COMPETITION FOR FOOD IN THE OCEAN: MAN AND OTHER APICAL PREDATORS

Tsutomu TAMURA

ABSTRACT

It is important to understand cetacean feeding ecology because cetaceans are top predators in the marine ecosystem and play an important role in the food web. Furthermore, interactions between cetacean and fisheries have become a major issue worldwide. Many international fisheries organizations have urged the development of multi-species management systems. It is an important issue in the context of world food security since it is estimated that cetaceans consume three to five times the amount of marine resources harvested for human consumption. In the waters around Japan there is a situation of declining catches in certain fisheries, while at the same time the sampling from the research programme reveals that minke whales are eating at least ten species of fish, including Japanese anchovy, Pacific saury, walleye pollock and other commercially important species.

Japan conducted a whale research programme in the northwestern Pacific from 1994 to1999 under Special Permit, as provided for by Article VIII of the International Convention for the Regulation of Whaling (ICRW). Since some scientific issues remained outstanding following the 1994-1999 programme, a second phase of the research – a feasibility study for the years 2000 and 2001 – began in July 2000. The priority for this phase of the research is feeding ecology, involving studies on prey consumption by cetaceans, prey preferences of cetaceans, and ecosystem modeling.

Significant observations and new findings were made during 2000, the first year of this research programme, concerning the distribution of minke and Bryde's whales and the species and size of the fish, krill and squid they consume. While the results of the previous whale research programme in the northwestern Pacific showed that minke whales feed mainly on Pacific saury during midsummer, the research in 2000 showed that minke whales prey on Japanese anchovy, common squid and walleye pollock, thus re-confirming the notion that minke whales are in competition with fisheries and that its food habits are variable and flexible. Research in 2000 also showed that Bryde's whale distribution areas coincided with the location of skipjack tuna fishing grounds. Since Bryde's whales feed on Japanese anchovy, which is also the prey of skipjack, the results suggest that Bryde's whale and skipjack tuna compete over anchovy as prey. The stomach of each sampled sperm whale contained a great amount of different squid species. The ongoing analysis of the stomach contents, including squid beaks, will contribute to the clarification of the feeding ecology of sperm whales.

Tsutomu TAMURA

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

Tel. +81-3-3536-6521
Fax +81-3-3536-6522
e-mail tamura@i-cetacean-r.or.jp

1. INTRODUCTION

[1] Seventy-nine species of cetaceans (whales, dolphins and porpoises) inhabit the world, among which 75 species live in the sea. As cetaceans are mammals, they need a large amount of energy to maintain their body temperature in the aquatic environment. Thus, they must consume large amounts of prey. The cetaceans are top predators of the food web, playing an important role in the marine ecosystem. It is important to elucidate the total prey consumption of cetaceans in the world, because these results can provide information useful to address the issue of long-term sustainability of marine living resources. This kind of work has practical difficulties, because the data available are incomplete and many assumptions are needed for such a study. The quantitative data on feeding ecology of top predators are insufficient. Some researchers have estimated the food consumption of cetaceans based on techniques such as energy-requirements calculations (Hinga, 1979; Lockyer, 1981; Innes *et al*., 1986; Sigurjónsson and Víkingsson, 1998; Tamura and Fujise, 2000a). Furthermore, in recent years, some scientists have tried to understand competition between fish stock and cetaceans in small areas using statistical simulation models.

[2] This study presents the daily and annual prey consumption of marine cetaceans based on available, recent abundance estimates, average body weight of each species, and three methods used previously (Tamura and Ohsumi, 2000). This presentation is carried out for three regions: the Southern Hemisphere including Indian Ocean (SHIO), the North Pacific (NP) and the North Atlantic (NA). Furthermore, the competition between cetaceans and fisheries in each region is presented. In addition, the author will introduce an assessment of the competition between cetaceans (minke whales and Bryde's whales) and fisheries in the Northwest Pacific, based on JARPN (The Japanese Whale Research Program under Special Permit in the Western North Pacific) and JARPN II's results.

2. MATERIALS AND METHODS

2.1 Regional assessments of prey consumption by marine cetaceans in the world

2.1.1 Available abundance estimates

[3] The Scientific Committee of the International Whaling Commission (IWC) uses estimates of current abundance based on direct methods such as sighting surveys. However, such data are limited for species and regions, and some of them are were old. For this study, the author used data from a recent report (Tamura and Ohsumi, 2000).

[4] In SHIO, the figures on abundance of 15 species out of 55 species of marine cetaceans found in this region are shown in Table 1-1. For NP, the figures on abundance of 25 species out of 40 species of marine cetaceans found in this region are shown in Table 1-2, and for NA, figures on abundance of 19 species out of 39 species of marine cetaceans in this region are shown in Table 1-3.

1.1.2 Estimation of biomass of cetaceans based on abundance and average body weight

[5] Biomass estimates are based on recent abundance estimates on each cetacean species from published sources, and estimated average body weights by use of the formula by Trites and Pauly (1998). They estimated the mean body weight by sex in each species. For sperm whales in the Southern Hemisphere, the average male weight was used. Biomass of each cetacean species in three ocean regions was calculated by multiplying abundance by average body weight.

1.1.3 Estimation of daily prey consumption of cetaceans

[6] Daily prey consumption was calculated using the rate of prey intake per body weight of each cetacean species per day (feeding rate: % of body weight) and average body weight. This terminology of 'the feeding rate' was proposed by Sergeant (1969). In this study, the daily prey consumption and feeding rate for each species was estimated based on three methods.

Method 1: Estimation of daily prey consumption from average body weight

[7] Innes *et al*.(1986) proposed the following method to estimate daily prey consumption of a cetacean from its average body weight:

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

where I is daily prey consumption (kg per day) and M is average body weight (kg).

Method 2: Estimation of daily prey consumption from the standard metabolism

[8] Sigurjónsson and Víkingsson (1998) proposed a method for estimation of daily prey consumption from the standard metabolism of each cetacean species. The daily prey consumption is given by:

$$D = 206.25M^{0.783}\ ;\ I = D/1\,110.3 \text{ (for baleen whales in Southern Hemisphere)} \quad (2)$$

$$D = 206.25M^{0.783}\ ;\ I = D/1\,300 \quad (3)$$

(for baleen whales in Northern Hemisphere and toothed whales in the world)

where D is daily caloric value of prey intake (kcal per day), M is average body weight (kg) and I is daily prey consumption (kg). The present writer assumed that estimated caloric values of prey were 1 110.3 kcal/kg for baleen whales in Southern Hemisphere (Clark, 1980) and 1 300 kcal/kg for baleen whales in Northern Hemisphere and toothed whales in the world (Steimle and Terranova, 1985).

Method-3 Estimation of daily prey consumption from Klumov's formula

[9] Klumov (1963) proposed a method for estimating daily prey consumption from the average body weight of each cetacean species, deriving the daily prey consumption from the formula:

$$I = 0.035M \quad (4)$$

where I is daily prey consumption (kg per day), and M is average body weight (kg).

2.1.4 Estimation of annual prey consumption of cetaceans

[10] The author recalculated the annual prey consumption (C) by each cetacean species in three ocean regions from available abundance estimates (N) and daily prey consumption rates (I) obtained from above three methods by applying the formula:

$$C = 365\ N\ I \quad (5)$$

2.1.5 Composition of prey species

[11] Moreover, the annual prey consumption in each prey category was calculated using the assumed prey composition (% of weight) in each region from published sources (e.g. Pauly *et al*., 1998). The categories of prey species were divided into three groups, namely fish (pelagic and mesopelagic), cephalopods (squids) and crustaceans (copepods, amphipods and krill).

2.1.6 Catch of marine organisms by fisheries in the worlds

[12] To compare the amount of prey consumed by cetaceans with the amount of catch by fisheries in the world, the annual catch statistics available from FAO for marine organisms capture by commercial fisheries were used. FAO divides the seas of the world into major fishing areas for statistical purposes (Figure 1), and for this study these statistical areas were aggregated into three ocean regions, namely SHIO (FAO areas 41 (Southwest Atlantic), 47 (Southeast Atlantic), 51 (Western Indian Ocean), 57 (Eastern Indian Ocean), 81 (Southwest Pacific), 87 (Southeast Pacific), and 48. 58. 88 (Southern Oceans)); NP (61 (Northwest Pacific), 67 (Northeast Pacific), 71 (Western Central Pacific) and 77 (Eastern Central Pacific)); and NA (21 (Northwest Atlantic), 27 (Northeast Atlantic), 31 (Western Central Atlantic), 34 (Eastern Central Atlantic) and 37 (Mediterranean and Black Sea)). Figures for fisheries catches excluding inland

fisheries and aquaculture in 1996 were taken from FAO (1998). For the sake of convenience, the three ocean regions have been designated SHIO, NP and NA, respectively. Catch species in 1996 were divided into four groups (fish, cephalopods, crustaceans and others) based on FAO Fishery statistics (Table 2; FAO, 1998). Among them, the category "others" that included seaweed and others was excluded from the analysis as it is not a prey organism of cetaceans.

2.2 Competition between whales and fisheries in the Northwest Pacific based on the results of JARPN and JARPN II

2.2.1 Resarch area and periods

[13] The JARPN research areas between 1994 and 1999 and those of JARPN II in 2000 were a part of sub-areas 7, 8 and 9, excluding the EEZ of foreign countries, which were established by the IWC (Figure 2; IWC, 1994). The whales were sampled according to sampling procedures described by Kato *et al* (1989). Sampled whales were immediately transported to a research base vessel, where biological measurements and sampling was carried out. A summary of the survey months, years and sample size in each sub-area is shown in Table 3.

2.2.2 Sampling of stomach contents and data analyses

[14] After the stomach contents of minke, Bryde's and sperm whales were sampled, each stomach's contents (with and without liquid) were weighed to the nearest 0.1 kg. Then, for minke and Bryde's whales, a sub-sample (3-4 kg) of forestomach contents was removed and frozen for later analyses. For sperm whales, forestomach contents were removed and frozen for later analyses. In the laboratory, prey species in the sub-samples were identified to the lowest taxonomic level possible, and the relative frequency of occurrence of each prey species and the relative prey importance by weight of each prey species were calculated.

3. RESULTS

3.1 Regional assessments of prey consumption by marine cetaceans in the world

3.1.1 Southern Hemisphere including Indian Ocean

[15] Estimated annual prey consumption of cetaceans is given in Table 4-1. Baleen whales consume 72-148 million tons of crustaceans (mainly *Euphausia superba*). Cephalopods (mainly squids) were consumed only by toothed whales, and amounted to 27-56 million tons. The annual crustacean consumption by minke whales accounted for 41-55% of total annual crustacean consumption by baleen whales. The annual cephalopod consumption by sperm whales accounted for 76-90% of total annual cephalopod consumption by cetaceans. Total fish consumption by cetaceans was 18-32 million tons, accounting for 66-120% of commercial fisheries fish catch (27 million tons) in 1996. Total cephalopod consumption by cetaceans was 27-56 million tons, which was one order of magnitude greater than the commercial catch of cephalopods (1 million tons) in 1996.

3.1.2. North Pacific

[16] Estimated annual prey consumption of cetaceans is given in Table 4-2. Baleen whales consumed 2-4 million tons of fish and 14-35 million tons of crustaceans (copepods and krill). Fin whales accounted for 9-14% and minke whales for 47-58% of total annual fish consumption by baleen whales. Consumption by toothed whales was 17-29 million tons of fish and 22-28 million tons of cephalopods (squids). Sperm whales consumed 12-44% and common dolphins 13-22% of total annual fish consumption by toothed whales. Sperm whales accounted for 36-75% of total annual cephalopod consumption by toothed whales. Total fish consumption by cetaceans was 21-31 million tons, equivalent to 67-99% of the commercial fisheries fish catch (31 million tons)

in 1996. Total cephalopod consumption by cetaceans was 22-28 million tons, one order of magnitude greater than the commercial cephalopod catch (1.6 million tons) in 1996.

3.1.3. North Atlantic

[17] Estimated annual prey consumption of cetaceans is given in Table 4-3. Baleen whales consumed 6-11 million tons of fish and 15-41 million tons of crustaceans (copepods and krill). Fin whales accounted for 5-9% and minke whales 68-78% of total annual fish consumption by baleen whales. Toothed whales consumed 9-14 million tons of fish and 24-39 million tons of cephalopods (squids). Sperm whales consumed 60-81% and long-finned pilot whales 15-31% of the total annual fish consumption by toothed whales. Sperm whales accounted for 62-82% of total annual cephalopod consumption by toothed whales. Total fish consumption by cetaceans was 15-25 million tons, equivalent to 87-144% of the commercial fisheries catch (17 million tons) in 1996. Total cephalopod consumption by cetaceans was 24-39 million tons, a value two orders of magnitude greater than the commercial fisheries cephalopod catch (0.4 million tons) in 1996.

3.2 Competition between whales and fisheries in the Northwest Pacific (Results of JARPN and JARPN II)

3.2.1 Geographical and seasonal changes in dominant prey species in forestomach contents

Minke whale

[18] From the 1994 to 1999 results of JARPN, on the Pacific side, Japanese anchovy was the most important prey species in May and June, while Pacific saury was the most important one in July and August in sub-areas 7, 8 and 9. However, in JARPN II, in sub-area 7 during August and September, Walleye pollock was the most important prey species. Furthermore, Japanese anchovy and Japanese common squid were also important prey species. At the same time, Pacific saury consumed by minke whales was low proportion (Table 5). In sub-area 9, Japanese anchovy was the most important prey species in August in 2000 (Table 5).

Bryde's whale

[19] In JARPN II, Japanese anchovy was most important prey species; krill were also important prey species in sub-area 7 (Table 5).

Sperm whale

[20] In JARPN II, deep-sea squid was the most important prey species in sub-area 7 (Table 5).

3.2.2 Competition between minke, Bryde's whales and fisheries

Minke whale

[21] Tamura and Fujise (2000b) showed the relationship between minke whales and fishing grounds of Pacific saury in summer near the Pacific side of Hokkaido (Figure 3).

Bryde's whale

[22] Figure 4 shows the fishing grounds of skipjack tuna and the positions of Bryde's whales sightings in sub-area 7 in the survey. Most of the Bryde's whales sightings occurred close to these fishing grounds; they feed mainly on Japanese anchovy.

4. DISCUSSION

4.1 Southern Hemisphere including Indian Ocean

[23] The total fish consumption by cetaceans was 18-32 million tons, equivalent to 66-120% of current commercial fisheries catch of fish. Northridge (1984) reported the distribution and prey species of cetaceans in SHIO, noting that the population and prey species of most cetaceans were

unknown. Most baleen whales (blue whale, fin whale, sei whale, minke whale and humpback whale) feed mainly on krill (mainly *Euphausia superba*), and their feeding grounds are in the Antarctic (Kawamura, 1980a; 1994).

[24] Nemoto (1959) categorized the feeding types of baleen whales in the Southern Hemisphere as follows:

- Euphausiid feeder: blue whale, fin whale, humpback whale and sei whale;
- Amphipod feeder: sei whale;
- Copepod feeder: right whale, sei whale; and
- Fish feeder: Bryde's whale.

[25] Minke whale is considered to be an euphausiid feeder (Horwood, 1990; Ichii and Kato, 1991; Tamura, 1998). Northridge (1984) stated that these baleen whales, excluding Bryde's whale, did not mainly feed on fish, and no interactions with fisheries were likely. Bryde's whale tends to stay in warmer waters. They are known to include some commercial fish species as prey. Best (1967) reported that they consumed 47% fish and 53% euphausiids in South Africa. Their fish prey included some commercial species, such as pilchard (*Sardinops ocellata*), anchovy (*Engraulis capensis*) and mackerels (*Trachurus* spp.). Best (1977) found that the inshore form of Bryde's whale eat mainly fish, especially pilchard (*S. ocellata*), anchovy (*E. capensis*) and horse mackerel (*Trachurus capensis*). Kawamura (1980b) reported that they feed mainly on krill (e.g. *Euphausia diomedeae*, *E. recurva* and *Thysanoessa gregaria*) in the South Pacific and Indian Ocean. Northridge (1984) stated that this species would seem to have some degree of competition with fisheries, but no conflict was evident at that time. For almost all small cetaceans, their population sizes and prey species are unknown. However, their main prey species seemed to be pelagic and mesopelagic fish and squid. Hence, there are some anecdotal information of interactions between fish fisheries and cetaceans such as killer whale, false killer whale, and common dolphin in the region.

[26] As for sperm whale, their biomass is large (5 630 thousand tons), occupying 29.4% of the total biomass of cetaceans in the region. However, this value refers only to the Antarctic, while sperm whales are found in all oceans, from equatorial waters to polar regions. Their prey species spectrum is dominated by mesopelagic squids, for which there is no commercial fishery. However, they eat mainly fish in regions such as New Zealand (Kawakami, 1980). Even though the share of commercial fish is small in their prey consumption, the absolute quantity of fish consumption is very large because of their huge biomass. There may be some interactions between sperm whales and fish fisheries. Furthermore, if either the commercial fisheries for squid or bottom fish or the abundance of sperm whales expand in the future, there may be some interactions between sperm whales and squid or bottom fish fisheries.

[27] In the Antarctic, baleen whales, excluding Bryde's whales, feed mainly on krill during austral summer, where the krill fisheries decreased recently because of diminishing markets. Of these species of cetaceans, the minke whales play an important role in the prey web in the Antarctic in particular. Armstrong and Siegfried (1991) indicated that the minke whales consume 95% of the total biomass of krill that is consumed by baleen whales in the Antarctic. This study showed that the annual crustacean consumption by minke whales was 42-64 million tons, and that this amounted to 40-54% of total annual crustacean consumption by cetaceans in the Southern Hemisphere. Tamura *et al.* (1997) estimated the prey consumption of krill by minke whales around the Ross Sea in the Antarctic to be an order of magnitude greater than the estimated consumption by Adelie penguins and crabeater seals. The writer considers that there was direct competition for krill among cetaceans, seals and seabirds in austral summer in the Antarctic. Krill fishery appears to be of minor importance now. However, any development of this fishery could lead to increased competition between cetaceans and fisheries. For better understanding of this phenomenon, it will be necessary to have more abundance estimates of cetaceans and quantitative

information of prey species to assess the interaction between fisheries and cetaceans, especially as – as for the Indian Ocean – there is no available abundance information for cetaceans.

4.2 North Pacific

[28] The total fish consumption by cetaceans was 21-31 million tons, accounting for 67-99% of commercial fish catches in recent years. In contrast to the Southern Hemisphere, many species of baleen whales feed on various pelagic prey species of zooplankton, squid and fish (Kawamura, 1980a).

[29] Nemoto (1959) categorized the feeding types of baleen whales in the North Pacific as:

- Euphausiid feeders: blue whale, fin whale, Bryde's whale, humpback whale and minke whale;
- Copepod feeders: right whale, sei whale and fin whale;
- Fish feeders: fin whale, Bryde's whale, humpback whale and minke whale; and
- Squid feeders: fin whale, sei whale.

[30] Northern right whales and bowhead whales feed on small copepods (e.g. *Calanus glacialis* and *C. hyperboreus*), and blue whales feed on krill (e.g. *Euphausia pacifica, Thysanoessa inermis* and *T. longipes*). Fin whales feed on many kinds of fish, mostly small, schooling fish such as Japanese anchovy (*Engraulis japonicus*), Pacific saury (*Cololabis saira*), chub mackerel (*Scomber japonicus*), Pacific herring (*Clupea pallasii*) and walleye pollock (*Theragra chalcogramma*), and they also eat a variety of pelagic zooplankton and even some squid, such as Japanese flying squid (*Todarodes pacificus*). Their prey species overlap with some commercial species and their biomass is larger than other baleen whales, so there may be interactions to some extent in the North Pacific.

[31] Humpback whale also feed on many kinds of fish, mostly small, schooling fish such as capelin (*Mallotus villosus*), chum salmon (*Oncorhynchus keta*), sand lance (*Ammodites hexapterus, A. personatus*), Pacific herring (*Clupea harengus*) and walleye pollock, as well as a variety of pelagic krill (e.g. *Euphausia pacifica*) (Nemoto, 1959; Kawamura, 1980a). Northridge (1984) stated that no interactions with fisheries were apparent. However, their prey species also overlap with some commercial catch, and thus there may be interactions to some extent in the North Pacific.

[32] Sei whales feed on copepods (*Calanus* spp.), but they also feed on some small, schooling fish such as Japanese anchovy, Japanese pilchard (*Sardinops melanostictus*) and Japanese flying squid. Bryde's whales feed on krill, but they also feed on some small, schooling fish such as Japanese anchovy and Japanese pilchard (Nemoto, 1959; Kawamura, 1980a). There is at least one report of a Bryde's whale that had been feeding upon penaeid shrimp in the South China Sea (Persons *et al*., 1999). Prey species of sei whales and Bryde's whales also varied both geographically and temporally in the North Pacific. Northridge (1984) stated that there appear to be no reported conflicts with fisheries. However, their prey species overlap with some commercial fisheries catch, so there may be an interaction to some extent in the North Pacific. In JARPN II, most of the Bryde's whales sightings occurred close to these fishing grounds; they feed mainly on Japanese anchovy and did not feed on skipjack tuna. The skipjack tuna is reported to feed on the Japanese anchovy (Kawasaki, 1965). There seems a suggestion of a relationship between Bryde's whales and skipjack tuna in summer in the western North Pacific.

[33] Minke whales feed on various pelagic prey species of zooplankton, squid and fish (Nemoto, 1959; Kawamura, 1980a; Tamura and Fujise, 2000b). Prey species varied both geographically and temporally. For example, Kasamatsu and Tanaka (1992) reported that the composition of prey of minke whales caught off the Sanriku-Hokkaido area changed greatly between 1965 and 1987. They suggested that chub mackerel was the dominant prey species in 1968-1976, but Japanese pilchard was then the dominant prey species after 1977. Tamura *et al.* (1998) examined

in detail the stomach contents of minke whales caught under JARPN, and they noted that dominant prey species have changed to Pacific saury and Japanese anchovy in recent years. The minke feed on pelagic zooplankton and pelagic schooling fish. Tamura and Fujise (2000b) reported that most of the minke whale sightings occurred close to Pacific saury fishing grounds (Figure 3). Tamura and Fujise (2000a) estimated the seasonal consumption of Pacific saury by minke whales along the Pacific side of Japan during August and September to be equivalent to 10–21% of the catch of Pacific saury in Japan. Northridge (1984) stated that there was some interaction between this species and fisheries in the North Pacific. The writer considers that there exists direct competition between minke whales and commercial Pacific saury fisheries from summer to autumn in the western North Pacific. In JARPN II, Pacific saury consumed by minke whales was in a low proportion. However, minke feed mainly on Walleye pollock and Japanese common squid, which are very important target species of fisheries in Japan. This research result seems to suggest a relationship between minke whales and Walleye pollock and Japanese common squid in summer in the western North Pacific, in addition to the relationship between minke whale and Pacific saury fishery.

[34] Wade and Gerrodette (1993) and Miyashita (1990, 1991, 1993a, b) estimated the population of small cetaceans in the North Pacific, where the main prey species seemed to be fish and squids, both pelagic and mesopelagic. There are at least some reports of interactions between fish fisheries and cetaceans such as killer whale, false killer whale, Dall's porpoise and common dolphin in the region. Abundance estimate of small cetaceans and quantitative data of prey species are necessary to assess the interaction between fisheries and small cetaceans in the future. As for sperm whale, their biomass is large (2 311 thousand tons), occupying 34.9% of total biomass of cetaceans. Their prey species is dominated by mesopelagic squid, for which there seems to be no commercial fish fishery. However, they eat some commercial pelagic fish, such as sardines, salmon (*Onchorhynchus gorbusha*), Pacific saury and Chub mackerel in the western North Pacific (Kawakami, 1980). Furthermore, Rice (1989) reported that sperm whales fed on black cod, or sablefish, from longlines being retrieved by fisherman in the eastern Gulf of Alaska. Although the fish quantity is a relatively small part of their consumption, it is conceivable that the total quantity of fish consumption is very large, because their biomass is so large. So there may be some interactions between sperm whales and fisheries. Furthermore, if either the commercial fisheries of squid or bottom fish or the abundance of sperm whales expand, there may be some interactions between sperm whale and the squid and bottom fish fisheries.

[35] In the Bering Sea, Lowry and Frost (1985) tried to clarify the biological situation by assessing potential interactions between marine mammals and commercial fisheries. They calculated ranked value based on diet composition, feeding strategy, importance, population size, and so on. However, there was some question that competition with fisheries occurred, because of insufficient knowledge as to how marine mammals eat their prey (especially in relation to geographical, seasonal and yearly changes of prey species) and how the energy obtained from feeding relates to growth, maturation, reproduction and survival. Trites *et al.* (1997) tried to assess the degree of competition between fisheries and marine mammals in the Pacific Ocean (FAO areas 61, 67, 71, 77, 81, 87 and 88). They calculated the total annual prey consumption of marine mammals as 150 million tons, equivalent to roughly three times the commercial fisheries catch. However, as the prey consisted primarily of mesopelagic squid and fish, they proposed that the most important consumers of fish and competitors of commercial fisheries were probably other predator fish, not marine mammals. However, they considered that there was indirect competition between fisheries and cetaceans in the Pacific Ocean. Furthermore, the available primary production for sustaining fish and marine mammals being reduced, they suggested that the commercial fisheries could not continue to expand as previously.

4.3 North Atlantic

[36] The total fish consumption by cetaceans was 15-25 million tons, equating to 87-144% of the commercial fisheries fish catch in recent years. In contrast to the Southern Hemisphere, many

species of baleen whales feed on various pelagic prey species of zooplankton and fish similar to those in North Pacific (Kawamura, 1980a). Northern right whales and bowhead whales feed on small copepods, while blue whales feed on krill (e.g. *Meganyctiphanes norvegica, Thysanoessa inermis*). Northridge (1984) stated that these species did not feed on fish, and was unlikely to be affected by commercial fisheries. However, fin whales consume various pelagic prey species of zooplankton, squid and fish. They feed on many kinds of fish, such as capelin (*Mallotus villosus*), sand lance, mackerel, herring, cod and lantern fish (Nemoto, 1959; Kawamura, 1980a). Prey species of fin whales vary both geographically and temporally in the North Atlantic. Perkins and Beamish (1979) reported that the fin whales feed mainly on capelin in Newfoundland. Northridge (1984) stated that there were no interactions with fisheries. However, there was the possibility of interactions with fisheries, because their biomass was larger than other baleen whales.

[37] Sei whales feed on copepods (*Calanus* spp.), but they also feed on some small, schooling fish and squids in other regions. Bryde's whales feed mainly on krill, but they also feed on some small, schooling fish in the North Pacific and Southern Hemisphere (Nemoto, 1959; Best, 1967, 1977; Kawamura, 1980a, b). Northridge (1984) stated that there appears to be no reported conflicts with fisheries. However, they consume some small, schooling fish in other regions, so there may be the possibility of interaction with fisheries.

[38] Humpback whales feed on many species of fish, mostly small, schooling fish such as capelin, as well as a variety of pelagic krill (e.g. *M. norvegica, T. inermis*). Perkins and Beamish (1979) reported that the humpback whale feed mainly on capelin in Newfoundland. Northridge (1984) stated that no interactions with fisheries were apparent. However, as their prey species overlap with some commercial catches, there may be an interaction to some extent in the North Atlantic.

[39] Minke whales eat various pelagic prey species of zooplankton and fish. Prey species of minke whales varied both geographically and temporally. In this region, feeding ecology of minke whales has already been studied, and their diet varies according to season, geographical area and prey availability. Although krill are the important prey species, a wide range of fish species, among which capelin, herring and sand lance are predominant, are prey species. In the North Sea, mackerel (*Scomber scombrus*) and sand lance are thought to be the dominant prey species. In the Northeast Atlantic and in the Barents Sea, a variety of prey is consumed, and the most important of which are krill, capelin and herring, but gadoids, especially cod (*Gadus morhua*), saithe (*Pollachius virens*) and haddock (*Melanogrammus aeglefinus*), are also significant prey items (Haug *et al*., 1995; 1996). In recent years, increased attention has been paid to interactions between commercial fisheries and minke whales in the North Atlantic. For example, consumption of Atlantic herring by minke whales was estimated to be 633 000 t/yr in a part of the Northeast Atlantic. This is more than half of the total Norwegian catch of herring (Folkow *et al*., 1997). Furthermore, Schweder *et al*. (2000) calculated using a simulation model that the net loss to the herring and cod fishery is some 5 000 kg of herring and cod due to direct and indirect effects from the catches of an extra minke whale in the Barents Sea. There seems to be evidence enough that there is direct competition between minke whales and commercial fisheries in the North Atlantic.

[40] The population and prey species of almost al small cetaceans are unknown (Northridge, 1984). Their main prey species seems to be pelagic and mesopelagic fish and squids. However, as for the North Pacific, there are some interactions between fish fisheries and cetaceans such as killer whale, false killer whale, harbour porpoise, bottlenose dolphin, white beaked dolphin, white whale and common dolphin in the region. There is need for more abundance estimates of small cetaceans, as well as quantitative data of prey species, in order to assess the interaction between fisheries and small cetaceans in the future.

[41] Sperm whale have a large biomass (3 519 000 t), occupying 42.9% of total biomass of cetaceans, similar to other regions. Their dominant prey species is mesopelagic squid, for which

there is no commercial fishery, although it has been reported that they eat mainly fish in Iceland waters (Sigurjónsson and Víkingsson, 1998). There may be some interactions between sperm whales and fish fisheries. Furthermore, if either the commercial fisheries of squid or bottom fish or the population of sperm whales expand, there will be interactions between sperm whales and squid or bottom fish fisheries.

[42] There seems to be evidence enough that there is direct competition between some cetaceans and commercial fisheries in the North Pacific and North Atlantic. However, it will be necessary to have more available abundance estimates of cetaceans and quantitative information on prey species to assess the interaction between fisheries and cetaceans. Furthermore, there is need to understand the potential for cetaceans to have an impact on commercial fisheries, either directly (by consuming commercial species such as herring, Pacific saury and anchovy), or indirectly (by competing for prey resources). using simulation models for the Antarctic, Barents Sea, and so on.

[43] Growing concerns about the possible consequences of competition between marine mammals and fisheries make this an increasingly important issue in fisheries management and conservation in the future. For this purpose, comparative research on the seasonal, local and annual distribution and abundance of cetaceans and their prey should be extended. This should make it possible to develop a blanket, multi-species management plan for marine organisms that also involves marine mammals such as whales, dolphins, porpoises and pinnipeds, in order to allow a more realistic fisheries management strategy, aiming for both short- and long-term sustainability of marine organisms, including marine mammals and their conservation in the world.

REFERENCES CITED AND SOURCES USED

Armstrong, A.J., & Siegfried, W.R. 1991. Consumption of Antarctic krill by minke whales. *Antarctic Science,* **3** (1): 13-8.

Best, P.B. 1967. Distribution and feeding habits of baleen whales off the Cape Province. *Investl. Rep. Div. Sea Fish. S. Afr.,* **57**: 1-44.

Best, P.B. 1977. Two allopatric forms of Bryde’s whale off South Africa. *Rep. Int. Whal. Commn* (Special Issue 1): 10-38.

Braham, H.W. 1991. Endangered whales: status update. (unpublished). 56 p.

Buckland, S.T., Cattanach, K.L., Gunnlaugsson, Th., Bloch, D., Lens, S., & Sigurjónsson, J. 1992. Abundance and distribution of long-finned pilot whales in the North Atlantic, estimated from NASS-87 and NASS-89 data. Paper SC/44/SM19 presented to the IWC Scientific Committee, July 1992. (unpublished). 17 p.

Buckland, S.T., Cattanach, K.L., & Hobbs, R.C. 1993. Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987-1990. *Int. N. Pac. Fish. Comm. Bull.*, **53**: 387-407.

Butterworth, D.S., Borchers, D.L., Chalis, S., DeDecker, J.B., & Kasamatsu, F. 1994. Estimates of abundance for Southern Hemisphere blue, fin, sei, humpback, sperm, killer and pilot whales from the 1978/79 to 1990/91 IWC/IDCR sighting survey cruises, with extrapolation to the area south of 30°S for the first five species based on Japanese scouting vessel data. Paper SC/46/SH24 presented to the IWC Scientific Committee, May 1994. (unpublished). 125 p. [Available from the author].

Calambokidis, J., Steiger, G.H., Straley, J.M., Quinn, T., Herman, L.M., Cerchio, S., Salden, D.R., Yamaguchi, M., Sato, F., Urban, J.R., Jacobsen, J., von Ziegesar, O., Balcomb, K.C., Gabriele, C.M., Dahlheim, M.E., Higashi, N., Ford, J.K.B., Miyamura, Y., de Guevara, P.L., Mizroch, S.A., Schlender, L., & Rasmussen, K.R. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final contr. rep. conducted by Cascadia Research Collective under Contr. 50ABNF500113 for NMFS Southwest Fisheries Science Center, La Jolla, Calif., 72 p.

Clark, A. 1980. The biochemical composition of krill, *Euphausia superba* DANA from South Georgia. *J. Exp. Mar. Biol. Ecol.*, **43**: 221-236.

Dawson, S.M., & Slooten, E. 1988. Hector's dolphin, *Cephalorhynchus hectori*: distribution and abundance. *Rep. Int. Whal. Commn* (Special Issue 9): 315-324.

FAO. 1997. Review of the state of world fishery resources: marine fisheries. *FAO Fisheries Circular,* No.920. 173 p.

FAO. 1998. *Fishery statistics capture production.* FAO yearbook. Vol.82. 678 p.

Folkow, L.P., Haug, T., Nilsen, K.T., & Nordøy, E.S. 1997. Estimated prey consumption of minke whales *Balaenoptera acutorostrata* in Northeast Atlantic waters in 1992-1995. Document ICES CM 1997/ GG:01. (unpublished). 26 p.

Gambell, R. 1976. World whale stocks. *Mammal Rev.*, **6**(1): 41-53.

Haug, T., Gjøæter, H., Lindstrøm, U., Nilssen, K.T., & Røttingen, I. 1995. Spatial and temporal variation in northeast Atlantic minke whale *Balaenoptera acutorostrata* feeding habits. p.225-239, *in*: A.S. Blix, L. Walløe and Ø. Ulltang (eds) *Whales, seal, fish and man*. Amsterdam: Elsevier. 720 p.

Haug, T., Lindstrøm, U., Nilssen, K.T., Røttingen, I., & Skaug, H.J. 1996. Diet and food availability for northeast Atalantic minke whales, *Balaenoptera acutorostrata. Rep. Int. Whal. Comm.,* **46**: 371-82.

Hinga, K.H. 1979. The prey requirements of whales in the Southern Hemisphere. *Deep-Sea Research,* **26**A: 569-577.

Hobbs, R.C., & Rugh, D.J. 1999. The abundance of gray whales in the 1997/98 southbound migration in the eastern North Pacific. Paper SC/51/AS10 presented to the IWC Scientific Committee, May 1999 (unpublished). 13 p.

Horwood, J. 1990. *Biology and exploitation of the minke whale*. Boca Raton FA: CRC Press. 238 p.

Ichii, T., & Kato, H. 1991. Food and daily food consumption of southern minke whales in the Antarctic. *Polar Biol.,* **11**: 479-487.

Innes, S., Lavigne, D.M., Eagle, W.M., & Kovacs, K.M. 1986. Estimating feeding rates of marine mammals from heart mass to body mass ratios. *Marine Mammal Science*, **2**: 227-229.

IWC [International Whaling Commission]. 1979. Report of the Scientific Committee on protected species. Annex G, Appendix I. *Rep. Int. Whal. Comm.,* **29**: 84-86.

——— 1980. Report of special meeting on Southern Hemisphere sei whales. *Rep. Int. Whal. Comm.,* **30**: 493-511.

——— 1984. Report of the Scientific Committee, Annex E2. Report of the sub-committee on Northern Hemisphere minke whales. *Rep. Int. Whal. Comm.,* **34**: 102-111.

——— 1986a. Report of the workshop on the status of right whales. *Rep. Int. Whal. Comm.,* (Special Issue 10): 1-34.

——— 1991a. Report of the Scientific Committee, Annex E. Report of the sub-committee on Southern Hemisphere minke whale. *Rep. Int. Whal. Comm.,* **41**: 113-131.

——— 1991b. Report of the Scientific Committee, Annex F. Report of the sub-committee on North Atlantic minke whales. *Rep. Int. Whal. Comm.,* **41**: 113-131.

——— 1992a. Report of the Scientific Committee, Annex E. Report of the Bowhead Whale Assessment Meeting. *Rep. Int. Whal. Comm.,* **42**: 137-55.

——— 1992b. Report of the Scientific Committee, Annex F. Report of the sub-committee on North Pacific minke whale. *Rep. Int. Whal. Comm.,* **42**: 156-77.

——— 1992c. Report of the Scientific Committee, Annex G. Report of the sub-committee on small cetaceans. *Rep. Int. Whal. Comm.,* **42**: 178-233.

——— 1992d. Report of the comprehensive assessment special meeting on North Atlantic fin whales. *Rep. Int. Whal. Comm.,* **42**: 595-606.

——— 1993. Report of the Scientific Committee, Annex G. Report of the sub-committee on small cetaceans. *Rep. Int. Whal. Comm.,* **43**: 130-145.

——— 1995. Report of the Scientific Committee, Annex E. Report of the sub-committee on Southern Hemisphere baleen whales. *Rep. Int. Whal. Comm.,* **45**: 120-41.

——— 1996. Report of the Scientific Committee, Annex E. Report of the sub-committee on Southern Hemisphere baleen whales. *Rep. Int. Whal. Comm.,* **46**: 117-31.

——— 1997a. Report of the Scientific Committee. *Rep. Int. Whal. Comm.,* **47**: 59-112.

——— 1997b. Report of the Scientific Committee, Annex G. Report of the sub-committee on North Pacific Bryde's whales. *Rep. Int. Whal. Comm.,* **47**: 163-8.

——— 1998. Draft report of the workshop on a comprehensive assessment of right whales: a worldwide comparison. Paper SC/50/Rep4 presented to the IWC Scientific Committee, May 1998 (unpublished). 88 p.

——— in press. Report of the Scientific Committee, Annex G. Report of the sub-committee on the Comprehensive Assessment of Other Whale Stocks.

Kasamatsu, F., & Tanaka. 1992. Annual changes in prey species of minke whales taken off Japan 1948-87. *Nippom Suisan Gakkaishi,* **58**: 637-651.

Kasamatsu, F., & Joyce, G. 1995. Current status of odontocetes in the Antarctic. *Antarctic Science,* **7**: 365-379.

Kasuya, T., & Kureha, K. 1979. The population of finless porpoise in the Inland Sea of Japan. *Sci. Rep. Whales Res. Inst.,* **31**: 1-44.

Kato, H., Hiroyama, H., Fujise, Y., & Ono, K. 1989. Preliminary report of the 1987/88 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. *Rep. Int. Whal. Comm.,* **39**: 235-248.

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

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

Kawamura, A. 1980a. A review of prey of Balaenopterid whales. *Sci. Rep. Whales Res. Inst.,* **32**: 155-97.

Kawamura, A. 1980b. Food habits of the Bryde's whales taken in the South Pacific and Indian Oceans. *Sci. Rep. Whales Res. Inst.,* **32**: 1-23.

Kawamura, A. 1994. A review of baleen whale feeding in the Southern Ocean. *Rep. Int. Whal. Comm.,* **44**: 261-71.

Kawasaki, K., 1965. Katsuo no seitai to shigen I. *Suisan kenkyu sousho* 8-1. Suisan sigen hogo-kyoukai 48pp. [in Japanese].

Klumov, S.K. 1963. Feeding and halminth fauna of whalebone whales (Mystacoceti). *Trudy. Inst. Okeanol.,* **71**: 94-194.

Leatherwood, S., Kastelein, R.A., & Hammond, P.S. 1988. Estimate of numbers of Commerson's dolphins in a portion of the northeastern Strait of Magellan, January-February 1984. *Rep. Int. Whal. Comm.,* (special issue 9): 93-102.

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

Lowry, L.F., & Frost, K.J. 1985. Biological interactions between marine mammals and commercial fisheries in the Bering Sea. p.41-61, *in:* J.R. Beddington, R.J.H. Beverton and D.M. Lavigne (eds) *Marine mammals and fisheries.* London: George Allen & Unwin.

Miyashita, T. 1990. Population estimate of Baird's beaked whales off Japan. Paper SC/42/SM28 presented to the IWC Scientific Committee, July 1990 (unpublished). 12 p. [Available from the author].

Miyashita, T. 1991. Stocks and abundance of Dall's porpoises in the Okhotsk Sea and adjancent waters. Paper SC/43/SM7 presented to the IWC Scientific Committee, May 1991 (unpublished). 24 p. [Available from the author].

Miyashita, T. 1993a. Abundance of dolphin stocks in the western north Pacific taken by the Japanese drive fishery. *Rep. Int. Whal. Comm.*, **43**: 417-437.

Miyashita, T. 1993b. Distribution and abundance of some dolphins taken in the North Pacific driftnet fisheries. *Bull. Int North Pacific Fish. Comm.*, **53**: 435-460.

Mizroch, S.A., Rice, D.W., & Breiwick, J.M. 1984. The sei whale. *Balaenoptera borealis*. *Mar. Fish. Rev.*, **46**(4): 25-9.

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

Northridge, S.P. 1984. World review of interactions between marine mammals and fisheries. *FAO Fisheries Technical Paper*, No.251. 197 p.

Odell, D.K. 1992. Sperm whale (*Physeter macrocephalus*), family Physeteridae, order Cetacea. p.168-75, *in:* S.R. Humphrey (ed). *Rare and endangered biota of Florida*. Gainesville FA: Univ. Press.

Ohsumi, S. 1981. Further estimation of population sizes of Bryde's whales in the South Pacific and Indian Ocean using sighting data. *Rep. Int. Whal. Comm.*, **31**: 407-415

Pauly, D. Trites, A.W., Capuli, E., & Christensen, V. 1998. Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Sci.*, **55**: 467-481.

Perkins, J.S., & Beamish, P.C. 1979. Net entanglements of baleen whales in the Inshore fishery of Newfoundland. *J. Fish. Res. Board Can.*, **36**: 521-528.

Persons, E.C.M., Chan, H.M., & Kinoshita, R. 1999. Trace metal and organochlorine concentrations in a pygmy Bryde's whale (*Balaenoptera edeni*) from the South China Sea. *Marine Pollution Bulletin*, **38**: 51-55.

Perry, S.L., DeMaster, D.P., & Silber, G.K. 1999. The great whales: History and status of six species listed as endangered under the U.S. endangered species act of 1973. *Mar. Fish. Rev.* (Special issue) **61**(1): 1-74.

Raftery, A.E., & Zeh, J.E. 1991. Bayes empirical Bayes estimation of bowhead whale population size based on the visual and acoustic census near Barrow, Alaska, in 1986 and 1988. Paper SC/43/PS8 presented to the IWC Scientific Committee, May 1991 (unpublished). 51 p.

Rice, D.W. 1989. Sperm whale – *Physeter macrocephalus* Linnaeus 1758. p.177-233, *in:* S.H. Ridgway and R. Harrison (eds). *Handbook of marine mammals* Vol 4. *River dolphins and the larger toothed whale*. London and San Diego: Academic Press. 442 p.

Schweder, T., Hagen, G.S., & Hatlebakk, E. 2000. Direct and indirect effects of minke whale abundance on cod and herring fisheries: A scenario experiment for the Greater Barents Sea. *NAMMCO Scientific publications*, (in press). 29pp. [Available from the author].

Sergeant, D.E. 1969. Feeding rates of cetacea. *Fisk. Dir. Skr. Ser. HavUnders.*, **15**: 246-258.

Shimada, H., & Miyashita, T. 1997. Population abundance of the western North Pacific Bryde's whale estimated from the sighting data collected from 1988 to 1996. Paper SC/49/NP4 presented to the IWC Scientific Committee, Sep. 1997 (unpublished). 9 p. [Available from the author].

Sigurjónsson, J., & Víkingsson, G.A. 1998. Seasonal abundance of and estimated prey consumption by cetaceans in Icelandic and adjacent waters. *J. Northw. Atl. Fish. Sci.*, **22**: 271-287.

Smith, T.D., Allen, J., Clapham, P.J., Hammond, P.S., Katona, S., Larsen, F., Lien, J., Mattila, D., Palsbøll, P.J., Sigurjónsson, J., Stevick, P.T., & Øien, N. 1999. An ocean-basin-wide mark-recapture study of the North Atlantic humpback whale (*Megaptera novaeangliae*). *Mar. Mamm. Sci.*, **15**: 1-32.

Steimle, F.W., & Terranova, R.J. 1985. Energy equivalents of marine organisms from the continental shelf of the temperate Northwest Atlantic. *J. Northw. Atl. Fish. Sci.*, **6**: 117-124.

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

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

Tamura, T., Fujise, Y., & Shimazaki, K. 1998. Diet of minke whales *Balaenoptera acutorostrata* in the northwestern part of the North Pacific the summer, 1994 and 1995. *Fisheries Science,* **64**: 71-76.

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

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

Tamura, T., & Ohsumi, S. 2000. Regional assessments of prey consumption by marine cetaceans in the world. Paper SC/52/E6 presented to the IWC Scientific Committee, June 2000 (unpublished). 42 p.

Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. *Rep. Int. Whal. Comm.,* Special Issue 1: 98-106.

Trites, A.W., Christensen, V., & Pauly, D. 1997. Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *J. Northw Atl. Fish Sci.,* **22**: 173-187.

Trites, A.W., & Pauly, D. 1998. Estimating mean body masses of marine mammals from maximum body length. *Can. J. Zool.,* **76**: 886-896.

Wade, P.R., & Gerrodette, T. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. *Rep. Int. Whal. Comm.,* 43: 477-493.

Zeh, J.E., Clark, C.W., George, J.C., Withrow, D., Carroll, G.M., & Koski, W.R. 1993. Current population size and dynamics. p.409-489, *in:* J.J. Burns, J.J. Montague and C.J. Cowles (eds). *The bowhead whale*. The Society for Marine Mammalogy, Lawrence, Special Publication No. 2). 787 p

Table 1. Assessments of abundance in each area

1-1. Southern Hemisphere including Indian Ocean

Species	Area	Abundance	CV	95% CI		Source of abundance
Blue whale	South of 30 °S	1,255	0.36-			IWC 1996; Perry *et al.* 1999
Pigmy blue whale		5,000	N.e.			Gambell 1976; Perry *et al.* 1999
Fin whale	South of 30 °S	85,200	N.e.			IWC 1979; Perry *et al* . 1999
Sei whale	South of 30 °S	10,860*1	N.e.			IWC 1980; Mizroch *et al* . 1984; Braham 1991; Perry *et al* . 1999
Bryde's whale		89,000	N.e.			Ohsumi 1981
Minke whale	South of 60 °S	761,000	0.14-0.28	510,000 -	1,140,000	IWC 1991a
Humpback whale	South of 30 °S	10,000	0.27	5,900 -	16,800	IWC in press
Southern right whale		7,000	N.e.			IWC in press; Perry *et al* . 1999
Pygmy right whale		N.D.	N.e.			
Baleen whales total						
Sperm whale	South of 30 °S	209,000*2	0.44-0.46			Butterworth *et al.* 1994; IWC 1995
Pygmy sperm whale		N.D.	N.e.			
Dwarf sperm whale		N.D.	N.e.			
Arnoux's beaked whale		N.D.	N.e.			
Southern bottlenose whale		N.D.	N.e.			
Beaked whales*3	South of 50 °S	**599,000**	0.15	450,000 -	800,000	Kasamatsu and Joyce 1995
Cuvier's beaked whale		N.D.	N.e.			
Shepherd's beaked whale		N.D.	N.e.			
Blainville's beaked whale		N.D.	N.e.			
Gray's beaked whale		N.D.	N.e.			
Ginkgo-toothed beaked whale		N.D.	N.e.			
Hector's beaked whale		N.D.	N.e.			
Pygmy beaked whale		N.D.	N.e.			
True's beaked whale		N.D.	N.e.			
Strap-toothed whale		N.D.	N.e.			
Andrew's beaked whale		N.D.	N.e.			
Longman's beaked whale		N.D.	N.e.			
Irrawaddy dolphin		N.D.	N.e.			
Killer whale	South of 60 °S	58,500*4	0.30			Butterworth *et al.* 1994; IWC 1995
Long-finned pilot whale	South of 60 °S	86,500*5	0.80-1.04			Butterworth *et al.* 1994; IWC 1995
Short-finned pilot whale		N.D.	N.e.			
False killer whale		N.D.	N.e.			
Pygmy killer whale		N.D.	N.e.			
Melon-headed whale		N.D.	N.e.			
Tucuxi		N.D.	N.e.			
Indo-Pacific hump-backed dolphin		N.D.	N.e.			
Rough-toothed dolphin		N.D.	N.e.			
Dusky dolphin		N.D.	N.e.			
Hourglass dolphin	South of 50 °S	144,000	0.17	100,000 -	200,000	Kasamatsu and Joyce 1995
Peale's dolphin		N.D.	N.e.			
Risso's dolphin		N.D.	N.e.			
Bottlenose dolphin		N.D.	N.e.			
Pantropical spotted dolphin		N.D.	N.e.			
Atlantic spotted dolphin		N.D.	N.e.			
Spinner dolphin		N.D.	N.e.			
Clymene dolphin		N.D.	N.e.			
Striped dolphin		N.D.	N.e.			
Common dolphin*6		N.D.	N.e.			
Fraser's dolphin		N.D.	N.e.			
Southern right whale dolphin		N.D.	N.e.			
Commerson's dolphin	the Magellan strait	3,211	N.e.			Letherwood *et al.* 1988
Heaviside's dolphin		N.D.	N.e.			
Hector's dolphin	New Zealand	3,408	N.e.			Dawson and Slooten 1988
Black dolphin		N.D.	N.e.			
Spectaced porpoise		N.D.	N.e.			
Burmeister's porpoise		N.D.	N.e.			
Finless porpoise		N.D.	N.e.			
Toothed whales total						
Cetaceans total						

*1: Estimates of abundance ranged from 9,720 to 12,000.
*2: Estimates of abundance ranged from 128,000 to 290,000.
*3: Arnoux's beaked whale + Southern bottlenose whale
*4: Estimates of abundance ranged from 53,000 to 64,000.
*5: Estimates of abundance ranged from 43,000 to 130,000.
*6: Including long-beaked common dolphin

1-2. North Pacific

Species	Area	Abundance	CV	95% CI		Source of abundance
Blue whale		3,300	0.24-			Wade and Gerrodette 1993; Perry *et al*. 1999
Fin whale		16,125*1	N.e.			Braham 1991; Perry *et al*. 1999
Sei whale		9,110	N.e.			Tillman 1977; Perry *et al*. 1999
Bryde's whale	Western Pacific	21,901	0.19	14,781 -	32,450	Shimada and Miyashita 1997; IWC 1997b
	Eastern tropical Pacific	13,023	0.20			Wade and Gerrodette 1993
Minke whale	Sea of Japan	7,600	0.40			IWC 1984
	Okhotsk Sea-West Pacific	25,000	0.30	12,800 -	48,600	IWC 1992b
Humpback whale		7,000*2	N.e.			Calambokidis *et al*. 1997; Perry *et al*. 1999
Northern right whale	Eastern	300*3	N.e.			IWC 1998; Perry *et al*. 1999
	Okhotsk Sea	900		404 -	2,108	IWC 1998; Perry *et al*. 1999
Bowhead whale	Bering-Chukchi-Beaufort Seas	7,500		6,400 -	9,200	Raftery and Zeh 1991; IWC 1992a
Gray whale	Eastern	26,300	0.03	21,900 -	32,400	Hobbs and Rugh 1999; IWC in press
Baleen whales total						
Sperm whale	Western Pacific	102,112	0.16			Kato and Miyashita 1998
	Eastern tropical Pacific	22,666	0.22			Wade and Gerrodette 1993
Pygmy sperm whale		N.D.	N.e.			
Dwarf sperm whale	Eastern tropical Pacific	11,215	0.29			Wade and Gerrodette 1993
Baird's beaked whale	Western Pacific	3,950	0.28			Miyashita 1990
	Sea of Japan	1,260	0.45			Miyashita 1990
	Okhotsk Sea	660	0.27			Miyashita 1990
Cuvier's beaked whale	Eastern tropical Pacific	20,000	0.27			Wade and Gerrodette 1993
Blainville's beaked whale		N.D.	N.e.			
Ginkgo-toothed beaked whale		N.D.	N.e.			
Hubbs' beaked whale		N.D.	N.e.			
Stejneger's beaked whale		N.D.	N.e.			
Killer whale	Eastern tropical Pacific	8,500	0.37			Wade and Gerrodette 1993
Short-finned pilot whale	Western Pacific	53,608	0.22	34,723 -	82,756	Miyashita 1993a
False killer whale	Western Pacific	16,668	0.26	10,034 -	27,689	Miyashita 1993a
	Eastern tropical Pacific	39,800	0.64			Wade and Gerrodette 1993
Pygmy killer whale	Eastern tropical Pacific	38,900	0.31			Wade and Gerrodette 1993
Melon-headed whale	Eastern tropical Pacific	45,400	0.47			Wade and Gerrodette 1993
Indo-Pacific hump-backed dolphin		N.D.	N.e.			
Rough-toothed dolphin	Eastern tropical Pacific	145,900	0.32			Wade and Gerrodette 1993
Pacific white-sided dolphin		988,000	0.17-1.50	164,000 -	6,790,000	Miyashita 1993b
Risso's dolphin	Western Pacific	83,289	0.18	58,764 -	118,049	Miyashita 1993a
	Eastern tropical Pacific	289,300	0.34			Wade and Gerrodette 1993
Bottlenose dolphin	Western Pacific	168,791	0.26	102,000 -	279,044	Miyashita 1993a
	Eastern tropical Pacific	243,500	0.29			Wade and Gerrodette 1993
Pantropical spotted dolphin	Western Pacific	438,064	0.17	312,285 -	614,503	Miyashita 1993a
	Northeastern	730,900	0.14			Wade and Gerrodette 1993
	Western / southern	1,298,400	0.15			Wade and Gerrodette 1993
	Coastal	29,800	0.35			Wade and Gerrodette 1993
Spinner dolphin	Eastern	631,800	0.24			Wade and Gerrodette 1993
	whitebelly	1,019,300	0.19			Wade and Gerrodette 1993
Striped dolphin	Western Pacific	570,038	0.18	397,435 -	817,602	Miyashita 1993a
	Eastern tropical Pacific	1,918,000	0.11			Wade and Gerrodette 1993
Common dolphin*4	Northern	476,300	0.37			Wade and Gerrodette 1993
	Central	406,100	0.38			Wade and Gerrodette 1993
	Southern	2,210,900	0.22			Wade and Gerrodette 1993
Fraser's dolphin	Eastern tropical Pacific	289,300	0.34			Wade and Gerrodette 1993
Northern right whale dolphin		308,000	0.31-1.13	59,000 -	1,680,000	Miyashita 1993b
Dall's porpoise	Pacific	1,186,000	0.09	991,000 -	1,420,000	Buckland *et al.* 1993
	Okhotsk	554,000				Miyashita 1991, IWC 1993
Harbour porpoise		N.D.	N.e.			
Vaquita		N.D.	N.e.			
Finless porpoise	Seto Inland Sea	5,000				Kasuya and Kureha 1979
White whale	Alaska	5,800				IWC 1992c
	USSR	27,000				IWC 1992c
Toothed whales total						
Cetaceans total						

*1: Estimates of abundance ranged from 14,620 to 18,630.
*2: Estimates of abundance ranged from 6,000 to 8,000.
*3: Estimates of abundance ranged from 100 to 500.
*4: Including long-beaked common dolphin

Table 2. Catch of each group by commercial fisheries in 1996 (FAO 1998).

Study Region	FAO area	Commercial Fisheries Catch in 1996 (tons)				
		Fish	Cephalopoda	Crustacean	Others	Total
Southern	41	1,667,613	716,652	81,745	8,061	2,474,071
Hemisphere	47	1,012,052	7,996	10,933	735	1,031,716
(including	51	3,602,001	94,367	323,099	11,336	4,030,803
Indian Ocean)	57	3,423,452	84,656	267,892	81,473	3,857,473
	81	550,967	73,554	7,203	6,395	638,119
	87	16,761,837	51,705	63,651	150,918	17,028,111
	48,58,88	9,963	28	101,212	0	111,203
	Total	**27,027,885**	**1,028,958**	**855,735**	**258,918**	**29,171,496**
North Pacific	61	19,716,050	1,156,571	2,329,317	1,764,243	24,966,181
	67	2,750,809	627	98,640	30,454	2,880,530
	71	7,505,751	282,374	675,117	375,276	8,838,518
	77	1,240,702	188,331	89,941	49,702	1,568,676
	Total	**31,213,312**	**1,627,903**	**3,193,015**	**2,219,675**	**38,253,905**
North Atlantic	21	1,013,674	38,880	392,028	586,150	2,030,732
	27	10,467,611	58,435	261,751	240,684	11,028,481
	31	1,275,317	31,143	257,865	132,342	1,696,667
	34	3,112,271	192,083	49,843	8,970	3,363,167
	37	1,277,218	60,480	45,193	111,126	1,494,017
	Total	**17,146,091**	**381,021**	**1,006,680**	**1,079,272**	**19,613,064**
Total		**75,387,288**	**3,037,882**	**5,055,430**	**3,557,865**	**87,038,465**

1-3. North Atlantic

Species	Area	Abundance	CV	95% CI		Source of abundance
Blue whale	North Western Atlantic	330*1	N.e.			Braham 1991; Perry *et al*. 1999
Fin whale		47,300		27,723 -	82,031	IWC 1992d
Sei whale		4,000	N.e.			Braham 1991; Perry *et al*. 1999
Bryde's whale		N.D.	N.e.			
Minke whale	North Eastern Atlantic	118,299		96,681 -	144,750	IWC 1997a
	Central Atlantic	28,000		21,600 -	31,400	IWC 1991b
	West Greenland	3,266		1,790 -	5,950	IWC 1991b
Humpback whale	West of Iceland	10,600	0.07	9,300 -	12,100	Smith *et al*. 1999
Northern right whale	North Western Atlantic	400*2	N.e.			IWC 1986a; Perry *et al.* 1999
Bowhead whale		450	N.e.			Zeh *et al*. 1993
Baleen whales total						
Sperm whale		190,000	N.e.			Rice, 1989; Odell, 1992
Pygmy sperm whale		N.D.	N.e.			
Dwarf sperm whale		N.D.	N.e.			
Cuvier's beaked whale		N.D.	N.e.			
Northern bottlenose whale	Iceland	44,300	N.e.			Sigurjónsson and Víkingsson 1998
Blainville's beaked whale		N.D.	N.e.			
Sowerby's beaked whale		N.D.	N.e.			
Gervais' beaked whale		N.D.	N.e.			
True's beaked whale		N.D.	N.e.			
Killer whale	Iceland	5,500	N.e.			Sigurjónsson and Víkingsson 1998
Long-finned pilot whale	Eastern	778,000	0.30	440,000 -	1,370,000	Buckland *et al.* 1992; IWC 1993
Short-finned pilot whale		N.D.	N.e.			
False killer whale		N.D.	N.e.			
Pygmy killer whale		N.D.	N.e.			
Melon-headed whale		N.D.	N.e.			
Atlantic hump-backed dolphin		N.D.	N.e.			
Rough-toothed dolphin		N.D.	N.e.			
White beaked dolphin	Iceland	13,420	N.e.			Sigurjónsson and Víkingsson 1998
Atlantic white sided dolphin	Iceland	38,680	N.e.			Sigurjónsson and Víkingsson 1998
Risso's dolphin		N.D.	N.e.			
Bottlenose dolphin		N.D.	N.e.			
Pantropical spotted dolphin		N.D.	N.e.			
Atlantic spotted dolphin		N.D.	N.e.			
Spinner dolphin		N.D.	N.e.			
Clymene dolphin		N.D.	N.e.			
Striped dolphin		N.D.	N.e.			
Common dolphin*3		N.D.	N.e.			
Fraser's dolphin		N.D.	N.e.			
Harbour porpoise	Iceland	28,510	N.e.			Sigurjónsson and Víkingsson 1998
White whale	Canada	45,700				IWC 1992c
	USSR	9,500				IWC 1992c
Narwhal	Canada-Greenland	28,000		22,000 -	33,500	IWC 1992c
	Northern Hudson Bay	1,300				IWC 1992c
Toothed whales total						
Cetaceans total						

*1: Estimates of abundance ranged from 100 to 560.
*2: Estimates of abundance ranged from 300 to 500.
*3: Including long-beaked common dolphin

Table 3. Sub-areas, months and years of surveys and sample size used in this study.

Minke whale

Sub-area	Survey month	Year	Sample size
7E	May	1998	56
	June	1997	2
	July	1996	1
7W	June	1999	50
	August	1996	15
		2000	6
	September	1996	15
		2000	18
8	May	1998	8
	June	1998	36
	July	1996	11
		1997	31
	August	1996	5
9	May	1997	27
	June	1995	14
		1997	40
	July	1994	8
		1995	61
	August	1994	9
		1995	25
		2000	16
	September	1994	4
11	July	1999	50
	August	1996	30
Total			538

Bryde's whale

Sub-area	Survey month	Year	Sample size
7	August	2000	24
	September	2000	19
Total			43

Sperm whale

Sub-area	Survey month	Year	Sample size
7	August	2000	4
	September	2000	1
Total			5

Table 4. Estimated the annual prey consumption based on three methods.

4-1. Southern Hemisphere including Indian Ocean

Species	Abundance	Method-1			Method-2			Method-3		
		Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean
Blue whale	1,255	0	0	438,574	0	0	714,615	0	0	1,647,144
Pigmy blue whale	5,000	0	0	1,336,962	0	0	2,082,294	0	0	4,400,988
Fin whale	85,200	98,651	0	19,631,460	149,965	0	29,842,936	302,529	0	60,203,295
Sei whale	10,860	2,257	0	1,126,290	2,997	0	1,495,707	4,665	0	2,327,635
Bryde's whale	89,000	4,230,381	0	4,770,429	5,592,243	0	6,306,146	8,626,468	0	9,727,719
Minke whale	761,000	0	0	42,122,913	0	0	50,301,128	0	0	63,833,175
Humpback whale	10,000	0	0	1,545,767	0	0	2,194,957	0	0	3,884,622
Southern right whale	7,000	0	0	907,410	0	0	1,250,816	0	0	2,091,025
Baleen whales total		**4,331,288**	**0**	**71,879,805**	**5,745,205**	**0**	**94,188,600**	**8,933,662**	**0**	**148,115,601**
Sperm whale	209,000	7,447,046	20,851,729	1,489,409	8,908,785	24,944,597	1,781,757	17,981,614	50,348,520	3,596,323
Beaked whales*1	599,000	4,722,578	5,312,900	1,770,967	4,046,717	4,552,556	1,517,519	4,303,611	4,841,563	1,613,854
Killer whale	58,500	797,282	159,456	0	721,575	144,315	0	852,338	170,468	0
Long-finned pilot whale	86,500	304,475	913,424	0	246,510	739,530	0	235,097	705,290	0
Hourglass dolphin	144,000	117,210	117,210	0	65,951	65,951	0	31,273	31,273	0
Commerson's dolphin	3,211	2,295	1,377	918	1,263	758	505	574	345	230
Hector's dolphin	3,408	4,370	3,933	437	2,655	2,389	265	1,458	1,313	146
Toothed whales total		**13,395,256**	**27,360,029**	**3,261,731**	**13,993,455**	**30,450,096**	**3,300,046**	**23,405,967**	**56,098,771**	**5,210,553**
Cetaceans total		**17,726,544**	**27,360,029**	**75,141,536**	**19,738,660**	**30,450,096**	**97,488,647**	**32,339,628**	**56,098,771**	**153,326,154**

*1: Arnoux's beaked whale + Southern bottlenose whale

4-2. North Pacific

Species	Abundance	Method-1			Method-2			Method-3		
		Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean
Blue whale	3,300	0	0	1,153,222	0	0	1,604,869	0	0	4,331,13
Fin whale	16,125	186,707	63,480	3,483,945	242,407	82,418	4,523,319	572,568	194,673	10,684,12
Sei whale	9,110	32,187	11,360	903,143	36,507	12,885	1,024,354	66,520	23,478	1,866,47
Bryde's whale	34,924	392,047	0	3,139,911	442,631	0	3,545,038	799,451	0	6,402,81
Minke whale	32,600	1,263,134	0	541,343	1,288,266	0	552,114	1,914,156	0	820,35
Humpback whale	7,000	186,110	0	895,927	225,709	0	1,086,554	467,708	0	2,251,52
Northern right whale	1,200	0	0	155,556	0	0	183,136	0	0	358,46
Bowhead whale	7,500	0	0	1,176,327	0	0	1,430,124	0	0	2,977,46
Gray whale	26,300	128,700	0	2,445,293	144,504	0	2,745,571	258,236	0	4,906,48
Baleen whales total		**2,188,885**	**74,841**	**13,894,667**	**2,380,025**	**95,303**	**16,695,079**	**4,078,641**	**218,151**	**34,598,84**
Sperm whale	124,778	3,458,788	9,684,606	691,758	3,966,122	11,105,140	793,224	7,380,002	20,664,005	1,476,00
Dwarf sperm whale	11,215	3,786	30,292	3,786	2,409	19,276	2,409	1,447	11,576	1,44
Baird's beaked whale	5,870	69,329	108,945	19,808	65,046	102,215	18,585	82,334	129,383	23,52
Cuvier's beaked whale	20,000	83,009	166,018	27,670	67,007	134,015	22,336	63,543	127,086	21,181
Killer whale	8,500	115,844	23,169	0	104,844	20,969	0	123,844	24,769	0
Short-finned pilot whale	53,608	250,226	375,340	0	196,274	294,411	0	176,141	264,212	0
False killer whale	56,468	306,765	306,765	0	237,742	237,742	0	208,478	208,478	0
Pygmy killer whale	38,900	38,613	64,355	0	24,487	40,812	0	14,610	24,350	0
Melon-headed whale	45,400	47,197	110,127	0	30,166	70,386	0	18,270	42,629	0
Rough-toothed dolphin	145,900	277,643	138,821	46,274	174,822	87,411	29,137	102,886	51,443	17,14
Pacific white-sided dolphin	988,000	1,823,542	981,907	0	1,127,000	606,846	0	639,920	344,572	0
Risso's dolphin	372,589	214,505	1,823,296	107,253	149,354	1,269,511	74,677	106,620	906,271	53,31
Bottlenose dolphin	412,291	1,583,044	527,681	0	1,080,623	360,208	0	742,649	247,550	0
Pantropical spotted dolphin	2,497,164	3,137,698	3,137,698	0	1,899,642	1,899,642	0	1,036,791	1,036,791	0
Spinner dolphin	1,651,100	1,828,235	1,218,823	0	1,050,698	700,465	0	518,883	345,922	0
Striped dolphin	2,488,038	5,530,155	3,225,923	460,846	3,574,558	2,085,159	297,880	2,212,214	1,290,458	184,35
Common dolphin*1	3,093,300	6,253,635	2,680,129	0	3,875,993	1,661,140	0	2,212,947	948,406	0
Fraser's dolphin	289,300	562,492	328,121	46,874	355,468	207,356	29,622	210,661	122,886	17,55
Northern right whale dolphin	308,000	533,654	533,654	0	341,079	341,079	0	206,572	206,572	0
Dall's porpoise	1,740,000	2,304,757	1,676,187	209,523	1,385,379	1,007,549	125,944	745,766	542,375	67,79
Finless porpoise	5,000	4,614	3,691	923	2,652	2,121	530	1,309	1,048	26
White whale	32,800	165,397	23,628	47,256	119,599	17,086	34,171	91,807	13,115	26,231
Toothed whales total		**28,592,930**	**27,169,178**	**1,661,972**	**19,830,964**	**22,270,539**	**1,428,515**	**16,897,696**	**27,553,897**	**1,888,80**
Cetaceans total		**30,781,815**	**27,244,018**	**15,556,639**	**22,210,989**	**22,365,843**	**18,123,594**	**20,976,337**	**27,772,048**	**36,487,64**

*1: Including long-beaked common dolphin

4-3. North Atlantic

Species	Abundance	Method-1			Method-2			Method-3		
		Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean
Blue whale	330	0	0	115,322	0	0	160,487	0	0	433,114
Fin whale	47,300	328,604	0	10,624,850	426,637	0	13,794,588	1,007,720	0	32,582,954
Sei whale	4,000	8,313	0	407,358	9,429	0	462,029	17,181	0	841,861
Minke whale	149,565	4,884,451	0	3,394,279	4,981,637	0	3,461,815	7,401,910	0	5,143,700
Humpback whale	10,600	983,108	0	655,405	1,192,285	0	794,857	2,470,620	0	1,647,080
Northern right whale	400	0	0	51,852	0	0	61,045	0	0	119,487
Bowhead whale	450	0	0	70,580	0	0	85,807	0	0	178,648
Baleen whales total		**6,204,476**	**0**	**15,319,646**	**6,609,988**	**0**	**18,820,629**	**10,897,430**	**0**	**40,946,844**
Sperm whale	190,000	5,266,711	14,746,792	1,053,342	6,039,231	16,909,845	1,207,846	11,237,561	31,465,170	2,247,512
Northern bottlenose whale	44,300	148,098	691,124	148,098	129,560	604,615	129,560	143,379	669,102	143,379
Killer whale	5,500	74,958	14,992	0	67,840	13,568	0	80,134	16,027	0
Long-finned pilot whale	778,000	2,738,511	8,215,534	0	2,217,165	6,651,494	0	2,114,512	6,343,535	0
White beaked dolphin	13,420	42,696	11,386	2,846	28,236	7,530	1,882	18,258	4,869	1,217
Atlantic white sided dolphin	38,680	79,741	30,669	12,268	50,210	19,311	7,725	29,549	11,365	4,546
Harbour porpoise	28,510	32,720	8,725	2,181	18,220	4,859	1,215	8,468	2,258	565
White whale	55,200	278,352	39,765	79,529	201,276	28,754	57,507	154,505	22,072	44,144
Narwhal	29,300	75,760	108,228	32,469	55,015	78,593	23,578	42,577	60,825	18,247
Toothed whales total		**8,737,547**	**23,867,215**	**1,330,733**	**8,806,752**	**24,318,569**	**1,429,314**	**13,828,944**	**38,595,223**	**2,459,611**
Cetaceans total		**14,942,023**	**23,867,215**	**16,650,379**	**15,416,740**	**24,318,569**	**20,249,942**	**24,726,374**	**38,595,223**	**43,406,455**

4-4. Total

Region	Method-1			Method-2			Method-3		
	Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean	Fish	Cephalopoda	Crustacean
Southern Hemisphere including Indian Ocean									
Baleen whales	4,331,288	0	71,879,805	5,745,205	0	94,188,600	8,933,662	0	148,115,601
Toothed whales	13,395,256	27,360,029	3,261,731	13,993,455	30,450,096	3,300,046	23,405,967	56,098,771	5,210,553
Cetacean total	**17,726,544**	**27,360,029**	**75,141,536**	**19,738,660**	**30,450,096**	**97,488,647**	**32,339,628**	**56,098,771**	**153,326,154**
North Pacific									
Baleen whales	2,188,885	74,841	13,894,667	2,380,025	95,303	16,695,079	4,078,641	218,151	34,598,842
Toothed whales	28,592,930	27,169,178	1,661,972	19,830,964	22,270,539	1,428,515	16,897,696	27,553,897	1,888,806
Cetacean total	**30,781,815**	**27,244,018**	**15,556,639**	**22,210,989**	**22,365,843**	**18,123,594**	**20,976,337**	**27,772,048**	**36,487,648**
North Atlantic									
Baleen whales	6,204,476	0	15,319,646	6,609,988	0	18,820,629	10,897,430	0	40,946,844
Toothed whales	8,737,547	23,867,215	1,330,733	8,806,752	24,318,569	1,429,314	13,828,944	38,595,223	2,459,611
Cetacean total	**14,942,023**	**23,867,215**	**16,650,379**	**15,416,740**	**24,318,569**	**20,249,942**	**24,726,374**	**38,595,223**	**43,406,455**
Total									
Baleen whales	12,724,649	74,841	101,094,119	14,735,218	95,303	129,704,308	23,909,733	218,151	223,661,287
Toothed whales	50,725,733	78,396,422	6,254,436	42,631,172	77,039,205	6,157,875	54,132,607	122,247,891	9,558,969
Cetacean total	**63,450,382**	**78,471,262**	**107,348,554**	**57,366,389**	**77,134,508**	**135,862,183**	**78,042,339**	**122,466,042**	**233,220,256**

Table 5. Stomach contents of minke and Bryde's whale revealed by Japan's Whale Research (JARPN and JARPN II) in the western North Paci

Species	Research periods		Sub-area 7			Sub-area 8			Sub-area 9		
			Prey species	FO(%)	WC(%)	Prey species	FO(%)	WC(%)	Prey species	FO(%)	WC(%)
Minke whale	JARPN	May – Jun.	Japanese anchovy	92.56	92.09	Japanese anchovy	91.80	92.67	Japanese anchovy	81.63	81.53
			Krill	1.15	1.16	Pacific saury	4.97	2.21	Pacific saury	12.63	12.79
			Walleye pollack	5.22	5.39	Krill	2.86	2.86	Krill	3.29	3.17
			Others	1.07	1.37	Others	0.37	2.33	Others	2.46	2.56
		July–Sept.	Pacific saury	49.89	51.68	Pacific saury	85.21	82.43	Pacific saury	76.36	76.30
			Krill	35.56	37.33	Japanese anchovy	10.50	8.59	Japanese anchovy	8.41	9.27
			Walleye pollack	6.57	9.03	Krill	2.14	4.43	Krill	9.67	7.59
			Others	7.97	2.06	Others	2.14	4.55	Others	5.55	6.83
	JARPNII	Aug.–Sept.	Japanese anchovy	36.36	34.81				Japanese anchovy	92.42	89.18
			Walleye pollack	35.55	37.15				Krill	5.83	7.77
			Japanese common squid	15.00	14.99				Mackerel	0.42	1.48
			Krill	8.64	6.94				Pacific saury	1.25	1.42
			Pacific saury	4.45	6.10						
Bryde's whale	JARPNII	Aug.–Sept.	Japanese anchovy	71.74	71.60						
			Krill	28.26	28.40						
			Others	0.00	0.00						
sperm whale	JARPNII	Aug.–Sept.	Deep-sea squids	100.00	99.00						
			Deep-sea fishes	0.00	1.00						

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

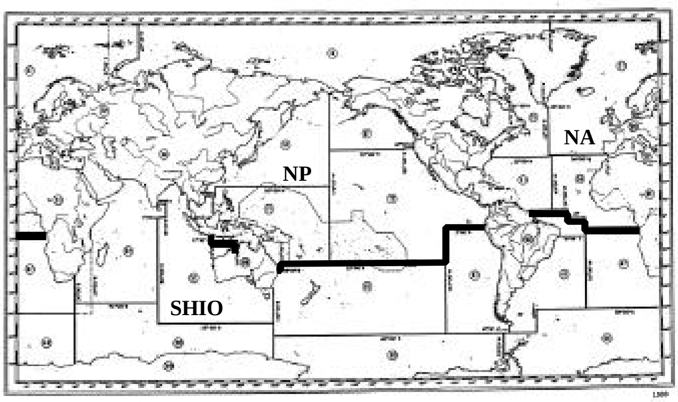

Figure 1. Map of major fishing areas for statistical purposes and ocean regions in this study, based on FAO (FAO, 1997).

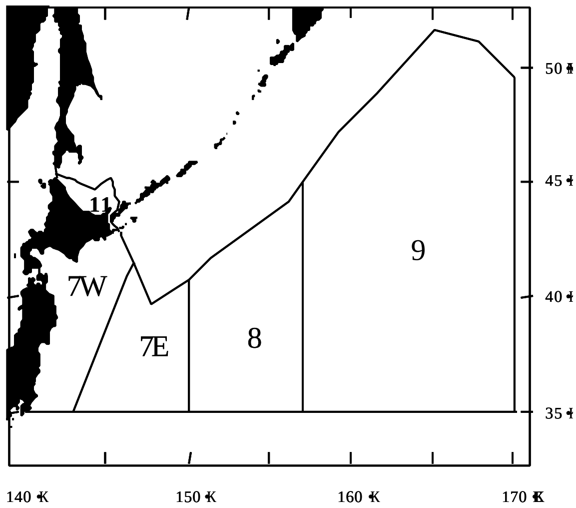

Figure 2. Sub-areas surveyed by the JARPN from 1994-1999. Sub-areas were based on IWC (1994), excluding the EEZ of foreign countries. Furthermore, sub-area 7 was divided into east (7E) and west (7W).

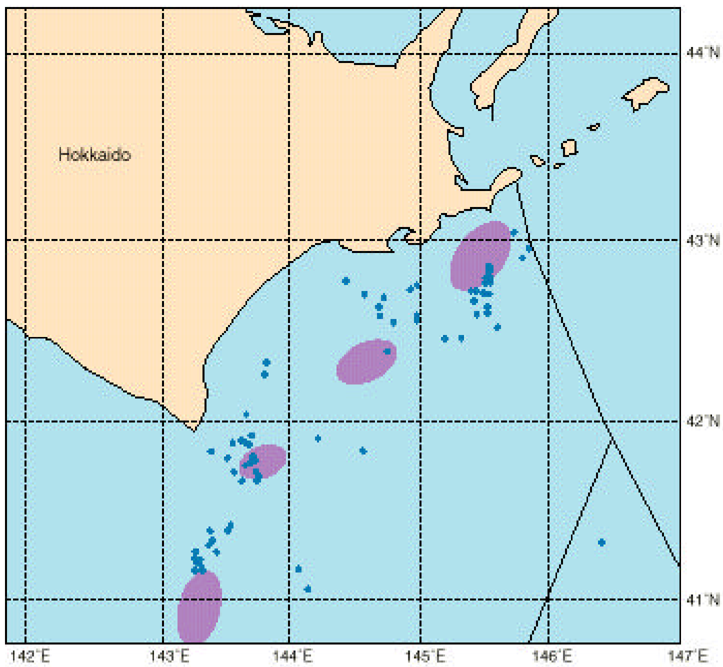

Figure 3. Relationship between minke whale sightings and the fishing grounds of Pacific saury in the Pacific side of Hokkaido (a part of sub area 7W). The information on the fishing grounds was obtained from the telex Nos. 27-33 on fishing grounds off the Pacific coast of eastern Hokkaido by the Fishing Information Service Center in Japan (Redraw from Tamura and Fujise, 2000b).

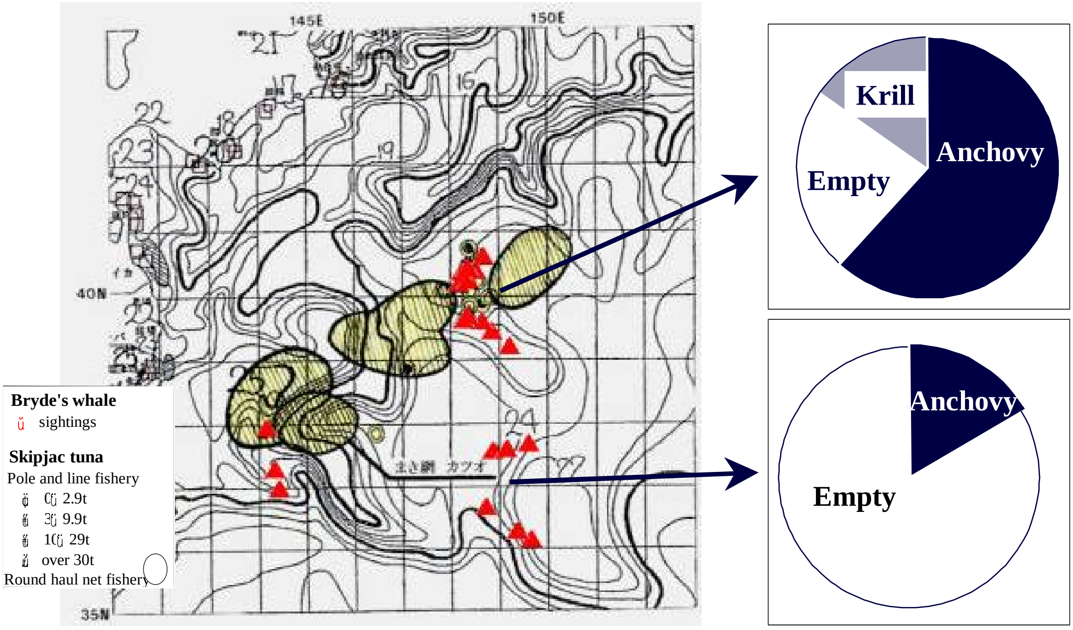

Figure 4. Relationship between Bryde's whale sightings and the fishing grounds of skipjack tuna in the Northwest Pacific during summer 2000.