areas 7W and 7E in spring, the dominant prey species were not significantly different ($p = 0.17$).

From these results it is concluded that the dominant prey species were significantly different within the sub-area between the spring and the summer. Furthermore, the dominant prey species were significantly different between coastal area (7W) and offshore area (8 and 9). Hence, division of research areas is essential to estimate the food consumption of minke whales.

Sample size of minke whale and Bryde's whale necessary for statistical examinations.

We examined necessary sample size of minke whales for estimating their food consumption in the research area. From our research findings, we have divided the data from the sub-area 7 (spring: 7W+7E, summer: 7W+7E) into two terms: the spring and the summer. The data we employed in this estimation were the number of the dominant prey species (krill, Pacific saury and Japanese anchovy), average stomach content weight and its *S.D.* in sub-area 7 (Table 4).

The result of our estimation is shown in Table 5. To control the coefficient of variation (*CV*) under 0.2 for consumption of all dominant prey species, a minimum of 201 minke whales are necessary. Furthermore, to cover the difference of food consumption between seasons, it is calculated that 72 minke whales in the spring and 129 minke whales in summer are necessary.

However these numbers of samples did not take into account those samples in which the stomachs were either empties or destroyed by harpoon. In the JARPN survey, stomach contents of 13 samples (3.1 %) were empty and 34 samples (8.1 %) were destroyed (Tables 6, 7). Thus, 81 samples in the spring and 144 samples in the summer were necessary in order to maintain the coefficient of variation (*CV*) under 0.2.

In the same way, we examined necessary sample size of Bryde's whales for estimating their food consumption in the research area. The data we employed in this estimation were the number of the dominant prey species (krill and fishes) of Bryde's whale, average stomach contents weight and the *S.D.* of minke whales (Table 4). The result of our estimation is shown in Table 5. To control the coefficient of variation (*CV*) under 0.2 for consumption of all dominant prey species, it is calculated that 48 Bryde's whales for krill and 602 Bryde's whales for fishes are necessary.

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Table 1. Dominant prey species of minke whales and Bryde's whales in the western North Pacific and their frequency of occurrence by the sub-areas and the seasons.

Minke whale

Sub-area	7W		7E		8		9		Sum
Period	(June)[1]	(Aug.-Sep.)[2]	(May-June)[3]	(July)[2]	(May-June)[4]	(July-Aug.)[5]	(May-June)[6]	(July-Sep.)[7]	
Prey species	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Krill		10 (38.5)	1 (2.2)		1 (2.9)	1 (2.4)	2 (2.9)	7 (7.4)	22 (6.0)
Japanese anchovy	45 (90.0)		44 (95.7)		33 (94.3)	4 (9.5)	57 (81.4)	9 (9.6)	192 (52.7)
Pacific saury		13 (50.0)		1 (100.0)	1 (2.9)	36 (85.7)	9 (12.9)	74 (78.7)	134 (36.8)
Others	5 (10.0)	3 (11.5)	1 (2.2)			1 (2.4)	2 (2.9)	4 (4.3)	16 (4.4)
Observed	50 (100)	26 (100)	46 (100)	1 (100)	35 (100)	42 (100)	70 (100)	94 (100)	364 (100)

1: 1999 JARPN, 2: 1996 JARPN, 3: 1997,1998 JARPN, 4: 1998 JARPN, 5: 1996,1997 JARPN, 6: 1995,1997 JARPN, 7: 1994,1995 JARPN.

Bryde's whale

Prey item	N	(%)
Krill	24	(88. 9)
Fishes	3	(11. 1)
Observed	27	(100)

Table 2. Examination of inhomogeneity of the dominant prey species of minke whales between spring and summer.

Sub-area	p (spring vs summer)
7W	< 0.0001
7(7W+7E)	< 0.0001
8	< 0.0001
9	< 0.0001

Table 3. Examination of inhomogeneity of the dominant prey species of minke whales among the sub-areas 7, 8 and 9.

Sub-areas	Spring p	Summer p
7W, 7E, 8, 9	0.01	< 0.0001
7E, 8, 9	0.14	0.92
7W, 7E	0.17	-
7W, 8	0.09	< 0.0001
7W, 9	0.01	< 0.0001

Table 4. Data of the dominant prey species of minke whales and Bryde's whales.

Minke whale

Prey item	N	Mean (kg)	S. D.
Spring (7E+7W)			
Krill	1	1.9	0.0
Japanese anchovy	89	13.1	17.5
Pacific saury	0	0.0	0.0
Summer (7E+7W)			
Krill	10	22.0	27.6
Japanese anchovy	0	0.0	0.0
Pacific saury	14	22.8	26.6

Bryde's whale

Prey item	N	Mean (kg)	SD
Krill	24	22.0	27.6
Fishes	3	13.1	17.5

Table 5. Calculated sample size of minke whale and Bryde's whale.

Minke whale

Sample size

Prey item	CV=0.1	CV=0.2	CV=0.3
Krill	804	201	90
Japanese anchovy	507	127	57
Pacific saury	476	119	53

Proportion of allocated sample size

		CV=0.1	CV=0.2	CV=0.3
Spring	0.358	288	72	32
Summer	0.642	516	129	58

Bryde's whale

Prey item	CV=0.1	CV=0.2	CV=0.3
Krill	190	48	22
Fishes	2,407	602	268

Table 6. Numbers of empty stomach of minke whales collected by the JARPN surveys.

Sub-area	Observed	Empty	Rate (%)
7	139	7	5.0
8	91	3	3.3
9	188	3	1.6
Sum	418	13	3.1

Table 7. Numbers of broken stomach by the harpoon of minke whales collected by the JARPN surveys.

Sub-area	Observed	Broken	Rate (%)
7	139	9	6.5
8	91	11	12.1
9	188	14	7.4
Sum	418	34	8.1

Appendix 6.
An examination of the effect on the whale stock
of future catches under JARPNII

ABSTRACT

The effect on the whale stock of future catches under JARPNII from 2000 to 2001 is examined by using Hitter methodology for minke and Bryde's whales. Hitter calculations show that the effect on the minke whale stocks and the Bryde's whale stocks is negligible. While no calculation is made for sperm whales, the sample size is so small that is obviously below critical level to affect the stocks. Therefore, it is concluded that the effect on the sperm whale stock is negligible.

MATERIALS AND METHODS

Western North Pacific minke whales

In this study, it is assumed that 50 minke whales are caught from sub-areas 7 and 9, respectively every year from 2000 to 2001. Based on results from the JARPN surveys, two O stock scenarios and one W stock scenario, are considered.

Scenario 1-1 Only O stock animals distribute in sub-areas 7, 8, 9, 11 and 12.

Scenario 1-2 Only O stock animals distribute in sub-areas 7, 8 and 11 and the percentage of O stock animals in sub-area 12 is 40% (this ratio is derived from [abundance in sub-areas 7, 8 and 11]/[abundance in sub-areas 7, 8, 9 and 11]).

Scenario 1-3 Only W stock animals distribute in the western part of sub-area 9 (i.e. west of 162 ° E) and the percentage of the W stock animals in sub-area 12 is 60%.

The past annual sex-disaggregated catches of western North Pacific minke whales are listed in Table 1 for scenario 1-1, in Table 2 for scenario 1-2 and in Table 3 for scenario 1-3. Incidental catches reported in the Japan Progress Report is taken into account. The number of incidental catches in sub-areas 2, 7 and 11 by sex used in this study is shown in Table 4. In this Hitter computations, the following parameter values, adopted by the Implementation Simulation Trials (IWC, 1999a), are used:

Age at recruitment (same for both sexes):	4 (50%) and 7.53 (95%)
Age at maturity (same for both sexes):	7 (50%) and 10.53 (95%)

Natural mortality (age-dependent and independent of sex):

0.085	if $a \leqq 4$
$0.0775 + 0.001875\,a$	if $4 < a < 20$
0.115	if $a \geqq 20$

where a is age.

MSY level (*MSYL*(mature)): 60% (of *K*)

The best estimate of total (1+) abundance from sighting surveys is taken to be 25,591 (5% lower limit 16,894) in scenario 1-1, 7,906 (5% lower limit 3,989) in scenario 1-2, and 10,494 (5% lower limit 6,456) in scenario 1-3 and to apply to 1990. The abundance estimate used for scenario 1-3 is simply calculated by the abundance estimate in sub-area 9 multiplied by the rate of the area of western part of sub-area 9 to the area of whole sub-area 9. These estimates were based on specifications of the North Pacific minke whaling trials (Appendix 5 of IWC, 1999a). The following four years are chosen; 1988 (when commercial whaling ceased), 1994 (the start of JARPN surveys), 2000 (the start of JARPN II survey) and 2002 (after the 2nd JARPN II survey). It was assumed that the sex ratio of samples collected during JARPN II is 50%. But it was suggested that male are dominant in the research area. To consider a more realistic case, the case where male sex ratio of samples collected during JARPN II is 87.8% (same as that of JARPN surveys in sub-areas 7) are also considered for scenario 1-2.

Western North Pacific Bryde's whales

It is assumed that 50 Bryde's whales are caught every year from 2000 to 2001. Two scenarios are considered.

Scenario 2－1 The case where a single stock exists in sub-areas 1 and 2

Scenario 2－2 The case where a single stock exists in sub-area 1

Historical catch information (Table 9 for Scenario 2－1, Table 10 for scenario 2－2) is referred from Appendix 2 of IWC (1997). The following biological parameters are used, which were adopted during the Comprehensive Assessment of Western North Pacific Bryde's whales:

Age at recruitment (coastal catches):	5.0 (both 50% and 95%)
Age at recruitment (pelagic catches):	8.0 (both 50% and 95%)
Age at maturity:	8.0 (both 50% and 95%)
Natural mortality (independent of age and sex):	0.07
MSY level (*MSYL*)	60% (of *K*)

Abundance estimate is referred from Shimada and Miyashita (1997). 21,402 (lower 95% confidential limit 15,856) in 1992 for Scenario 2-1, 19,301 (lower 95% confidential limit 13,913) in 1992 for Scenario 2-2. Sub-areas 1 and 2 are as described in Appendix 14 of IWC (1999b). The following three years are chosen; 1988 (when commercial whaling are ceased), 2000 (the start of JARPN II survey) and 2002 (after the 2nd JARPN II survey).

RESULTS AND DISCUSSIONS

Western North Pacific minke whales

Results for HITTER runs for both the best estimate and its 5% lower limit are given in Table 5-8 for *MSYR* (mature) = 0%, 1%, 2%, 3%, 4% and 5%. These tables show depletion (the ratio of the population for the year indicated to the pre-exploitation level) for mature female component. Table 5 shows the result in the case of scenario 1-1. Table 6 shows the result in the case of scenario 1-2. Table 7 shows the result in the case of scenario 1-2 assuming that sex ratio is 87.8%. Table 8 shows the result in the case of scenario 1-3. In all tables, except in the case of most conservative scenario (Table 6), the population of mature female component increase between 2000 and 2002 even under the conservative assumption of abundance equal to the 5% lower limit from sighting survey and *MSYR* (mature) = 1%. But assumption that males are dominant can be considered more realistic than assumption that the sex ratio of male is 50% because males are dominant on JARPN surveys. Therefore, the results in Table 7 (i.e. under the assumption that males are dominant) are more realistic than those in Table 6. So it can be concluded that effect on the minke whale stock is negligible.

Western North Pacific Bryde's whales

Results for HITTER runs for both the best estimate and its 5% lower limit are given in Table 11-12 for *MSYR* (mature) = 0%, 1%, 2%, 3%, 4%, 5% and 6%. These tables show depletion for mature female component. Table 11 shows the result under the scenario 2-1. Table 12 shows the result under the scenario 2-2. The population of mature female component increases between 2000 and 2002 even under the conservative assumption of abundance equal to the 5% lower limit from sighting survey and *MSYR* (mature) = 1%. The only conclusion possible is that the catches proposed would not have an adverse effect on the Bryde's whale stock.

Western North Pacific Sperm whales

While no calculation is made for sperm whales, the sample size is so small that is obviously below critical level to affect the stocks. It is also concluded that effect on the sperm whale stock can be negligible.

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Table 1. Catch data, including incidental catch, used in this study under the Scei Historical catch from 1930 to 1999 and assumed future catch from 2000 to 2001 from the O stock of minke whales in the North Pacific for two Scenarios examined using Hitter Fitter program.

Scenario 1-1 (Catch from subareas 7, 11, 8, 9 and 12)			Scenario 1-1 (continued)		
year	male	female	year	male	female
1930	7	6	1966	162	200
1931	7	6	1967	112	160
1932	7	6	1968	78	138
1933	8	6	1969	75	140
1934	13	11	1970	151	158
1935	13	11	1971	143	122
1936	13	11	1972	129	210
1937	33	24	1973	264	256
1938	38	30	1974	178	190
1939	38	30	1975	175	155
1940	45	34	1976	152	189
1941	33	24	1977	162	86
1942	38	30	1978	246	156
1943	59	42	1979	262	130
1944	45	34	1980	201	165
1945	38	30	1981	216	142
1946	45	51	1982	167	142
1947	55	60	1983	139	142
1948	81	87	1984	200	170
1949	72	62	1985	192	127
1950	125	77	1986	180	135
1951	113	120	1987	183	122
1952	114	179	1988	3	1
1953	115	119	1989	4	0
1954	111	162	1990	11	5
1955	167	209	1991	3	0
1956	239	219	1992	1	0
1957	163	196	1993	5	0
1958	226	292	1994	28	3
1959	124	159	1995	99	9
1960	115	144	1996	75	15
1961	146	189	1997	106	13
1962	103	138	1998	98	11
1963	97	125	1999	84	29
1964	130	161	2000	63	50
1965	128	186	2001	63	50

Table 2. Catch data, including incidental catch, used in this study under the Scenario 1 Historical catch from 1930 to 1999 and assumed future catch from 2000 to 2001 from the O stock of minke whales in the North Pacific for two Scenarios examined using Hitter Fitter program. Numbers in parentheses are used in the case that male sex ratio of future catch is 87.8%, same as that of past JARPN survey.

Scenario 1-2 (Catch from subareas 7, 8, 11 and 40% of subarea12)			Scenario 1-2 (continued)		
year	male	female	year	male	female
1930	7	6	1966	162	200
1931	7	6	1967	112	160
1932	7	6	1968	78	138
1933	8	6	1969	72	132
1934	13	11	1970	145	158
1935	13	11	1971	142	122
1936	13	11	1972	129	210
1937	33	24	1973	246	233
1938	38	30	1974	162	169
1939	38	30	1975	168	141
1940	45	34	1976	152	189
1941	33	24	1977	162	86
1942	38	30	1978	246	156
1943	59	42	1979	262	130
1944	45	34	1980	201	165
1945	38	30	1981	216	142
1946	45	51	1982	167	142
1947	55	60	1983	139	142
1948	81	87	1984	200	170
1949	69	60	1985	192	127
1950	122	76	1986	180	135
1951	113	116	1987	183	122
1952	113	177	1988	3	1
1953	112	116	1989	4	0
1954	110	160	1990	11	5
1955	164	208	1991	3	0
1956	236	216	1992	1	0
1957	162	194	1993	5	0
1958	225	289	1994	10	0
1959	124	159	1995	8	0
1960	114	143	1996	75	15
1961	146	188	1997	51	1
1962	103	137	1998	98	11
1963	97	125	1999	84	29
1964	130	161	2000	38 (57)	25 (6)
1965	128	186	2001	38 (57)	25 (6)

Table 3. Catch data, including incidental catch, used in this study under the Scenario 1-3. Historical catch from 1994 to 1999 and assumed future catch from 2000 to 2001 from the W stock of minke whales in the North Pacific examined using Hitter Fitter pro

Scenario 1-3 (Catch from western part of sub-area 9 and 60% of subarea12)		
year	male	female
1994	6	1
1995	73	6
1996	0	0
1997	13	5
1998	0	0
1999	0	0
2000	25	25
2001	25	25

Table 4. Historical and future incidental catch from 195 in sub-areas 2, 7 and 11 calculated following the Appen of the annex D of the report of 51 IWC/SC .

year	male	female
1955-1978	1	1
1979	0	0
1980	1	1
1981	0	0
1982	0	0
1983	1	1
1984	2	1
1985	0	0
1986	3	1
1987	1	0
1988	3	1
1989	4	0
1990	11	5
1991	3	0
1992	1	0
1993	5	0
1994	10	0
1995	8	0
1996	12	1
1997	19	0
1998	9	0
1999-	13	0

Table 5. The case where 100 minke whales (50 males and 50 females)
from 2000 to 2001 under the Scenario 1-1 (sub-areas 7, 11, 8, 9 and 12 for O-
taking the incidental catch into account. Depletion is given for mature fe

a) Hit 1990 total (1+) population of 25591 (best

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	39378	35980	33194	30937	29144	27759
Depletion - 1988	64.7%	68.4%	72.1%	75.8%	79.3%	82.7%
Depletion - 1994	65.6%	71.1%	76.4%	81.5%	86.2%	90.4%
Depletion - 2000	65.0%	72.1%	78.9%	85.2%	90.6%	95.0%
Depletion - 2002	64.4%	72.0%	79.2%	85.7%	91.1%	95.3%
RY - 2002	55	135	184	198	180	140
MSY (recruited)	0	108	199	279	352	420
MSY (+1)	0	116	216	303	382	457

b) Hit 1990 total (1+) population of 16894 (5% lower

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	30678	27723	25248	23179	21456	20035
Depletion - 1988	54.8%	58.0%	61.4%	64.9%	68.5%	72.1%
Depletion - 1994	55.9%	61.1%	66.4%	71.7%	76.9%	82.0%
Depletion - 2000	55.1%	62.0%	69.0%	75.9%	82.5%	88.5%
Depletion - 2002	54.3%	61.7%	69.2%	76.5%	83.3%	89.4%
RY - 2002	55	122	172	200	203	181
MSY (recruited)	0	83	152	209	259	303
MSY (+1)	0	90	164	227	281	330

Table 6. The case where 50 minke whales (25 males and 25 females) are caught
from 2000 to 2001 under the Scenario 1-2 (sub-areas 7, 8, 11 and 40% of 12 on
taking the incidental catch into account. Depletion is given for mature fe

a) Hit 1990 total (1+) population of 10158 (best

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	23756	21340	19296	17558	16073	14799
Depletion - 1988	42.4%	44.8%	47.4%	50.0%	52.7%	55.4%
Depletion - 1994	43.8%	48.1%	52.5%	57.1%	61.8%	66.5%
Depletion - 2000	43.0%	48.9%	55.0%	61.4%	67.8%	74.3%
Depletion - 2002	42.5%	48.9%	55.6%	62.5%	69.5%	76.5%
RY - 2002	40	88	131	166	189	197
MSY (recruited)	0	64	116	159	194	224
MSY (+1)	0	69	125	172	211	244

b) Hit 1990 total (1+) population of 6663 (5% lower

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	20257	18208	16470	14984	13707	12603
Depletion - 1988	32.5%	34.2%	35.9%	37.6%	39.4%	41.2%
Depletion - 1994	34.2%	37.4%	40.8%	44.3%	47.9%	51.5%
Depletion - 2000	33.2%	37.8%	42.6%	47.7%	53.0%	58.4%
Depletion - 2002	32.6%	37.6%	43.0%	48.6%	54.4%	60.5%
RY - 2002	40	75	109	141	169	191
MSY (recruited)	0	55	99	135	165	191
MSY (+1)	0	59	107	147	180	207

Table 7. The case where 50 minke whales (44 males and 6 females) are caught fr from 2000 to 2001 under the Scenario 1-2 (sub-areas 7, 8, 11 and 40% of 12 onl with the assumption males are dominant taking the incidental catch into Depletion is given for mature female

a) Hit 1990 total (1+) population of 10158 (best

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	23756	21340	19296	17558	16073	14799
Depletion - 1988	42.4%	44.8%	47.4%	50.0%	52.7%	55.4%
Depletion - 1994	43.8%	48.1%	52.5%	57.1%	61.8%	66.5%
Depletion - 2000	43.0%	48.9%	55.0%	61.4%	67.8%	74.3%
Depletion - 2002	43.0%	49.4%	56.1%	63.1%	70.1%	77.1%
RY - 2002	41	89	133	167	190	198
MSY (recruited)	0	64	116	159	194	224
MSY (+1)	0	69	125	172	211	244

b) Hit 1990 total (1+) population of 6663 (5% lower

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	20257	18208	16470	14984	13707	12603
Depletion - 1988	32.5%	34.2%	35.9%	37.6%	39.4%	41.2%
Depletion - 1994	34.2%	37.4%	40.8%	44.3%	47.9%	51.5%
Depletion - 2000	33.2%	37.8%	42.6%	47.7%	53.0%	58.4%
Depletion - 2002	33.1%	38.2%	43.6%	49.2%	55.1%	61.2%
RY - 2002	41	76	110	142	170	192
MSY (recruited)	0	55	99	135	165	191
MSY (+1)	0	59	107	147	180	207

Table 8. The case where 50 minke whales (25 males and 25 females) are caught fro from 2000 to 2001 under the Scenario 1-3 (western part of sub-areas 9 and 60% Depletion is given for mature female

a) Hit 1990 total (1+) population of 10494 (best

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	10494	10494	10494	10494	10494	10494
Depletion - 1994	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Depletion - 2000	99.7%	99.7%	99.7%	99.7%	99.7%	99.7%
Depletion - 2002	98.5%	98.5%	98.5%	98.5%	98.5%	98.5%
RY - 2002	12	13	14	15	16	16
MSY (recruited)	0	31	63	95	127	159
MSY (+1)	0	34	68	103	138	173

b) Hit 1990 total (1+) population of 6456 (5% lower

Statistic	MSYR (mature)					
	0	1	2	3	4	5
K (1+)	6456	6456	6456	6456	6456	6456
Depletion - 1994	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Depletion - 2000	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
Depletion - 2002	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%
RY - 2002	12	13	14	15	15	16
MSY (recruited)	0	17	34	52	69	87
MSY (+1)	0	21	42	63	85	106

Table 9. Catch data used Hitter calculation in this study under the Scenario 2-1.
Historical catch from 1911 to 1987 and assumed future catch from 2000 to 2001 from the stock of Bryde's whales in the Western North Pacific examined using Hitter Fitter program.

	Catch in sub-areas 1 and 2			
	coastal		pelagic	
year	male	female	male	female
1911	94	74	0	0
1912	0	0	0	0
1913	0	0	0	0
1914	35	27	0	0
1915	90	72	0	0
1916	50	40	0	0
1917	40	31	0	0
1918	47	37	0	0
1919	44	34	0	0
1920	41	33	0	0
1921	53	42	0	0
1922	47	37	0	0
1923	41	33	0	0
1924	63	49	0	0
1925	67	53	0	0
1926	77	61	0	0
1927	65	51	0	0
1928	43	34	0	0
1929	34	27	0	0
1930	36	28	0	0
1931	75	60	0	0
1932	56	45	0	0
1933	51	41	0	0
1934	56	45	0	0
1935	56	44	0	0
1936	54	42	0	0
1937	82	65	0	0
1938	95	75	0	0
1939	114	90	0	0
1940	27	22	0	0
1941	84	67	0	0
1942	12	9	0	0
1943	27	22	0	0
1944	68	53	0	0
1945	6	5	0	0
1946	63	49	7	22
1947	25	20	86	72
1948	51	41	53	52
1949	64	51	64	52
1950	15	12	109	134
1951	13	11	155	125
1952	42	33	270	141
1953	32	25	0	0
1954	39	31	0	0
1955	32	57	0	0
1956	15	9	0	0

	(continued)			
	coastal		pelagic	
year	male	female	male	female
1957	14	25	0	0
1958	114	140	0	0
1959	154	109	0	0
1960	189	215	0	0
1961	84	83	0	0
1962	212	292	0	0
1963	102	108	0	0
1964	26	42	0	0
1965	3	5	0	0
1966	20	35	0	0
1967	18	27	0	0
1968	71	100	0	0
1969	34	55	0	0
1970	36	37	27	39
1971	80	92	302	445
1972	38	46	26	50
1973	23	17	207	451
1974	61	86	493	683
1975	45	71	669	648
1976	111	91	679	578
1977	135	112	368	331
1978	114	66	238	178
1979	351	275	239	163
1980	442	351	0	0
1981	249	236	0	0
1982	275	207	0	0
1983	402	143	0	0
1984	353	175	0	0
1985	249	108	0	0
1986	217	100	0	0
1987	256	61	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	25	25	0	0
2001	25	25	0	0

Table 10. Catch data used Hitter calculation in this study under the Scenario 2-2. Historical catch from 1911 to 1987 and assumed future catch from 2000 to 2001 from the stock of Bryde's whales in the Western North Pacific examined using Hitter Fitter program.

	Catch in sub-area 1			
	coastal		pelagic	
year	male	female	male	female
1911	94	74	0	0
1912	0	0	0	0
1913	0	0	0	0
1914	35	27	0	0
1915	90	72	0	0
1916	50	40	0	0
1917	40	31	0	0
1918	47	37	0	0
1919	44	34	0	0
1920	41	33	0	0
1921	53	42	0	0
1922	47	37	0	0
1923	41	33	0	0
1924	63	49	0	0
1925	67	53	0	0
1926	77	61	0	0
1927	65	51	0	0
1928	43	34	0	0
1929	34	27	0	0
1930	36	28	0	0
1931	75	60	0	0
1932	56	45	0	0
1933	51	41	0	0
1934	56	45	0	0
1935	56	44	0	0
1936	54	42	0	0
1937	82	65	0	0
1938	95	75	0	0
1939	114	90	0	0
1940	27	22	0	0
1941	84	67	0	0
1942	12	9	0	0
1943	27	22	0	0
1944	68	53	0	0
1945	6	5	0	0
1946	63	49	7	22
1947	25	20	86	72
1948	51	41	53	52
1949	64	51	64	52
1950	15	12	109	134
1951	13	11	155	125
1952	42	33	270	141
1953	32	25	0	0
1954	39	31	0	0
1955	32	57	0.	0
1956	15	9	0	0

	(continued)			
	coastal		pelagic	
year	male	female	male	female
1957	14	25	0	0
1958	114	140	0	0
1959	154	109	0	0
1960	189	215	0	0
1961	84	83	0	0
1962	212	292	0	0
1963	102	108	0	0
1964	26	42	0	0
1965	3	5	0	0
1966	20	35	0	0
1967	18	27	0	0
1968	71	100	0	0
1969	34	55	0	0
1970	36	37	16	24
1971	80	92	201	305
1972	38	46	17	37
1973	23	17	191	420
1974	61	86	346	524
1975	45	71	442	440
1976	111	91	654	572
1977	135	112	364	326
1978	114	66	230	173
1979	351	275	239	163
1980	442	351	0	0
1981	249	236	0	0
1982	275	207	0	0
1983	402	143	0	0
1984	353	175	0	0
1985	249	108	0	0
1986	217	100	0	0
1987	256	61	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	25	25	0	0
2001	25	25	0	0

Table 11. The effect on the stock of Western North Pacific Bryde's whales under the condition that there is a single stock in sub-areas 1 and 2. Depletion is given for mature female component.

a) Hit 1992 total (1+) population of 21403 (best estimate)

Statistic	MSYR(mature) (%)						
	0	1	2	3	4	5	6
K(1+)	41760	36236	32245	29285	27005	25177	23667
Depletion - 1988	52.2%	55.8%	58.9%	61.4%	63.5%	65.3%	66.9%
Depletion - 2000	52.7%	60.7%	68.2%	75.1%	81.5%	87.4%	93.0%
Depletion - 2002	52.4%	61.1%	69.3%	76.8%	83.7%	90.0%	95.8%
RY - 2002	28	135	212	258	272	251	194
MSY(recruited)	0	128	228	311	383	448	506
MSY(+1)	0	139	249	341	421	494	560

b) Hit 1992 total (1+) population of 15856 (5% lower limit)

Statistic	MSYR(mature) (%)						
	0	1	2	3	4	5	6
K(1+)	36209	31195	27550	24841	22762	21104	19738
Depletion - 1988	44.8%	48.0%	50.6%	52.7%	54.4%	55.7%	56.9%
Depletion - 2000	45.4%	52.7%	59.7%	66.2%	72.3%	78.0%	83.4%
Depletion - 2002	45.1%	53.0%	60.7%	67.9%	74.7%	81.0%	86.9%
RY - 2002	28	118	190	245	279	294	286
MSY(recruited)	0	110	195	264	323	375	422
MSY(+1)	0	119	212	289	355	414	467

Table 12. The effect on the stock of Western North Pacific Bryde's whales under the condition that there is a different stock in sub-area 1 from the one in sub-area 2. Depletion is given for mature female component.

a) Hit 1992 total (1+) population of 19301 (best estimate)

Statistic	MSYR(mature) (%)						
	0	1	2	3	4	5	6
K(1+)	38429	33184	29408	26626	24502	22813	21427
Depletion - 1988	51.2%	55.0%	58.3%	61.0%	63.2%	65.1%	66.7%
Depletion - 2000	51.8%	60.0%	67.7%	74.8%	81.2%	87.2%	92.9%
Depletion - 2002	51.5%	60.3%	68.7%	76.4%	83.4%	89.8%	95.7%
RY - 2002	28	126	197	239	251	232	180
MSY(recruited)	0	117	208	283	348	405	458
MSY(+1)	0	127	227	310	382	448	507

b) Hit 1992 total (1+) population of 13913 (5% lower limit)

Statistic	MSYR(mature) (%)						
	0	1	2	3	4	5	6
K(1+)	33036	28307	24874	22332	20392	18858	17603
Depletion - 1988	43.3%	46.5%	49.3%	51.5%	53.3%	54.8%	56.0%
Depletion - 2000	43.9%	51.3%	58.4%	65.0%	71.2%	77.0%	82.5%
Depletion - 2002	43.6%	51.5%	59.3%	66.6%	73.5%	79.9%	86.0%
RY - 2002	28	109	174	224	256	271	266
MSY(recruited)	0	100	176	237	289	335	376
MSY(+1)	0	108	192	260	318	370	417