Regional assessments of prey consumption by marine cetaceans in the world

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ABSTRACT

The total annual prey consumption by 37 species out of 75 species of marine cetaceans in the world was assessed. The assessment was based on 1) recently available abundance estimates of cetaceans, 2) daily prey consumption rates of cetaceans estimated by use of three methods, 3) estimated biomass of cetaceans by use of average body weight and abundance, and 4) composition of prey species of cetaceans. The annual prey consumption of cetaceans was estimated for three ocean regions, the Southern Hemisphere including the Indian Ocean (121-245 million tons), the North Pacific (62-85 million tons) and the North Atlantic (55-107 million tons). Total annual prey consumption by cetaceans in the world was estimated to be 249-436 million tons as the minimum, because our data are not covered on all cetacean species and whole the distribution areas of them. The fish consumption by cetaceans in the Southern Hemisphere including the Indian Ocean was estimated to be 18-32 million tons and accounted for 66-120% of commercial fisheries catches in 1996. In the case of the North Pacific, the fish consumption was estimated to be 21-30 million tons and accounted for 66-96% of commercial fisheries catches in 1996. In the North Atlantic, the fish consumption by cetaceans was 15-25 million tons and accounted for 87-144% of commercial fisheries catches in 1996. We consider that at least, there was probably direct competition between cetaceans and commercial fisheries in the North Pacific and the North Atlantic. However, as the information on the abundance of cetaceans was not included for all species, the actual figures of annual prey consumption by all cetaceans are most probably larger than present results. More information of abundance, body weight and prey composition of cetaceans in each region is necessary to consider competition between cetaceans and commercial fisheries in order to address a more realistic for strategy fisheries management and the conservation of cetaceans in future.

KEYWORDS:

PREY, PREY CONSUMPTION, ENERGETICS, CETACEANS, SOUTHERN HEMISPHERE, NORTH PACIFIC, NORTH ATLANTIC, WORLD

INTRODUCTION

Seventy-nine species of cetaceans (whales, dolphins and porpoises) inhabit in the world, among which 75 species live in the sea. As cetaceans are mammals, they need a large amount of energy to keep their body temperature in the environment of water. 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 is practically difficult, because the data available are incomplete and many assumptions are

needed for this sort of study. The quantitative data on feeding ecology of top predators are insufficient. Some researchers have estimated the food consumption by cetaceans based on techniques such as energy-requirements calculations (Hinga, 1979; Lockyer, 1981; Innes *et al*., 1986; Armstrong and Siegfried, 1991; Sigurjónsson and Víkingsson, 1998; Tamura and Fujise, 2000b).

Furthermore, in recent years, some researchers tried to understand the competition between fish stock and cetaceans in small areas based on the statistical simulation model.

Tamura and Ohsumi (1999) tried to estimate the total prey consumption by marine cetaceans in the world. They reported that total prey consumption of cetaceans was 279-498 million tons, which were equivalent to three to six times of the total catch by marine commercial fisheries in recent years.

Young (1999) reported the potential for impact of large whales on commercially fishing in the South Pacific Ocean. He reported the large whales in the Southern Hemisphere fed on krill, and dietary overlap with commercial by fished species was relatively low. He noted that any assessment of interactions between cetacean and fisheries was limited by a lack of qualitative and quantitative data in the South Pacific Ocean.

Tamura and Ohsumi's paper was introduced in the Scientific Committee of the IWC (IWC/SC) in 1999 and there were some comments as follows:

1. There are some unreliable data of the estimates of abundance of cetaceans. Furthermore, some estimates of the abundance of cetaceans used in this paper are old.
2. The species composition of the prey taken by cetaceans is not presented.

The IWC/SC agreed that the subjects discussed in these papers were important, but there was no consensus on whether any conclusions could be drawn from them regarding the likely or potential direct or indirect competitive impact of cetaceans on fisheries. It agreed that these topics should be considered at a future meeting of the Committee (IWC, in press). An intersessional working group was established for the Committee's work on these topics over the next two years, and a major was consideration planned for 2001.

In this study, we again assessed the daily and annual prey consumption of marine cetaceans based on newly available and recent abundance estimates, new average body weight of each species and three methods used previously (Tamura and Ohsumi, 1999). This assessment was carried out for three regions; the Southern Hemisphere including Indian Ocean (SHIO), the North Pacific (NP) and the North Atlantic (NA).

In addition, we estimated the annual prey consumption of cetaceans by prey categories using assumed composition ratios. Finally, we considered the competition between cetaceans and fisheries at present in each region.

MATERIALS AND METHODS

Available abundance estimates

The IWC/SC uses the estimates of current abundance based on direct methods such as sighting surveys or other methods that do not depend on catch data, such as photo-identification. However, such available data were limited for species and regions, and some of them were old. For this study, we tried to find as many as possible abundance estimates of cetacean in each region. We evaluated and obtained the abundance figures as current and reasonable as possible from published sources for calculating the biomass of cetaceans.

Southern Hemisphere including Indian Ocean

The figures on abundance of 15 species out of 55 species of marine cetaceans distributing in this region are shown in Table 1-1.

Blue whale (*Balaenoptera musculus*): There are two sub-species of blue whale in the study region. The most current abundance is 1,255 true blue whales (no CV available) based on combining data of IWC/IDCR cruises from 1978/79 to 1987/88 (IWC, 1996), and pigmy blue whale abundance was estimated at 5,000 individuals in the mid 1970's (no CV available) (Gambell, 1976). We used these two estimates (1,255 and 5,000) for calculation of biomass.

Fin whale (*Balaenoptera physalus*): The IWC has calculated an abundance of 85,200 individuals (no CV available) based on the history of catches and trends in CPUE (IWC, 1979). Another estimate is 15,178 individuals based on combining data of IWC/IDCR cruises from 1978/79 to 1987/88 (Butterworth *et al*. 1994; IWC, 1996). We used former estimate for calculation of biomass, because the IDCR cruises did not cover all the life range of this species, so that the figure by the IDCR was underestimated.

Sei whale (*Balaenoptera borealis*): The current abundance ranged from 9,720 to 12,000 individuals (no CV available) based on the history of catches and trends in CPUE (IWC, 1980; Mizroch *et al*., 1984; Perry *et al*. 1999). We used an average estimate (10,860 individuals) for calculation of biomass.

Bryde's whale (*Balaenoptera edeni*): The most current abundance is 89,000 individuals (no CV available) based on the accumulated sightings data from 1976/77 to 1979/80 (Ohsumi, 1981).

Minke whale (*Balaenoptera acutorostrata*): The current abundance is 761,000 individuals (95% confidence interval of 510,000-1,140,000) based on combining data of IWC/IDCR cruises from 1982/83 to 1988/89 (IWC, 1991a). The IWC has recognized this estimate is the best estimate of the current abundance within the south of 60^{o} S during the summer. We used this estimate for calculation of biomass.

Humpback whale (*Megaptera novaeangliae*): The most current abundance is 10,000 individuals (95% C.I. 5,900-16,800) based on combining data of IWC/IDCR-SOWER surveys from 1985/86 to 1990/91. The IWC has recognized this is the best estimate of the current abundance (IWC, in press). We used this estimate for calculation of biomass.

Southern right whale (*Eubalaena australis*): The Workshop on the Comprehensive Assessment of Right Whales (IWC, 1998) emphasized that the current best estimated abundance is preferably expressed as "about 7,000" individuals. We used this estimate for calculation of biomass.

Sperm whale (*Physeter macrocephalus*): The current abundance ranged from 128,000 to 290,000 individuals (CV=0.44-0.46) within the south of 30^{o} S from combining data using IWC/IDCR surveys from 1978/79 to 1990/91 (Butterworth *et al*., 1994; IWC, 1995). These numbers most likely represent a large proportion of male whales. We used an average estimate (209,000 individuals) for calculation of biomass. However, the abundance is under-biased. Because, these numbers represent abundance only in the Antarctic, while species distribute in all oceans from equatorial waters to the Polar Regions.

Beaked whales: Arnoux's beaked whale (*Berardius arnuxii*) and southern bottlenose whale (*Hyperoodon planifrons*) were included in this category. The current abundance is 599,000 individuals (95% C.I. 450,000-800,000) south of 50^{o} S from combining data using IWC/IDCR surveys from 1976/77 to 1987/88 (Kasamatsu and Joyce, 1995). We used this estimate for calculation of biomass. However, these beaked whales distribute south of 30^{o} S, and therefore, this abundance is an underestimate.

Killer whale (*Orcinus orca*): The abundance are 53,000 and 64,000 individuals (CV=0.30) in south of 60^{o} S from combining data using IWC/IDCR surveys from 1978/79 to 1990/91 (Butterworth *et al*., 1994; IWC, 1995). We used an average estimate (58,500 individuals) for calculation of biomass. However, killer whales distribute in all oceans from equatorial waters to the Polar Regions, and therefore the estimate is under-biased.

Long-finned pilot whale (*Globicephala melas*): The abundance are 43,000 and 130,000 individuals (CV=0.80-1.04) south of 60^{o} S from combining data using IWC/IDCR surveys from 1978/79 to 1990/91 (Butterworth *et al*., 1994; IWC, 1995). We used an average estimate (86,500 individuals) for calculation of biomass. However, the abundance is under-biased, because long-finned pilot whales distribute in south of 30^{o} S in the Southern Hemisphere.

Hourglass dolphin (*Lagenorhynchus cruciger*): The current abundance is 144,000 individuals (95% C.I. 100,000-200,000) south of 50° S from combining data using IWC/IDCR surveys from 1976/77 to 1987/88 (Kasamatsu and Joyce, 1995). We used this estimate for calculation of biomass.

Commerson's dolphin (*Cephalorhynchus commersonii*): The current abundance is 3,211 individuals (no CV) from the Magellan Strait (Letherwood *et al.* 1988). We used this estimate for calculation of biomass.

Hector's dolphin (*Cephalorhynchus hectori*): The current abundance is 3,408 individuals (no CV) around New Zealand (Dawson and Slooten, 1988). We used this estimate for calculation of biomass.

There are many other cetacean species in the Southern Hemisphere of which information on the abundance has not yet available. When abundance estimates are available, even in the same cetacean species, the research area for whale sightings has not covered the whole of its distribution range. For almost all the available abundance, the research areas that were in the waters of south of 60° S. Especially the knowledge on abundance of cetaceans in the Indian Ocean is scarce.

North Pacific

The figures on abundance of 25 species out of 40 species of marine cetaceans distributing in this region are shown in Table 1-2.

Blue whale: Wade and Gerrodette (1993) estimated 1,415 individuals (CV=0.24) in the eastern tropical Pacific. Perry *et al.* (1999) described that at a minimum there are currently over 3,300 blue whales in the North Pacific. We used 3,300 individuals for calculation of biomass.

Fin whale: The current abundance ranged from 14,620 to 18,630 individuals in the entire North Pacific based on the history of catches and trends in CPUE (Braham, 1991). We used an average estimate (16,125 individuals) for calculation of biomass.

Sei whale: The current abundance is 9,110 individuals (no CV available) based on the history of catches and trends in CPUE (Tillman, 1977). We used this estimate for calculation of biomass.

Bryde's whale: The current abundance is 21,901 whales based on the ship-based line transect survey data in the western North Pacific (Shimada and Miyashita, 1997; IWC, 1997b). The other available abundance estimate is 13,023 (CV=0.20) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used a sum estimate (34,924 individuals) for calculation of biomass.

Minke whale: The current abundance is 25,000 individuals (95% C.I. 12,800-48,600) for the Okhotsk Sea-West Pacific stock (IWC, 1992b) and the current abundance is 7,600 individuals (CV=0.40) for the Sea of Japan stock (IWC, 1984). The IWC has recognized this is the best estimate of the present abundance for the Okhotsk Sea-West Pacific stock (IWC, 1992b). We used a sum estimate (32,600 individuals) for calculation of biomass. This species also distributes in the eastern North Pacific, but no available information was obtained. The information on minke whale abundance in this region should be made available in the future.

Humpback whale: The most current abundance ranged from 6,000 to 8,000 individuals based on using photo-identification methods, but considering statistical biases and separated regional estimates (Calambokidis *et al.* 1997), Perry *et al.* (1999) described that the true abundance is likely to be higher than this figure. We used 7,000 individuals as the average for calculation of biomass.

Northern right whale (*Eubalaena glacialis*): The current abundance ranged from 100 to 500 individuals in the eastern North Pacific and the current abundance is 900 individuals (95% C.I. 404-2,108) in the Sea of Okhotsk (IWC, 1998). We used a sum estimate (1,200 individuals) for calculation of biomass.

Bowhead whale (*Balaena mysticetus*): The current abundance is 7,500 individuals (95% C.I. 6,400-9,200) in the Bering-Chukchi-Beaufort Seas stock. The IWC has recognized this is the best estimate of the present abundance (Raftery and Zeh, 1991; IWC, 1992a). We used this estimate for

calculation of biomass.

Gray whale (*Eschrichtius robustus*): It is reported that their recent number is being estimated with 26,300 (95% C.I. 21,900-32,400) individuals and be increasing with 3.2% of year rate in the eastern North Pacific stock (Hobbs and Rugh, 1999). The IWC has recognized this is the best estimate of the current abundance for this stock (IWC, in press). We used this estimate for calculation of biomass. However, there are additionally some hundred estimates for western Pacific stock.

Sperm whale: Kato and Miyashita (1998) estimated 102,112 individuals (CV=0.16) based on Japanese Sighting Vessels surveys from 1982 to 1996 in western North Pacific. Another abundance is 22,666 (CV=0.22) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used a sum estimate (124,778 individuals) for calculation of biomass. However, the sperm whales distribute in all oceans from equatorial waters to the polar seas, and therefore the abundance that we used is under-biased.

Dwarf sperm whale (*Kogia simus*): The abundance is 11,215 individuals (CV=0.29) based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used this estimate for calculation of biomass, though this is under-biased because the dwarf sperm whales distribute in the entire North Pacific.

Baird's beaked whale (*Berardius bairdii*): The estimated abundance is 3,950 individuals (CV=0.28) in the Pacific coast of Japan based on sighting and effort data using Japanese Sighting Vessels surveys from 1983 to 1989. The population size in the Sea of Japan and the Okhotsk Sea were preliminarily estimated as 1,260 (CV=0.45) and 660 (CV=0.27) whales, respectively (Miyashita, 1990). We used a sum estimate (5,870 individuals) for calculation of biomass. However, the Baird's beaked whales distribute in the entire North Pacific, Sea of Japan, Okhotsk Sea and Bering Sea, these estimates are underestimates.

Cuvier's beaked whale (*Ziphius cavirostris*): The abundance is 20,000 individuals (CV=0.27) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used this estimate for calculation of biomass. However, this estimate is under-biased, because the Cuvier's beaked whales distribute in the entire North Pacific.

Killer whale: The current abundance is 8,500 (CV=0.37) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used this estimate for calculation of biomass. However, the killer whales distribute in the entire North Pacific. Above estimate seems to be only a part of the large number in the North Pacific.

Short-finned pilot whale (*Globicephala macrorhynchus*): The most current abundance is 53,608 individuals (95% C.I. 34,723-82,756) in the western North Pacific based on sighting and effort data using Japanese Sighting Vessels from 1983 to 1991 (Miyashita, 1993a). We used this estimate for calculation of biomass. However, this estimate is under-biased, because, short-finned pilot whales distribute in the entire North Pacific.

False killer whale (*Pseudorca crassidens*): The most current abundance is 16,668 individuals (95% C.I. 10,034-27,689) in the western North Pacific based on combining data using Japanese Sighting Vessels surveys from 1983 to 1991 (Miyashita, 1993a). Another abundance is 39,800 (CV=0.64) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used a sum estimate (56,468 individuals) for calculation of biomass. However, false killer whales distribute in the southern part of the North Pacific, and therefore the estimate is under-biased.

Pygmy killer whale (*Feresa attenuata*): The current abundance is 38,900 (CV=0.31) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used this estimate for calculation of biomass. However, the abundance is under-biased, because the pygmy killer whales distribute in the entire North Pacific.

Melon-headed whale (*Peponocephala electra*): The current abundance is 45,400 (CV=0.47) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993).

We used this estimate for calculation of biomass. As well, the melon-headed whales distribute in the entire North Pacific; this estimate seems to be under-biased.

Rough-toothed whale (*Steno bredanensis*): The current abundance is 145,900 (CV=0.32) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used this estimate for calculation of biomass. However, this estimate is under-biased, because the rough-toothed whales distribute in the entire North Pacific.

Pacific white-sided dolphin (*Lagenorhynchus obliquidens*): The most current abundance is 988,000 individuals (95% C.I. 164,000-6,790,000) in the North Pacific based on combining data using Japanese sighting Vessels surveys from 1983 to 1990 (Miyashita, 1993b). We used this estimate for calculation of biomass.

Risso's dolphin (*Grampus griseus*): Estimated abundance for the western North Pacific is 83,289 individuals (95% C.I. 58,764-118,049) based on combining data using Japanese sighting vessels surveys from 1983 to 1991 (Miyashita, 1993a). Another abundance was 289,300 individuals (CV=0.34) based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used a sum estimate (372,589 individuals) for calculation of biomass.

Bottlenose dolphin (*Tursiops truncatus*): Estimated abundance is 168,791 individuals (95% C.I. 102,000-279,044) in the western North Pacific based on combining data using Japanese Sighting Vessels surveys from 1983 to 1990 (Miyashita, 1993a). Another abundance is 243,500 (CV=0.29) whales based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used a sum estimate (412,291 individuals) for calculation of biomass.

Pantropical spotted dolphin (*Stenella attenuata*): The most current abundance are 730,900 individuals (CV=0.14) of Northeastern, 1,298,400 individuals (CV=0.15) of Western/southern and 29,800 individuals (CV=0.35) of Coastal based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). Another abundance was 438,064 individuals (95% C.I. 312,285-614,503) in the western North Pacific based on combining data using Japanese Sighting Vessels surveys from 1983 to 1990 (Miyashita, 1993a). We used a sum estimate (2,497,164 individuals) for calculation of biomass. However, pantropical spotted dolphins distribute in the southern part of North Pacific (south of 40^{o} N), so this estimate is under-biased.

Spinner dolphin (*Stenella longirostris*): The most current abundance are 631,800 individuals (CV=0.24) of eastern and 1,019,300 individuals (CV=0.19) of whitebelly area based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). We used a sum estimate (1,651,100 individuals) for calculation of biomass. However, spinner dolphins distribute in the southern part of North Pacific (south of 40^{o} N), and this number is an underestimate.

Striped dolphin (*Stenella coeruleoalba*): The most current abundance is 1,918,000 individuals (CV=0.11) based on the ship-based sighting survey data in the eastern tropical Pacific (Wade and Gerrodette, 1993). And, the other abundance was 570,038 individuals (95% C.I. 397,435-817,602) in the western North Pacific based on combining data using Japanese sighting vessels surveys from 1983 to 1990 (Miyashita, 1993a). We used a sum estimate (2,488,038 individual) for calculation of biomass.

Common dolphin (*Delphinus delphis*): The most current abundance are 476,300 individuals (CV=0.37) of Northern, 406,100 individuals (CV=0.38) of Central and 2,210,900 individuals (CV=0.22) of Southern in the eastern tropical Pacific based on the ship-based sighting survey data from 1986 to 1990 (Wade and Gerrodette, 1993). We used a sum estimate (2,664,300 individuals) for calculation of biomass. However, this abundance estimate is an underestimate, because common dolphins distribute in the southern part of North Pacific (south of 50^{o} N).

Fraser's dolphin (*Lagenodelphis hosei*): The abundance estimate is 289,300 individuals (CV=0.34) in the eastern tropical Pacific based on Sighting Vessels surveys from 1986 to 1990 (Wade and Gerrodette, 1993). We used this estimate for calculation of biomass. However, Fraser's dolphins distribute in the

southern part of the North Pacific (south of 30° N), this estimate seems to be under-biased.

Northern right whale dolphin (*Lissodelphis borealis*): Estimated abundance is 308,000 individuals (95% C.I. 59,000-1,680,000) in the North Pacific based on combining data using Japanese Sighting Vessels surveys from 1983 to 1990 (Miyashita, 1993b). We used this estimate for calculation of biomass.

Dall's porpoise (*Phocoenoides dalli*): The most current abundance estimate are 1,186,000 individuals (95% C.I. 991,000-1,420,000) of Pacific and 554,000 individuals (no CV) of Okhotsk in the western North Pacific (Miyashita, 1991; Buckland *et al*., 1993; IWC, 1993). We used a sum (1,740,000 individuals) for calculation of biomass. However, this abundance estimate is an underestimate, because Dall's porpoises distribute in the northern part of the North Pacific (north of 30° N).

Finless porpoise (*Neophocaena phocaenoides*): Estimated abundance is 5,000 individuals (no CV) in Seto Inland Sea (Kasuya and Kureha, 1979). We used this estimate for calculation of biomass. However, finless porpoise also distributes in other regions. This estimate is under-biased.

White whale (*Delphinapterus leucas*): the abundance estimate are 5,800 individuals (no CV) for Alaska and 27,000 individuals (no CV) for USSR (IWC, 1992c). We used a sum estimate (32,800 individuals) for calculation of biomass.

There is many other cetacean species distributing in the North Pacific for which information on the abundance has not been produced yet. Reliable estimates for baleen whales are insufficient, too. We need to have more abundance information of cetaceans based on the direct methods such as sighting surveys in future.

North Atlantic

The figures on abundance of 19 species out of 39 species of marine cetaceans distributing in this region are shown in Table 1-3.

Blue whale: The most current abundance is ranging from 100 to 560 individuals based on the history of catches and trends in CPUE (Braham, 1991). In the Gulf of St. Lawrence, the most current abundance is 320 individuals based on using photo-identification methods (Sears *et al*., 1990). There is no statistically reliable estimate in the eastern North Atlantic. We used 330 individuals for calculation of biomass as the minimum value.

Fin whale: The current abundance is 47,300 whales (95% C.I. 27,723-82,031) based on the ship-based line transect survey data (IWC, 1992d). The IWC has recognized this is the best estimate of the present abundance. We used this estimate for calculation of biomass.

Sei whale: The current abundance is 4,000 individuals (no CV) based on the history of catches and trends in CPUE (Braham, 1991). We used this estimate for calculation of biomass.

Bryde's whale: There is no statistically reliable estimate of abundance in the North Atlantic. We omitted this species from the calculation of abundance.

Minke whale: The current abundance are 118,299 individuals (95% C.I. 96,681-144,750) for North Eastern Atlantic, 28,000 individuals (95% C.I. 21,600-31,400) for Central Atlantic and 3,266 individuals (95% C.I. 1,790-5,950) for West Greenland (IWC, 1991b; 1997a). The IWC has recognized these estimates are the best estimate of the present abundance. We used a sum estimate (149,000 individuals) for calculation of biomass.

Humpback whale: The current abundance is 5,561 individuals of west of Greenland based on using photo-identification methods (IWC, 1986b). The IWC has recognized this estimate is the best estimate of the present abundance. However, Smith *et al.* (1999) estimated 10,600 humpback whales (95% C.I. 9,300-12,100) based on mark recapture analysis of photo-identification methods in the North Atlantic. We used this estimate for calculation of biomass.

Northern right whale: The current abundance ranged from 300 to 500 individuals in the western North Atlantic (IWC, 1986a). We used the average estimate (400 individuals) for calculation of biomass.

Bowhead whale: Estimated abundance is 450 individuals (no CV) (Zeh *et al*, 1993). We used this estimate for calculation of biomass.

Sperm whale: Rice (1989) calculated the current abundance estimates in three regions (Southern Hemisphere, North Pacific and North Atlantic), He calculated their abundance in North Atlantic as 190,000 individuals (no CV). Estimated abundance is also 190,000 individuals (no CV) for entire North Atlantic based on the history of catches and trends in CPUE (Odell, 1992). There is no other statistically reliable estimated abundance in the North Atlantic. We used this estimate for calculation of biomass.

Northern bottlenose whale (*Hyperoodon ampullatus*): The current abundance is 44,300 individuals for Iceland based on using photo-identification methods (Sigurjónsson and Víkingsson, 1998). We used this estimate for calculation of biomass.

Killer whale: The current abundance estimate is 5,500 (no CV) individuals in the Iceland based on data of Sighting Vessels surveys in 1987 (Sigurjónsson and Víkingsson, 1998). We used this estimate for calculation of biomass. However, the Killer whales distribute in the entire North Atlantic, so this estimate is under-biased.

Long-finned pilot whale: The current abundance estimate is 778,000 individuals (95% C.I. 440,000-1,370,000) based on Sighting Vessels Surveys in 1987 and 1989 in the central and eastern North Atlantic (Buckland, *et al*., 1992; IWC, 1993). The IWC has recognized this is the best estimate of the present abundance. We used this estimate for calculation of biomass. However, this estimate is under-biased, because this did not include the western and southern Atlantic areas.

White-beaked dolphin (*Lagenorhynchus albirostris*): The current abundance estimate is 13,420 individuals in Iceland based on data of Sighting Vessels surveys in 1987 (Sigurjónsson and Víkingsson, 1998). We used this estimate for calculation of biomass.

Atlantic white-sided dolphin (*Lagenorhynchus acutus*): The current abundance estimate is 38,680 individuals in Iceland based on data of Sighting Vessels surveys in 1987 (Sigurjónsson and Víkingsson, 1998). We used this estimate for calculation of biomass.

Harbour porpoise (*Phocoena phocoena*): Estimated abundance is 28,510 individuals in Iceland based on data of Sighting Vessels surveys in 1987 (Sigurjónsson and Víkingsson, 1998). We used this estimate for calculation of biomass.

White whale: Estimated abundance are 45,700 individuals (no CV) of Canada and 9,500 individuals (no CV) of USSR (IWC, 1992c). We used a sum estimate (55,200 individuals) for calculation of biomass.

Narwhal (*Monodon monoceros*): Estimated abundance were 28,000 individuals (22,000-33,500) for Canada-Greenland and 1,300 individuals (no CV) for Northern Hudson Bay (IWC, 1992c). We used a sum estimate (29,300 individuals) for calculation of biomass.

In the North Atlantic, there are many other cetacean species for which information on the abundance has not yet made available. Even in the cetacean species where with information exists, the research area for the sightings has not covered the whole of its distribution range. For many small cetaceans, there are a few abundance estimates in the North Atlantic. We need the more abundance information of cetaceans based on direct methods such as sighting surveys in the future.

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

We used newly available and recent figures of abundance estimates on each cetacean species from published sources, and estimated their average body weights by use of the formula by Trites and Pauly (1998). They estimated the mean body weight by sex in each species. In this study, we applied the average weight of male and female for cetaceans excluding sperm whales in the Southern Hemisphere. For sperm whales in the Southern Hemisphere, we applied the average weight of male. Biomass of each cetacean species in three ocean regions was calculated with these data by multiplying the abundance and average body weight.

Estimation of daily prey consumption of cetaceans

We calculated daily prey consumption 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). Some researchers have estimated the prey consumption by cetaceans on the basis of energy–requirement (*e.g*. Hinga, 1979, Lockyer, 1981, Armstrong and Siegfried, 1991; Tamura and Fujise, 2000b). In this study, we estimated the daily prey consumption and feeding rate by each cetacean species based on the following three methods.

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

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

$$I = 0.42M^{0.67} \tag{1}$$

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

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:

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

$$D = 206.25M^{0.783}; \quad I = D/1{,}300$$
(for baleen whales in Northern Hemisphere and toothed whales in the world) (3)

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). We 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

Klumov (1963) proposed a method for estimating daily prey consumption from the average body weight of each cetacean species. The daily prey consumption is given in the following formula by him:

$$I = 0.035M \tag{4}$$

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

Estimation of annual prey consumption of cetaceans

We 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 use of the following formula:

$$C = 365\,N\,I \tag{5}$$

Composition of prey species

Moreover, we calculated the annual prey consumption in each prey category using the assumed prey composition (% of weight) in each region from published sources (*e.g*. Pauly *et al*., 1998). Pauly *et al*. (1998) categorized marine mammal's prey among eight prey types for use in trophic modelling and related food web studies. However, we reconsidered the prey composition of baleen whales, because they used different prey species in each region. As to the categories of prey species, we divided them into three groups such as fish (pelagic and mesopelagic), cephalopods (squids) and crustaceans (copepods, amphipods and krill).

Catch of marine organisms by fisheries in the worlds

For the comparison of amount of prey consumption by cetaceans with the amount of catch by fisheries in the world, we used the annual catch statistics of marine organisms capture by commercial fisheries by the Food of Agriculture Organization of the United Nations (FAO).

FAO divides the seas of the world into major fishing areas for statistical purposes (Fig. 1). We grouped these statistical areas into three ocean regions. They are the Southern Hemisphere including the Indian Ocean (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)), the North Pacific (61 (Northwest Pacific), 67 (Northeast Pacific), 71 (Western Central Pacific) and 77 (Eastern Central Pacific)) and the North Atlantic (21 (Northwest Atlantic), 27 (Northeast Atlantic), 31 (Western Central Atlantic), 34 (Eastern Central Atlantic) and 37 (Mediterranean and Black Sea)). The amounts of fisheries catch statistics excluding inland fisheries and Aquaculture in 1996 was used from FAO (1998). For the sake of convenience we name these three ocean regions SHIO, NP and NA, respectively.

We summed up the catch species in 1996 into four groups (fish, cephalopods, crustaceans and others) based on FAO Fishery statistics (FAO, 1998). Among them a group of others which include seaweed and others is not a prey organisms of cetaceans, so that this group is excluded from the analysis. Table 2 shows the results.

RESULTS

Southern Hemisphere including Indian Ocean

Estimated biomass of cetaceans

The biomass of fin, minke and sperm whales accounted respectively for 24.7%, 26.1% and 29.4% of total biomass of cetaceans (19,147 thousand tons) calculated in this study (Table 3-1).

Estimated daily prey consumption of cetaceans based on three methods

Estimated daily prey consumption of each cetacean species is given in Table 4-1.

Estimated daily rate of prey intake per body weight from equation (1) ranges from 0.93% in the case of the blue whale of which average body weight is 102,737kg (*i.e*. 957kg of prey weight per day) to 13.99% in a 28kg in Commerson's dolphin (*i.e.* 4kg prey per day).

Estimates of the rate of prey intake per body weight per day from equation (2) range from 1.52% in the blue whale (*i.e.* 1,560kg prey per day) to 7.70% in Commerson's dolphin (*i.e*. 2kg prey per day).

When we apply the Method-3, the blue whale takes 3,596 kg of prey (3.5%) per day and the Commerson's dolphin takes 1 kg of prey (3.5%) per day.

Estimated annual prey consumption of cetaceans based on three methods

Estimated annual prey consumption of cetaceans is given in Table 5-1.

We calculated the annual prey consumption by baleen and toothed whales to be 77-159 and 45-85 million tons, respectively. Among them the annual prey consumption by minke and sperm whales accounted for 40-55% of total annual prey consumption by baleen whales and 67-84% of total annual prey consumption by toothed whales, respectively.

According to the assumed prey composition as shown in Table 6-1, 76-155 million tons of crustaceans (mainly *Euphausia superba*) were consumed by baleen whales. Cephalopods (mainly squids) were consumed by only toothed whales and amounted to 27-56 million tons. The annual crustacean consumption by minke whales accounted for 42-58% of total annual crustacean consumption by baleen whales. And the annual cephalopod consumption by sperm whales accounted for 76-90% of total annual cephalopod consumption by cetaceans (Table 7-1).

Competition between commercial fisheries and 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, it was one order of magnitude greater than the commercial fisheries cephalopods catch (one million tons) in 1996.

North Pacific

Estimated biomass of cetaceans

The biomass of fin and sperm whales accounted respectively for 13.5% and 34.9% of total biomass by cetaceans (6,646 thousand tons) (Table 3-2).

Estimated daily prey consumption of cetaceans based on three methods

Estimated daily prey consumption of each cetacean species is given in Table 4-2.

Estimated daily rate of prey intake per body weight from equation (1) ranges from 0.93% in the case of the blue whale of which average body weight is 102,737kg (*i.e*. 957kg of prey weight per day) to 15.14% in a 22kg in vaquita (*i.e.* 3kg prey per day).

Estimates of the rate of prey intake per body weight per day from equation (3) range from 1.30% in the blue whale (*i.e.* 1,332kg prey per day) to 8.11% in vaquita (*i.e*. 2kg prey per day).

When we apply the Method-3, the blue whale takes 3,596 kg of prey (3.5%) per day and the vaquita takes 1 kg of prey (3.5%) per day.

Estimated annual prey consumption of cetaceans based on three methods

Estimated annual prey consumption of cetaceans is given in Table 5-2.

The annual prey consumption by baleen and toothed whales was 16-39 million tons and 43-56 million tons, respectively. Among them the annual prey consumption by fin, minke and sperm whales accounted for 23-29%, 7-11% of total annual prey consumption by baleen whales and 25-64% of total annual prey consumption by toothed whales, respectively.

According to the estimated prey composition (Table 6-2), consumption by baleen whales feeding on fish and crustaceans (copepods and krill), amounted to 2-4 and 14-35 million tons, respectively. The annual fish consumption by fin and minke whales accounted for 9-14%, 47-58% of total annual fish consumption by baleen whales, respectively. Consumption by toothed whales mainly feeding on fish and cephalopods (squids), amounted to 17-28, 22-27 million tons, respectively. The annual fish consumption by sperm whales and common dolphins accounted for 12-44%, 11-19% of total annual fish consumption by toothed whales, respectively. The annual cephalopod consumption by sperm whales accounted for 36-75% of total annual cephalopod consumption by toothed whales (Table 7-2).

Competition between commercial fisheries and cetaceans

Total fish consumption by cetaceans was 21-30 million tons accounting for 66-96% of 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 fisheries cephalopods catch (1.6 million tons) in 1996.

North Atlantic

Estimated biomass of cetaceans

The biomass of fin, minke and sperm whales accounted respectively for 31.5%, 11.7% and 42.1% of total biomass by cetaceans (8,356 thousand tons) (Table 3-2).

Estimated daily prey consumption of cetaceans based on three methods

Estimated daily prey consumption of each cetacean species is given in Table 4-3.

Estimated daily rate of prey intake per body weight from equation (1) ranges from 0.93% in the case of the blue whale of which average body weight is 102,737kg (*i.e*. 957kg of prey weight per day) to 13.52% in a 31kg in the harbour porpoise (*i.e.* 4kg prey per day).

Estimates of the rate of prey intake per body weight per day from equation (3) range from 1.30% in the blue whale (*i.e.* 1,332kg prey per day) to 7.53% in harbour porpoise (*i.e*. 2kg prey per day).

When we apply the Method-3, the blue whale takes 3,596 kg of prey (3.5%) per day and the harbour porpoise takes 1 kg of prey (3.5%) per day.

Estimated annual prey consumption of cetaceans based on three methods

Estimated annual prey consumption of cetaceans is given in Table 5-3.

The annual prey consumption by baleen and toothed whales was 21-52 and 34-55 million tons, respectively. Among them the annual prey consumption by fin, minke and sperm whales accounted for 51-65%, 24-38% of total annual prey consumption by baleen whales and 62-82% of total annual prey consumption by toothed whales, respectively.

According to the estimated prey composition (Table 6-3), baleen whales feeding on fish and crustaceans (copepods and krill), amounted to 6-11, 15-41 million tons, respectively. The annual fish consumption by fin and minke whales accounted for 5-9%, 68-78% of total annual fish consumption by baleen whales, respectively. Consumption by toothed whales mainly feeding on fish and cephalopods (squids), amounted to 14-24, 24-39 million tons, respectively. The annual fish consumption by sperm whales and long-finned pilot whales accounted for 60-81%, 15-31% of total annual fish consumption by toothed whales, respectively. The annual cephalopod consumption by sperm whales accounted for 62-82% of total annual cephalopod consumption by toothed whales (Table 7-3).

Competition between commercial fisheries and cetaceans

Total fish consumption by cetaceans was 15-25 million tons, accounting for 87-144% of commercial fisheries fish catch (17 million tons) in 1996. Total cephalopod consumption by cetaceans was 24-39 million tons, this value was two orders of magnitude greater than the commercial fisheries cephalopod catch (0.4 million tons) in 1996.

DISCUSSION

In this paper, we assessed again the annual prey consumption of cetaceans in the worlds based on newly available and recent abundance estimates of cetaceans, new average body weight and three previous methods to estimate daily prey consumption. As for the difference from the first assessment, new estimate

is 30-60 million tons lesser for annual prey consumption by cetaceans in the world. This is due to the average weight of the sperm whales.

As mentioned above, information on the abundance of many species of cetaceans was not included in our tables, because of the lack of data on abundance estimates for them. Furthermore, the research areas of them have not yet covered whole the range of their distribution.

The same figure of average body weight is used in this paper. However, the size compositions are different by stocks, and there are sexual and age segregation in the distribution of some cetacean species. These factors will be better to consider for further study on this problem. Therefore, the actual figures of annual prey consumption by all cetaceans should be larger than the present results.

Because of the different types of assumptions in three methods used to estimate daily prey consumption, the highest estimate was nearly twice of the lowest. However, the total annual prey consumption was estimated to be 248-434 million tons in the world, and it is clear from the present study that cetaceans feed on the range of hundreds of million tons of marine organisms.

We tried to assess the competition between cetaceans and commercial fisheries in each region as follows:

Southern Hemisphere including Indian Ocean

The total fish consumption by cetaceans was 18-32 million tons that accounted for 67-119% of current commercial fisheries catch of fish. Northridge (1984) reported the distribution, prey species of cetaceans in the Southern Hemisphere including Indian Ocean, and he stated 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).

Nemoto (1959) categorized that the feeding types of baleen whales in the Southern, as follows:

Euphausiid feeder: blue whale, fin whale, humpback whale and sei whale

Amphipod feeder: sei whale

Copepod feeder: right whale, sei whale

Fish feeder: Bryde's whale

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 as prey species. Best (1967) reported that they consumed 47% fish and 53% euphausiids in South Africa. Their fish are including some commercial fish 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 amount of competition with fisheries, however, no conflict was evident at present.

In almost all of small cetacean, their population sizes and prey species are unknown (Northridge, 1984). However, their main prey species seemed to be the fish and squid distribute pelagic and mesopelagic. Hence, there are some notorious information of interactions between fish fisheries and cetaceans such as killer whale, false killer whale, and common dolphin in the region (Northridge, 1984).

As for sperm whale, their biomass is large (5,630 thousand tons), occupying 29.4% of total biomass of cetaceans in the region. However, this value refers only to Antarctic, while sperm whales distribute all oceans from equatorial waters to the Polar Regions. Their prey species is dominated by mesopelagic

squids, for which there is no commercial fishery. However, they eat mainly fish in such region 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 the commercial fisheries of squid or bottom fish and/or the abundance of sperm whales expand in the future, there may be some interactions between sperm whales and squid or bottom fish fisheries.

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 of market. 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 which is consumed by baleen whales in the Antarctic. This study showed that the annual crustacean consumption by minke whales was 40-60 million tons, and the amount accounted for 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. We considered that there was direct competition for krill among cetaceans, seals and sea birds in austral summer in the Antarctic. Krill fishery appears to be of minor importance now. However, any development of this fishery can lead to increased competition between cetaceans and fisheries.

For better understanding of this phenomenon, it will be necessary to have more abundance estimate of cetaceans, quantitative information of prey species to assess the interaction between fisheries and cetaceans. Especially as for Indian Ocean, there is no available abundance information of cetaceans at all.

North Pacific

The total fish consumption by cetaceans was 20-29 million tons accounting for 68-97% of commercial fisheries fish catch in recent years.

In contrast to Southern Hemisphere, many species of baleen whales feed on various pelagic prey species of zooplankton, squid and fish (Kawamura, 1980a). Nemoto (1959) categorized that the feeding types of baleen whales in the North Pacific, as follows:

Euphausiid feeder: blue whale, fin whale, Bryde's whale, humpback whale and minke whale
Copepod feeder: right whale, sei whale and fin whale
Fish feeder: fin whale, Bryde's whale, humpback whale and minke whale
Squid feeder: fin whale, sei whale

Northern right whales and bowhead whales feed on small copepods (e.g. *Calanus glacialis* and *C. hyperboreus*) (Nemoto, 1959; Kawamura, 1980a). And, blue whales feed on krill (e.g. *Euphausia pacifica, Thysanoessa inermis* and *T. longipes*) (Nemoto, 1959; Kawamura, 1980a).

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 catch and their biomass is larger than other baleen whales, so there may be interactions to some extent in the North Pacific.

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.

On the other hand, 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). At least, there is 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, there may be an interaction to some extent in the North Pacific.

As for minke whales, they feed on various pelagic prey species of zooplankton, squid and fish (Nemoto, 1959; Kawamura, 1980a; Tamura and Fujise, 2000a). 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 largely during 1965-1987. 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 on the stomach contents of minke whales caught under the JARPN, and they noted that dominant prey species have changed to Pacific saury and Japanese anchovy in recent years. They feed on pelagic zooplankton and pelagic schooling fish. Tamura and Fujise (2000a) reported most of the minke whale sightings occurred close to Pacific saury fishing grounds. Tamura and Fujise (2000b) estimated seasonal consumption of Pacific saury by minke whales in Pacific side of Japan during August and September; this value was 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. At least, we consider that there exists direct competition between minke whales and commercial Pacific saury fisheries existed from summer to autumn in the western North Pacific.

Gray whale feed mainly on benthic amphipods and shrimp. It is reported that their recent number is being estimated with 26,300 individuals and is increasing with 3.2% of year rate. Many stranding are being reported and the lack of prey resource is pointed out as major one of the factor. There may demonstrate that the gray whales the eastern North Pacific stock are approaching their carrying capacity.

Wade and Gerrodette (1993) and Miyashita (1990, 1991, 1993a, b) estimated the population of small cetaceans in the North Pacific. Their main prey species seemed to be fish and squids, which distributed pelagic and mesopelagic. At least, there are 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, 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, Chub mackerel in the western North Pacific (Kawakami, 1980). Furthermore, Rice (1989) reported sperm whales fed on black cod, or sablefish, from longlines being from retrieved by fisherman in the eastern Gulf of Alaska. Although their fish quantity is relatively small consumption, it is conceivable that the whole quantity of fish consumption is very large, because their biomass is too large. There may be some interactions between sperm whale and fisheries. Furthermore, if the commercial fisheries of squid or bottom fish and/or the abundance of sperm whales expand, there may be some interactions between sperm whale and squid and/or bottom fish fisheries.

In the Bering Sea, Lowry and Frost (1985) tried to clearly the biological interactions between marine mammals and commercial fisheries. They assessed the potential interactions between marine mammals and fisheries in the Bering Sea. They calculated the ranked value based on diet composition, feeding

strategy, importance, population size, and so on. However, there was no question that competition with fisheries occurred, because it were 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 got from feeding relates to growth, maturation, reproduction and survival.

Trites *et al*. (1997) tried the assessment of 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, their prey consisted of mesopelagic squids and fish, they proposed that the most important consumers of fish and competitor of commercial fisheries were probably other predator fish, not marine mammals. But, they considered that there was an 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.

According to the North Pacific Marine Science Organization (PICES), there still exists drastic shortage of quantitative data on feeding ecology of top predators. In 2000, a workshop on " A review of the technical basis for estimating the abundance of marine birds and mammals, and the impact of their predation on other organisms " will be held in Japan. It is expected that improvement of knowledge on prey consumption of marine mammals and their potential for top-down impacts in marine ecosystem in the North Pacific will be furthered.

North Atlantic

The total fish consumption by cetaceans was 15-25 million tons accounting for 87-144% of commercial fisheries fish catch in recent years.

In contrast to 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 (e.g. *Calanus glacialis* and *C. hyperboreus*). And, 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.

On the other hand, fin whales consumed 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 varied both geographically and temporally in the North Atlantic. Perkins and Beamish (1979) reported that the fin whale 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.

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, there may be the possibility of the interaction with fisheries.

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 are apparent. However, as their prey species overlap with some commercial catch, so there may be an interaction to some extent in the North Atlantic.

As for Minke whales, they 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, their diet varies according to season, geographical area and prey availability. Although krill (e.g. *M. norvegica, T. inermis*) are the important prey species, a wide range of fish species, among which capelin, herring and sand lance are predominant 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 tons per year 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) described that the net loss to the herring and cod fishery is some five tones of herring and cod due to direct and indirect effect on the catches of an extra minke whale in the Barents Sea using simulation model. There seems to be evidence enough that there is direct competition between minke whales and commercial fisheries in the North Atlantic.

The population and prey species of almost all small cetacean are unknown (Northridge, 1984). Their main prey species seems to be fish and squids, which distribute pelagic and mesopelagic. However, as same as North Pacific Ocean, 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. We need to have more abundance estimate of small cetaceans available, as well as quantitative data of prey species to assess the interaction between fisheries and small cetaceans in the future.

As for sperm whale, their biomass is large (3,519 thousand tons), occupying 42.9% of total biomass of cetaceans similar to other regions. Their prey species is dominated by mesopelagic squid, for which there is no commercial fishery, however, it has been reported that they eat mainly fish in Iceland (Sigurjónsson and Víkingsson, 1998). There may be some interactions between sperm whales and fish fisheries. Furthermore, if the commercial fisheries of squid or bottom fish and/or the population of sperm whales will expand, there will be some interactions between sperm whales and squid or bottom fish fisheries.

In the Barents Sea, Bogstad *et al*. (1997) studied the effect on stocks of cod, herring and capelin by removing the stock of minke whale in a simulation study using the MULTSPEC model. They noted that the increasing harp seal (*Phoca groenlandica*) stock would most heavily affect the capelin and cod stock. Furthermore, Schweder *et al*. (2000) describe that the net loss to herring and cod fisheries is some five tones of herring and cod due to direct and indirect effect on the catches of an extra minke whale using simulation model in the Barents Sea.

We again tried the assessment of daily and annual prey consumption of marine cetaceans based on newly available and recent abundance estimates, new average body weight of each species and three methods used previously. Furthermore, we estimated the annual prey consumption of cetaceans by prey categories using assumed composition ratios, and considered the competition between cetaceans and fisheries at present for three regions (SHIO, NP and NA). 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 estimate of cetaceans, quantitative information of prey species to assess the interaction between fisheries and cetaceans. The meeting of Competition between Fisheries and Cetaceans will be held and organized along the lines of previous IWC-sponsored conferences, with an open symposium and an invitational workshop in 2001. In

this meeting, we will have more detail knowledge of available abundance estimate of cetaceans, quantitative information of prey species. Furthermore, we will understand the potential of cetaceans having a 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 model in the Antarctic, Barents Sea, and so on.

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 enlarged. It makes possible to develop a blanket multi-species management of marine organisms involving marine mammals as whales, dolphins, porpoises and pinnipeds in order to allow a more realistic fisheries management strategy, long-term and/or short-term sustainability of marine organisms involving marine mammals and their conservation in the world.

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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 Jovce 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 Jovce 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 Stoolen 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

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 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**

Table 3. Estimated the annual prey consumption based on three methods.

3-1. Southern Hemisphere including Indian Ocean

Species	Average body weight (kg)	Abundance (inds.)	Biomass (t)	Biomass %
Blue whale	102,737	1,255	128,935	0.7
Pigmy blue whale	102,737	5,000	513,685	2.7
Fin whale	55,590	85,200	4,736,268	24.7
Sei whale	16,811	10,860	182,567	1.0
Bryde's whale	16,143	89,000	1,436,727	7.5
Minke whale	6,566	761,000	4,996,726	26.1
Humpback whale	30,408	10,000	304,080	1.6
Southern right whale	23,383	7,000	163,681	0.9
Pygmy right whale	N.d.	N.d.		
Baleen whales total			**12,462,669**	**65.1**
Sperm whale	26,939 *1	209,000	5,630,251	29.4
Pygmy sperm whale	177	N.d.		
Dwarf sperm whale	101	N.d.		
Arnoux's beaked whale	1,733	N.d.		
Southern bottlenose whale	1,079	N.d.		
Beaked whales *2	1,406	**599,000**	842,194	4.4
Cuvier's beaked whale	829	N.d.		
Shepherd's beaked whale	N.D.	N.d.		
Blainville's beaked whale	449	N.d.		
Gray's beaked whale	501	N.d.		
Ginkgo-toothed beaked whale	376	N.d.		
Hector's beaked whale	294	N.d.		
Pygmy beaked whale	N.D.	N.d.		
True's beaked whale	445	N.d.		
Strap-toothed whale	631	N.d.		
Andrew's beaked whale	334	N.d.		
Longman's beaked whale	1,069	N.d.		
Irrawaddy dolphin	87	N.d.		
Killer whale	2,281	58,500	133,439	0.7
Long-finned pilot whale	851	86,500	73,612	0.4
Short-finned pilot whale	643	N.d.		
False killer whale	578	N.d.		
Pygmy killer whale	98	N.d.		
Melon-headed whale	105	N.d.		
Tucuxi	39	N.d.		
Indo-Pacific hump-backed dolphin	115	N.d.		
Rough-toothed dolphin	92	N.d.		
Dusky dolphin	50	N.d.		
Hourglass dolphin	34	144,000	4,896	0.0
Peale's dolphin	59	N.d.		
Risso's dolphin	224	N.d.		
Bottlenose dolphin	188	N.d.		
Pantropical spotted dolphin	65	N.d.		
Atlantic spotted dolphin	66	N.d.		
Spinner dolphin	41	N.d.		
Clymene dolphin	47	N.d.		
Striped dolphin	116	N.d.		
Common dolphin *3	80	N.d.		
Fraser's dolphin	95	N.d.		
Southern right whale dolphin	62	N.d.		
Commerson's dolphin	28	3,211	90	0.0
Heaviside's dolphin	33	N.d.		
Hector's dolphin	67	3,408	228	0.0
Black dolphin	31	N.d.		
Spectaced porpoise	58	N.d.		
Burmeister's porpoise	42	N.d.		
Finless porpoise	41	N.d.		
Toothed whales total			**6,684,709**	**34.9**
Cetaceans total			**19,147,379**	**100.0**

*1: Only average weight of male (26,939kg)

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

*3: Including long-beaked common dolphin

3-2. North Pacific

Species	Average body weight (kg)	Abundance (inds.)	Biomass (t)	Biomass %
Blue whale	102,737	3,300	339,032	5.1
Fin whale	55,590	16,125	896,389	13.5
Sei whale	16,811	9,110	153,148	2.3
Bryde's whale	16,143	34,924	563,778	8.5
Minke whale	6,566	32,600	214,052	3.2
Humpback whale	30,408	7,000	212,856	3.2
Northern right whale	23,383	1,200	28,060	0.4
Bowhead whale	31,076	7,500	233,070	3.5
Gray whale	15,372	26,300	404,284	6.1
Baleen whales total			**3,044,668**	**46.0**
Sperm whale	18,519	124,778	2,310,764	34.9
Pygmy sperm whale	177	N.D.		
Dwarf sperm whale	101	11,215	1,133	0.0
Baird's beaked whale	3,137	5,870	18,414	0.3
Cuvier's beaked whale	829	20,000	16,580	0.3
Blainville's beaked whale	449	N.D.		
Ginkgo-toothed beaked whale	376	N.D.		
Hubbs' beaked whale	470	N.D.		
Stejneger's beaked whale	455	N.D.		
Killer whale	2,281	8,500	19,389	0.3
Short-finned pilot whale	643	53,608	34,470	0.5
False killer whale	578	56,468	32,639	0.5
Pygmy killer whale	98	38,900	3,812	0.1
Melon-headed whale	105	45,400	4,767	0.1
Indo-Pacific hump-backed dolphin	115	N.D.		
Rough-toothed dolphin	92	145,900	13,423	0.2
Pacific white-sided dolphin	78	988,000	77,064	1.2
Risso's dolphin	224	372,589	83,460	1.3
Bottlenose dolphin	188	412,291	77,511	1.2
Pantropical spotted dolphin	65	2,497,164	162,316	2.5
Spinner dolphin	41	1,651,100	67,695	1.0
Striped dolphin	116	2,488,038	288,612	4.4
Common dolphin[*1]	80	2,664,300	213,144	3.2
Fraser's dolphin	95	289,300	27,484	0.4
Northern right whale dolphin	105	308,000	32,340	0.5
Dall's porpoise	61	1,740,000	106,140	1.6
Harbour porpoise	31	N.D.		
Vaquita	22	N.D.		
Finless porpoise	41	5,000	205	0.0
White whale	313	32,800	10,266	0.2
Toothed whales total			**3,601,626**	**54.4**
Cetaceans total			**6,646,294**	**100.4**

*1: Including long-beaked common dolphin

3-3. North Atlantic

Species	Average body weight (kg)	Abundance (inds.)	Biomass (t)	Biomass %
Blue whale	102,737	330	33,903	0.4
Fin whale	55,590	47,300	2,629,407	31.5
Sei whale	16,811	4,000	67,244	0.8
Bryde's whale	16,143	N.D.		
Minke whale	6,566	149,000	978,334	11.7
Humpback whale	30,408	10,600	322,325	3.9
Northern right whale	23,383	400	9,353	0.1
Bowhead whale	31,076	450	13,984	0.2
Baleen whales total			**4,054,550**	**48.5**
Sperm whale	18,519	190,000	3,518,610	42.1
Pygmy sperm whale	177	N.D.		
Dwarf sperm whale	101	N.D.		
Cuvier's beaked whale	829	N.D.		
Northern bottlenose whale	1,689	44,300	74,823	0.9
Blainville's beaked whale	449	N.D.		
Sowerby's beaked whale	455	N.D.		
Gervais' beaked whale	393	N.D.		
True's beaked whale	445	N.D.		
Killer whale	2,281	5,500	12,546	0.2
Long-finned pilot whale	851	778,000	662,078	7.9
Short-finned pilot whale	643	N.D.		
False killer whale	578	N.D.		
Pygmy killer whale	98	N.D.		
Melon-headed whale	105	N.D.		
Atlantic hump-backed dolphin	77	N.D.		
Rough-toothed dolphin	92	N.D.		
White beaked dolphin	142	13,420	1,906	0.0
Atlantic white sided dolphin	92	38,680	3,559	0.0
Risso's dolphin	224	N.D.		
Bottlenose dolphin	188	N.D.		
Pantropical spotted dolphin	65	N.D.		
Atlantic spotted dolphin	66	N.D.		
Spinner dolphin	41	N.D.		
Clymene dolphin	47	N.D.		
Striped dolphin	116	N.D.		
Common dolphin*1	80	N.D.		
Fraser's dolphin	95	N.D.		
Harbour porpoise	31	28,510	884	0.0
White whale	313	55,200	17,278	0.2
Narwhal	325	29,300	9,523	0.1
Toothed whales total			**4,301,204**	**51.5**
Cetaceans total			**8,355,755**	**100.0**

*1: Including long-beaked common dolphin

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

4-1. Southern Hemisphere including Indian Ocean

Species	Average body weight (kg)	Method-1 (kg)	%	Method-2 (kg)	%	Method-3 (kg)	%
Baleen whales							
Blue whale	102,737	957	0.93	1,560	1.52	3,596	3.50
Pigmy blue whale	102,737	957	0.93	1,560	1.52	3,596	3.50
Fin whale	55,590	634	1.14	964	1.73	1,946	3.50
Sei whale	16,811	285	1.69	378	2.25	588	3.50
Bryde's whale	16,143	277	1.72	366	2.27	565	3.50
Minke whale	6,566	152	2.31	181	2.76	230	3.50
Humpback whale	30,408	423	1.39	601	1.98	1,064	3.50
Southern right whale	23,383	355	1.52	490	2.09	818	3.50
Pygmy right whale	N.d.						
Toothed whales							
Sperm whale	26,939[*1]	390	1.45	467	1.73	943	3.50
Pygmy sperm whale	177	13	7.61	9	5.16	6	3.50
Dwarf sperm whale	101	9	9.16	6	5.83	4	3.50
Arnoux's beaked whale	1,733	62	3.58	55	3.15	61	3.50
Southern bottlenose whale	1,079	45	4.19	38	3.49	38	3.50
Beaked whales[*2]	1,406	54	3.84	46	3.29	49	3.50
Cuvier's beaked whale	829	38	4.57	31	3.69	29	3.50
Shepherd's beaked whale	N.D.						
Blainville's beaked whale	449	25	5.60	19	4.22	16	3.50
Gray's beaked whale	501	27	5.40	21	4.12	18	3.50
Ginkgo-toothed beaked whale	376	22	5.94	16	4.38	13	3.50
Hector's beaked whale	294	19	6.44	14	4.62	10	3.50
Pygmy beaked whale	N.D.						
True's beaked whale	445	25	5.61	19	4.22	16	3.50
Strap-toothed whale	631	32	5.00	25	3.92	22	3.50
Andrew's beaked whale	334	21	6.17	15	4.50	12	3.50
Longman's beaked whale	1,069	45	4.20	37	3.49	37	3.50
Irrawaddy dolphin	87	8	9.62	5	6.02	3	3.50
Killer whale	2,281	75	3.27	68	2.96	80	3.50
Long-finned pilot whale	851	39	4.53	31	3.67	30	3.50
Short-finned pilot whale	643	32	4.97	25	3.90	23	3.50
False killer whale	578	30	5.15	23	3.99	20	3.50
Pygmy killer whale	98	9	9.25	6	5.87	3	3.50
Melon-headed whale	105	9	9.04	6	5.78	4	3.50
Tucuxi	39	5	12.54	3	7.16	1	3.50
Indo-Pacific hump-backed dolphin	115	10	8.77	7	5.67	4	3.50
Rough-toothed dolphin	92	9	9.44	5	5.95	3	3.50
Dusky dolphin	50	6	11.55	3	6.79	2	3.50
Hourglass dolphin	34	4	13.12	3	7.38	1	3.50
Peale's dolphin	59	6	10.94	4	6.55	2	3.50
Risso's dolphin	224	16	7.04	11	4.90	8	3.50
Bottlenose dolphin	188	14	7.46	10	5.09	7	3.50
Pantropical spotted dolphin	65	7	10.59	4	6.41	2	3.50
Atlantic spotted dolphin	66	7	10.54	4	6.39	2	3.50
Spinner dolphin	41	5	12.33	3	7.09	1	3.50
Clymene dolphin	47	6	11.79	3	6.88	2	3.50
Striped dolphin	116	10	8.75	7	5.66	4	3.50
Common dolphin[*3]	80	8	9.89	5	6.13	3	3.50
Fraser's dolphin	95	9	9.35	6	5.91	3	3.50
Southern right whale dolphin	62	7	10.76	4	6.48	2	3.50
Commerson's dolphin	28	4	13.99	2	7.70	1	3.50
Heaviside's dolphin	33	4	13.25	2	7.43	1	3.50
Hector's dolphin	67	7	10.49	4	6.37	2	3.50
Black dolphin	31	4	13.52	2	7.53	1	3.50
Spectaced porpoise	58	6	11.00	4	6.57	2	3.50
Burmeister's porpoise	42	5	12.21	3	7.04	1	3.50
Finless porpoise	41	5	12.33	3	7.09	1	3.50

*1: Only average weight of male (26,939kg)

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

*3: Including long-beaked common dolphin

4-2. North Pacific

Species	Average body weight (kg)	Method-1 (kg)	%	Method-2 (kg)	%	Method-3 (kg)	%
Baleen whales							
Blue whale	102,737	957	0.93	1,332	1.30	3,596	3.50
Fin whale	55,590	634	1.14	824	1.48	1,946	3.50
Sei whale	16,811	285	1.69	323	1.92	588	3.50
Bryde's whale	16,143	277	1.72	313	1.94	565	3.50
Minke whale	6,566	152	2.31	155	2.36	230	3.50
Humpback whale	30,408	423	1.39	514	1.69	1,064	3.50
Northern right whale	23,383	355	1.52	418	1.79	818	3.50
Bowhead whale	31,076	430	1.38	522	1.68	1,088	3.50
Gray whale	15,372	268	1.74	301	1.96	538	3.50
Toothed whales							
Sperm whale	18,519	304	1.64	348	1.88	648	3.50
Pygmy sperm whale	177	13	7.61	9	5.16	6	3.50
Dwarf sperm whale	101	9	9.16	6	5.83	4	3.50
Baird's beaked whale	3,137	92	2.95	87	2.77	110	3.50
Cuvier's beaked whale	829	38	4.57	31	3.69	29	3.50
Blainville's beaked whale	449	25	5.60	19	4.22	16	3.50
Ginkgo-toothed beaked whale	376	22	5.94	16	4.38	13	3.50
Hubbs' beaked whale	470	26	5.51	20	4.17	16	3.50
Stejneger's beaked whale	455	25	5.57	19	4.20	16	3.50
Killer whale	2,281	75	3.27	68	2.96	80	3.50
Short-finned pilot whale	643	32	4.97	25	3.90	23	3.50
False killer whale	578	30	5.15	23	3.99	20	3.50
Pygmy killer whale	98	9	9.25	6	5.87	3	3.50
Melon-headed whale	105	9	9.04	6	5.78	4	3.50
Indo-Pacific hump-backed dolphin	115	10	8.77	7	5.67	4	3.50
Rough-toothed dolphin	92	9	9.44	5	5.95	3	3.50
Pacific white-sided dolphin	78	8	9.97	5	6.16	3	3.50
Risso's dolphin	224	16	7.04	11	4.90	8	3.50
Bottlenose dolphin	188	14	7.46	10	5.09	7	3.50
Pantropical spotted dolphin	65	7	10.59	4	6.41	2	3.50
Spinner dolphin	41	5	12.33	3	7.09	1	3.50
Striped dolphin	116	10	8.75	7	5.66	4	3.50
Common dolphin[*1]	80	8	9.89	5	6.13	3	3.50
Fraser's dolphin	95	9	9.35	6	5.91	3	3.50
Northern right whale dolphin	105	9	9.04	6	5.78	4	3.50
Dall's porpoise	61	7	10.82	4	6.50	2	3.50
Harbour porpoise	31	4	13.52	2	7.53	1	3.50
Vaquita	22	3	15.14	2	8.11	1	3.50
Finless porpoise	41	5	12.33	3	7.09	1	3.50
White whale	313	20	6.31	14	4.56	11	3.50

*1: Including long-beaked common dolphin

4-3. North Atlantic

Species	Average body weight (kg)	Method-1 (kg)	%	Method-2 (kg)	%	Method-3 (kg)	%
Baleen whales							
Blue whale	102,737	957	0.93	1,332	1.30	3,596	3.50
Fin whale	55,590	634	1.14	824	1.48	1,946	3.50
Sei whale	16,811	285	1.69	323	1.92	588	3.50
Bryde's whale	16,143	277	1.72	313	1.94	565	3.50
Minke whale	6,566	152	2.31	155	2.36	230	3.50
Humpback whale	30,408	423	1.39	514	1.69	1,064	3.50
Northern right whale	23,383	355	1.52	418	1.79	818	3.50
Bowhead whale	31,076	430	1.38	522	1.68	1,088	3.50
Toothed whales							
Sperm whale	18,519	304	1.64	348	1.88	648	3.50
Pygmy sperm whale	177	13	7.61	9	5.16	6	3.50
Dwarf sperm whale	101	9	9.16	6	5.83	4	3.50
Cuvier's beaked whale	829	38	4.57	31	3.69	29	3.50
Northern bottlenose whale	1,689	61	3.62	53	3.16	59	3.50
Blainville's beaked whale	449	25	5.60	19	4.22	16	3.50
Sowerby's beaked whale	455	25	5.57	19	4.20	16	3.50
Gervais' beaked whale	393	23	5.85	17	4.34	14	3.50
True's beaked whale	445	25	5.61	19	4.22	16	3.50
Killer whale	2,281	75	3.27	68	2.96	80	3.50
Long-finned pilot whale	851	39	4.53	31	3.67	30	3.50
Short-finned pilot whale	643	32	4.97	25	3.90	23	3.50
False killer whale	578	30	5.15	23	3.99	20	3.50
Pygmy killer whale	98	9	9.25	6	5.87	3	3.50
Melon-headed whale	105	9	9.04	6	5.78	4	3.50
Atlantic hump-backed dolphin	77	8	10.02	5	6.18	3	3.50
Rough-toothed dolphin	92	9	9.44	5	5.95	3	3.50
White beaked dolphin	142	12	8.18	8	5.41	5	3.50
Atlantic white sided dolphin	92	9	9.44	5	5.95	3	3.50
Risso's dolphin	224	16	7.04	11	4.90	8	3.50
Bottlenose dolphin	188	14	7.46	10	5.09	7	3.50
Pantropical spotted dolphin	65	7	10.59	4	6.41	2	3.50
Atlantic spotted dolphin	66	7	10.54	4	6.39	2	3.50
Spinner dolphin	41	5	12.33	3	7.09	1	3.50
Clymene dolphin	47	6	11.79	3	6.88	2	3.50
Striped dolphin	116	10	8.75	7	5.66	4	3.50
Common dolphin*1	80	8	9.89	5	6.13	3	3.50
Fraser's dolphin	95	9	9.35	6	5.91	3	3.50
Harbour porpoise	31	4	13.52	2	7.53	1	3.50
White whale	313	20	6.31	14	4.56	11	3.50
Narwhal	325	20	6.23	15	4.52	11	3.50

*1: Including long-beaked common dolphin

Table 5. Estimated the annual prey consumption based on three methods.

5-1. Southern Hemisphere including Indian Ocean

Species	Average body weight (kg)	Abundance	Method-1 (tons)	Method-2 (tons)	Method-3 (tons)
Blue whale	102,737	1,255	438,574	714,615	1,647,144
Pigmy blue whale	102,737	5,000	1,747,307	2,847,073	6,562,326
Fin whale	55,590	85,200	19,730,111	29,992,901	60,505,824
Sei whale	16,811	10,860	1,128,547	1,498,705	2,332,299
Bryde's whale	16,143	89,000	9,000,810	11,898,389	18,354,187
Minke whale	6,566	761,000	42,122,913	50,301,128	63,833,175
Humpback whale	30,408	10,000	1,545,767	2,194,957	3,884,622
Southern right whale	23,383	7,000	907,410	1,250,816	2,091,025
Pygmy right whale	N.d.	N.d.			
Baleen whales total			**76,621,439**	**100,698,584**	**159,210,602**
Sperm whale	26,939 *1	209,000	29,788,184	35,635,138	71,926,457
Pygmy sperm whale	177	N.d.			
Dwarf sperm whale	101	N.d.			
Arnoux's beaked whale	1,733	N.d.			
Southern bottlenose whale	1,079	N.d.			
Beaked whales *2	1,406	**599,000**	11,806,445	10,116,791	10,759,028
Cuvier's beaked whale	829	N.d.			
Shepherd's beaked whale	N.D.	N.d.			
Blainville's beaked whale	449	N.d.			
Gray's beaked whale	501	N.d.			
Ginkgo-toothed beaked whale	376	N.d.			
Hector's beaked whale	294	N.d.			
Pygmy beaked whale	N.D.	N.d.			
True's beaked whale	445	N.d.			
Strap-toothed whale	631	N.d.			
Andrew's beaked whale	334	N.d.			
Longman's beaked whale	1,069	N.d.			
Irrawaddy dolphin	87	N.d.			
Killer whale	2,281	58,500	1,594,564	1,443,150	1,704,677
Long-finned pilot whale	851	86,500	1,217,898	986,040	940,387
Short-finned pilot whale	643	N.d.			
False killer whale	578	N.d.			
Pygmy killer whale	98	N.d.			
Melon-headed whale	105	N.d.			
Tucuxi	39	N.d.			
Indo-Pacific hump-backed dolphin	115	N.d.			
Rough-toothed dolphin	92	N.d.			
Dusky dolphin	50	N.d.			
Hourglass dolphin	34	144,000	234,420	131,903	62,546
Peale's dolphin	59	N.d.			
Risso's dolphin	224	N.d.			
Bottlenose dolphin	188	N.d.			
Pantropical spotted dolphin	65	N.d.			
Atlantic spotted dolphin	66	N.d.			
Spinner dolphin	41	N.d.			
Clymene dolphin	47	N.d.			
Striped dolphin	116	N.d.			
Common dolphin *3	80	N.d.			
Fraser's dolphin	95	N.d.			
Southern right whale dolphin	62	N.d.			
Commerson's dolphin	28	3,211	4,590	2,526	1,149
Heaviside's dolphin	33	N.d.			
Hector's dolphin	67	3,408	8,740	5,310	2,917
Black dolphin	31	N.d.			
Spectaced porpoise	58	N.d.			
Burmeister's porpoise	42	N.d.			
Finless porpoise	41	N.d.			
Toothed whales total			**44,654,841**	**48,320,858**	**85,397,161**
Cetaceans total			**121,276,280**	**149,019,442**	**244,607,762**

*1: Only average weight of male (26,939kg)

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

*3: Including long-beaked common dolphin

5-2. North Pacific

Species	Average body weight (kg)	Abundance	Method-1 (tons)	Method-2 (tons)	Method-3 (tons)
Blue whale	102,737	3,300	1,153,222	1,604,869	4,331,135
Fin whale	55,590	16,125	3,734,132	4,848,145	11,451,366
Sei whale	16,811	9,110	946,691	1,073,746	1,956,468
Bryde's whale	16,143	34,924	3,531,958	3,987,669	7,202,266
Minke whale	6,566	32,600	1,804,477	1,840,381	2,734,509
Humpback whale	30,408	7,000	1,082,037	1,312,263	2,719,235
Northern right whale	23,383	1,200	155,556	183,136	358,461
Bowhead whale	31,076	7,500	1,176,327	1,430,124	2,977,469
Gray whale	15,372	26,300	2,573,992	2,890,075	5,164,723
Baleen whales total			**16,158,393**	**19,170,407**	**38,895,634**
Sperm whale	18,519	124,778	13,835,152	15,864,486	29,520,007
Pygmy sperm whale	177	N.D.			
Dwarf sperm whale	101	11,215	37,865	24,095	14,470
Baird's beaked whale	3,137	5,870	198,082	185,846	235,241
Cuvier's beaked whale	829	20,000	276,697	223,358	211,810
Blainville's beaked whale	449	N.D.			
Ginkgo-toothed beaked whale	376	N.D.			
Hubbs' beaked whale	470	N.D.			
Stejneger's beaked whale	455	N.D.			
Killer whale	2,281	8,500	231,689	209,688	247,688
Short-finned pilot whale	643	53,608	625,566	490,684	440,354
False killer whale	578	56,468	613,531	475,483	416,957
Pygmy killer whale	98	38,900	128,710	81,625	48,701
Melon-headed whale	105	45,400	157,324	100,552	60,898
Indo-Pacific hump-backed dolphin	115	N.D.			
Rough-toothed dolphin	92	145,900	462,738	291,370	171,476
Pacific white-sided dolphin	78	988,000	2,805,450	1,733,846	984,493
Risso's dolphin	224	372,589	2,145,055	1,493,543	1,066,201
Bottlenose dolphin	188	412,291	2,110,726	1,440,831	990,199
Pantropical spotted dolphin	65	2,497,164	6,275,396	3,799,283	2,073,583
Spinner dolphin	41	1,651,100	3,047,058	1,751,163	864,805
Striped dolphin	116	2,488,038	9,216,924	5,957,596	3,687,024
Common dolphin[*1]	80	2,664,300	7,694,769	4,769,206	2,722,915
Fraser's dolphin	95	289,300	937,487	592,447	351,102
Northern right whale dolphin	105	308,000	1,067,308	682,159	413,144
Dall's porpoise	61	1,740,000	4,190,467	2,518,871	1,355,939
Harbour porpoise	31	N.D.			
Vaquita	22	N.D.			
Finless porpoise	41	5,000	9,227	5,303	2,619
White whale	313	32,800	236,282	170,855	131,153
Toothed whales total			**56,303,501**	**42,862,292**	**46,010,777**
Cetaceans total			**72,461,894**	**62,032,699**	**84,906,410**

*1: Including long-beaked common dolphin

5-3. North Atlantic

Species	Average body weight (kg)	Abundance	Method-1 (tons)	Method-2 (tons)	Method-3 (tons)
Blue whale	102,737	330	115,322	160,487	433,114
Fin whale	55,590	47,300	10,953,453	14,221,225	33,590,674
Sei whale	16,811	4,000	415,671	471,458	859,042
Bryde's whale	16,143	N.D.			
Minke whale	6,566	149,000	8,247,456	8,411,556	12,498,217
Humpback whale	30,408	10,600	1,638,513	1,987,142	4,117,699
Northern right whale	23,383	400	51,852	61,045	119,487
Bowhead whale	31,076	450	70,580	85,807	178,648
Baleen whales total			**21,492,847**	**25,398,720**	**51,796,881**
Sperm whale	18,519	190,000	21,066,845	24,156,922	44,950,243
Pygmy sperm whale	177	N.D.			
Dwarf sperm whale	101	N.D.			
Cuvier's beaked whale	829	N.D.			
Northern bottlenose whale	1,689	44,300	987,320	863,736	955,860
Blainville's beaked whale	449	N.D.			
Sowerby's beaked whale	455	N.D.			
Gervais' beaked whale	393	N.D.			
True's beaked whale	445	N.D.			
Killer whale	2,281	5,500	149,916	135,681	160,269
Long-finned pilot whale	851	778,000	10,954,046	8,868,658	8,458,046
Short-finned pilot whale	643	N.D.			
False killer whale	578	N.D.			
Pygmy killer whale	98	N.D.			
Melon-headed whale	105	N.D.			
Atlantic hump-backed dolphin	77	N.D.			
Rough-toothed dolphin	92	N.D.			
White beaked dolphin	142	13,420	56,928	37,648	24,345
Atlantic white sided dolphin	92	38,680	122,678	77,246	45,461
Risso's dolphin	224	N.D.			
Bottlenose dolphin	188	N.D.			
Pantropical spotted dolphin	65	N.D.			
Atlantic spotted dolphin	66	N.D.			
Spinner dolphin	41	N.D.			
Clymene dolphin	47	N.D.			
Striped dolphin	116	N.D.			
Common dolphin*1	80	N.D.			
Fraser's dolphin	95	N.D.			
Harbour porpoise	31	28,510	43,627	24,293	11,291
White whale	313	55,200	397,645	287,537	220,721
Narwhal	325	29,300	216,457	157,187	121,650
Toothed whales total			**33,995,462**	**34,608,907**	**54,947,885**
Cetaceans total			**55,488,310**	**60,007,627**	**106,744,767**

*1: Including long-beaked common dolphin

5-4. Total

Region	Method-1 (tons)	Method-2 (tons)	Method-3 (tons)
Southern Hemisphere including Indian Ocean			
Baleen whales	76,621,439	100,698,584	159,210,602
Toothed whales	44,654,841	48,320,858	85,397,161
Cetacean total	**121,276,280**	**149,019,442**	**244,607,762**
North Pacific			
Baleen whales	16,158,393	19,170,407	38,895,634
Toothed whales	56,303,501	42,862,292	46,010,777
Cetacean total	**72,461,894**	**62,032,699**	**84,906,410**
North Atlantic			
Baleen whales	21,492,847	25,398,720	51,796,881
Toothed whales	33,995,462	34,608,907	54,947,885
Cetacean total	**55,488,310**	**60,007,627**	**106,744,767**
Total			
Baleen whales	114,272,679	145,267,711	249,903,117
Toothed whales	134,953,804	125,792,057	186,355,822
Cetacean total	**249,226,484**	**271,059,768**	**436,258,939**

Table 6. Assumed prey composition (% of weght) of cetaceans in each Region

6-1. Southern Hemisphere including Indian Ocean

Species	Fish	Cephalopoda	Crustacean	Others	Source
Blue whale			100.0		Nemoto and Kawamura 1977
Pigmy blue whale			100.0		Kawamura 1994
Fin whale	0.5		99.5		Nemoto and Kawamura 1977
Sei whale	0.2		99.8		Nemoto and Kawamura 1977
Bryde's whale	47.0		53.0		Kawamura 1980
Minke whale			100.0		Nemoto and Kawamura 1977
Humpback whale			100.0		Nemoto and Kawamura 1977
Southern right whale			100.0		Nemoto 1959
Pygmy right whale			100.0		Pauly *et al* . 1998
Sperm whale	25.0	70.0	5.0		Pauly *et al* . 1998
Pygmy sperm whale	20.0	75.0	5.0		Pauly *et al* . 1998
Dwarf sperm whale	10.0	80.0	10.0		Pauly *et al* . 1998
Arnoux's beaked whale	60.0	30.0	10.0		Pauly *et al* . 1998
Southern bottlenose whale	20.0	60.0	20.0		Pauly *et al* . 1998
Beaked whales [*1]	**40.0**	**45.0**	**15.0**		
Cuvier's beaked whale	30.0	60.0	10.0		Pauly *et al* . 1998
Shepherd's beaked whale					
Blainville's beaked whale	50.0	50.0			Pauly *et al* . 1998
Gray's beaked whale					
Ginkgo-toothed beaked whale					
Hector's beaked whale	20.0	80.0			Pauly *et al* . 1998
Pygmy beaked whale					
True's beaked whale		100.0			Pauly *et al* . 1998
Strap-toothed whale	30.0	70.0			Pauly *et al* . 1998
Andrew's beaked whale					
Longman's beaked whale					
Irrawaddy dolphin	70.0	10.0	20.0		Pauly *et al* . 1998
Killer whale	50.0	10.0		40.0	Pauly *et al* . 1998
Long-finned pilot whale	25.0	75.0			Pauly *et al* . 1998
Short-finned pilot whale	40.0	60.0			Pauly *et al* . 1998
False killer whale	50.0	50.0			Odell and McClune 1999
Pygmy killer whale	30.0	50.0		20.0	Pauly *et al* . 1998
Melon-headed whale	30.0	70.0			Pauly *et al* . 1998
Tucuxi	70.0	10.0	20.0		Pauly *et al* . 1998
Indo-Pacific hump-backed dolphin	90.0		10.0		Pauly *et al* . 1998
Rough-toothed dolphin	60.0	30.0	10.0		Pauly *et al* . 1998
Dusky dolphin	80.0	20.0			Pauly *et al* . 1998
Hourglass dolphin	50.0	50.0			Brownell and Donahue 1999
Peale's dolphin	50.0	40.0	10.0		Pauly *et al* . 1998
Risso's dolphin	10.0	85.0	5.0		Pauly *et al* . 1998
Bottlenose dolphin	75.0	25.0			Pauly *et al* . 1998
Pantropical spotted dolphin	50.0	50.0			Pauly *et al* . 1998
Atlantic spotted dolphin	50.0	50.0			Pauly *et al* . 1998
Spinner dolphin	60.0	40.0			Pauly *et al* . 1998
Clymene dolphin	50.0	40.0		10.0	Pauly *et al* . 1998
Striped dolphin	60.0	35.0	5.0		Pauly *et al* . 1998
Common dolphin [*2]	70.0	30.0			Pauly *et al* . 1998
Fraser's dolphin	60.0	35.0	5.0		Pauly *et al* . 1998
Southern right whale dolphin	50.0	50.0			Pauly *et al* . 1998
Commerson's dolphin	50.0	30.0	20.0		Pauly *et al* . 1998
Heaviside's dolphin	60.0	40.0			Pauly *et al* . 1998
Hector's dolphin	50.0	45.0	5.0		Pauly *et al* . 1998
Black dolphin					
Spectaced porpoise					
Burmeister's porpoise	60.0	30.0	10.0		Pauly *et al* . 1998
Finless porpoise	50.0	40.0	10.0		Pauly *et al* . 1998

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

*2: Including long-beaked common dolphin

6-2. North Pacific

Species	Fish	Cephalopoda	Crustacean	Others	Source
Blue whale			100.0		Nemoto and Kawamura 1977
Fin whale	5.0	1.7	93.3		Nemoto and Kawamura 1977
Sei whale	3.4	1.2	95.4		Nemoto and Kawamura 1977
Bryde's whale	11.1		88.9		Nemoto and Kawamura 1977
Minke whale	70.0		30.0		Tamura and Fujise 2000a
Humpback whale	17.2		82.8		Nemoto and Kawamura 1977
Northern right whale			100.0		Nemoto and Kawamura 1977
Bowhead whale			100.0		Nemoto 1959
Gray whale	5.0		95.0		Pauly *et al* . 1998
Sperm whale	25.0	70.0	5.0		Pauly *et al* . 1998
Pygmy sperm whale	20.0	75.0	5.0		Pauly *et al* . 1998
Dwarf sperm whale	10.0	80.0	10.0		Pauly *et al* . 1998
Baird's beaked whale	35.0	55.0	10.0		Pauly *et al* . 1998
Cuvier's beaked whale	30.0	60.0	10.0		Pauly *et al* . 1998
Blainville's beaked whale	50.0	50.0			Pauly *et al* . 1998
Ginkgo-toothed beaked whale					
Hubbs' beaked whale	20.0	80.0			Pauly *et al* . 1998
Stejneger's beaked whale	5.0	95.0			Pauly *et al* . 1998
Killer whale	50.0	10.0		40.0	Pauly *et al* . 1998
Short-finned pilot whale	40.0	60.0			Pauly *et al* . 1998
False killer whale	50.0	50.0			Odell and McClune 1999
Pygmy killer whale	30.0	50.0		20.0	Pauly *et al* . 1998
Melon-headed whale	30.0	70.0			Pauly *et al* . 1998
Indo-Pacific hump-backed dolphin	90.0		10.0		Pauly *et al* . 1998
Rough-toothed dolphin	60.0	30.0	10.0		Pauly *et al* . 1998
Pacific white-sided dolphin	65.0	35.0			Pauly *et al* . 1998
Risso's dolphin	10.0	85.0	5.0		Pauly *et al* . 1998
Bottlenose dolphin	75.0	25.0			Pauly *et al* . 1998
Pantropical spotted dolphin	50.0	50.0			Pauly *et al* . 1998
Spinner dolphin	60.0	40.0			Pauly *et al* . 1998
Striped dolphin	60.0	35.0	5.0		Pauly *et al* . 1998
Common dolphin *1	70.0	30.0			Pauly *et al* . 1998
Fraser's dolphin	60.0	35.0	5.0		Pauly *et al* . 1998
Northern right whale dolphin	50.0	50.0			Pauly *et al* . 1998
Dall's porpoise	55.0	40.0	5.0		Pauly *et al* . 1998
Harbour porpoise	75.0	20.0	5.0		Pauly *et al* . 1998
Vaquita	50.0	50.0			Pauly *et al* . 1998
Finless porpoise	50.0	40.0	10.0		Pauly *et al* . 1998
White whale	70.0	10.0	20.0		Pauly *et al* . 1998

*1: Including long-beaked common dolphin

6-3. North Atlantic

Species	Fish	Cephalopoda	Crustacean	Others	Source
Blue whale			100.0		Sigurjónsson and Víkingsson 1998
Fin whale	3.0		97.0		Sigurjónsson and Víkingsson 1998
Sei whale	2.0		98.0		Sigurjónsson and Víkingsson 1998
Bryde's whale	11.1		88.9		Nemoto and Kawamura 1977
Minke whale	59.0		41.0		Sigurjónsson and Víkingsson 1998
Humpback whale	60.0		40.0		Sigurjónsson and Víkingsson 1998
Northern right whale			100.0		Nemoto 1959
Bowhead whale			100.0		Nemoto 1959
Sperm whale	25.0	70.0	5.0		Pauly *et al* . 1998
Pygmy sperm whale	20.0	75.0	5.0		Pauly *et al* . 1998
Dwarf sperm whale	10.0	80.0	10.0		Pauly *et al* . 1998
Cuvier's beaked whale	30.0	60.0	10.0		Pauly *et al* . 1998
Northern bottlenose whale	15.0	70.0	15.0		Pauly *et al* . 1998
Blainville's beaked whale	50.0	50.0			Pauly *et al* . 1998
Sowerby's beaked whale	45.0	55.0			Pauly *et al* . 1998
Gervais' beaked whale					
True's beaked whale		100.0			Pauly *et al* . 1998
Killer whale	50.0	10.0		40.0	Pauly *et al* . 1998
Long-finned pilot whale	25.0	75.0			Pauly *et al* . 1998
Short-finned pilot whale	40.0	60.0			Pauly *et al* . 1998
False killer whale	50.0	50.0			Odell and McClune 1999
Pygmy killer whale	30.0	50.0		20.0	Pauly *et al* . 1998
Melon-headed whale	30.0	70.0			Pauly *et al* . 1998
Atlantic hump-backed dolphin	100.0				Pauly *et al* . 1998
Rough-toothed dolphin	60.0	30.0	10.0		Pauly *et al* . 1998
White beaked dolphin	75.0	20.0	5.0		Pauly *et al* . 1998
Atlantic white sided dolphin	65.0	25.0	10.0		Pauly *et al* . 1998
Risso's dolphin	10.0	85.0	5.0		Pauly *et al* . 1998
Bottlenose dolphin	75.0	25.0			Pauly *et al* . 1998
Pantropical spotted dolphin	50.0	50.0			Pauly *et al* . 1998
Atlantic spotted dolphin	50.0	50.0			Pauly *et al* . 1998
Spinner dolphin	60.0	40.0			Pauly *et al* . 1998
Clymene dolphin	50.0	40.0		10.0	Pauly *et al* . 1998
Striped dolphin	60.0	35.0	5.0		Pauly *et al* . 1998
Common dolphin*1	70.0	30.0			Pauly *et al* . 1998
Fraser's dolphin	60.0	35.0	5.0		Pauly *et al* . 1998
Harbour porpoise	75.0	20.0	5.0		Pauly *et al* . 1998
White whale	70.0	10.0	20.0		Pauly *et al* . 1998
Narwhal	35.0	50.0	15.0		Pauly *et al* . 1998

*1: Including long-beaked common dolphin

Table 7. Estimated the annual prey consumption based on three methods.

7-1. 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	1,747,307	0	0	2,847,073	0	0	6,562,326
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
Pygmy right whale	N.d.	0	0	0	0	0	0	0	0	0
Baleen whales total		**4,331,288**	**0**	**72,290,150**	**5,745,205**	**0**	**94,953,379**	**8,933,662**	**0**	**150,276,940**
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
Pygmy sperm whale	N.d.									
Dwarf sperm whale	N.d.									
Arnoux's beaked whale	N.d.									
Southern bottlenose whale	N.d.									
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
Cuvier's beaked whale	N.d.									
Shepherd's beaked whale	N.d.									
Blainville's beaked whale	N.d.									
Gray's beaked whale	N.d.									
Ginkgo-toothed beaked whale	N.d.									
Hector's beaked whale	N.d.									
Pygmy beaked whale	N.d.									
True's beaked whale	N.d.									
Strap-toothed whale	N.d.									
Andrew's beaked whale	N.d.									
Longman's beaked whale	N.d.									
Irrawaddy dolphin	N.d.									
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
Short-finned pilot whale	N.d.									
False killer whale	N.d.									
Pygmy killer whale	N.d.									
Melon-headed whale	N.d.									
Tucuxi	N.d.									
Indo-Pacific hump-backed dolphin	N.d.									
Rough-toothed dolphin	N.d.									
Dusky dolphin	N.d.									
Hourglass dolphin	144,000	117,210	117,210	0	65,951	65,951	0	31,273	31,273	0
Peale's dolphin	N.d.									
Risso's dolphin	N.d.									
Bottlenose dolphin	N.d.									
Pantropical spotted dolphin	N.d.									
Atlantic spotted dolphin	N.d.									
Spinner dolphin	N.d.									
Clymene dolphin	N.d.									
Striped dolphin	N.d.									
Common dolphin *2	N.d.									
Fraser's dolphin	N.d.									
Southern right whale dolphin	N.d.									
Commerson's dolphin	3,211	2,295	1,377	918	1,263	758	505	574	345	230
Heaviside's dolphin	N.d.									
Hector's dolphin	3,408	4,370	3,933	437	2,655	2,389	265	1,458	1,313	146
Black dolphin	N.d.									
Spectaced porpoise	N.d.									
Burmeister's porpoise	N.d.									
Finless porpoise	N.d.									
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**	**75,551,881**	**19,738,660**	**30,450,096**	**98,253,426**	**32,339,628**	**56,098,771**	**155,487,492**

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

*2: Including long-beaked common dolphin

7-2. 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	4,331,135
Fin whale	16,125	186,707	63,480	3,483,945	242,407	82,418	4,523,319	572,568	194,673	10,684,125
Sei whale	9,110	32,187	11,360	903,143	36,507	12,885	1,024,354	66,520	23,478	1,866,471
Bryde's whale	34,924	392,047	0	3,139,911	442,631	0	3,545,038	799,451	0	6,402,814
Minke whale	32,600	1,263,134	0	541,343	1,288,266	0	552,114	1,914,156	0	820,353
Humpback whale	7,000	186,110	0	895,927	225,709	0	1,086,554	467,708	0	2,251,527
Northern right whale	1,200	0	0	155,556	0	0	183,136	0	0	358,461
Bowhead whale	7,500	0	0	1,176,327	0	0	1,430,124	0	0	2,977,469
Gray whale	26,300	128,700	0	2,445,293	144,504	0	2,745,571	258,236	0	4,906,487
Baleen whales total		**2,188,885**	**74,841**	**13,894,667**	**2,380,025**	**95,303**	**16,695,079**	**4,078,641**	**218,151**	**34,598,842**
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	1,476,000
Pygmy sperm whale	N.D.									
Dwarf sperm whale	11,215	3,786	30,292	3,786	2,409	19,276	2,409	1,447	11,576	1,447
Baird's beaked whale	5,870	69,329	108,945	19,808	65,046	102,215	18,585	82,334	129,383	23,524
Cuvier's beaked whale	20,000	83,009	166,018	27,670	67,007	134,015	22,336	63,543	127,086	21,181
Blainville's beaked whale	N.D.									
Ginkgo-toothed beaked whale	N.D.									
Hubbs' beaked whale	N.D.									
Stejneger's beaked whale	N.D.									
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
Indo-Pacific hump-backed dolphin	N.D.									
Rough-toothed dolphin	145,900	277,643	138,821	46,274	174,822	87,411	29,137	102,886	51,443	17,148
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	53,310
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	184,351
Common dolphin *1	2,664,300	5,386,338	2,308,431	0	3,338,444	1,430,762	0	1,906,040	816,874	0
Fraser's dolphin	289,300	562,492	328,121	46,874	355,468	207,356	29,622	210,661	122,886	17,555
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	67,797
Harbour porpoise	N.D.									
Vaquita	N.D.									
Finless porpoise	5,000	4,614	3,691	923	2,652	2,121	530	1,309	1,048	262
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		**27,725,633**	**26,797,479**	**1,661,972**	**19,293,415**	**22,040,161**	**1,428,515**	**16,590,790**	**27,422,366**	**1,888,806**
Cetaceans total		**29,914,518**	**26,872,320**	**15,556,639**	**21,673,440**	**22,135,464**	**18,123,594**	**20,669,430**	**27,640,517**	**36,487,648**

*1: Including long-beaked common dolphin

7-3. 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
Bryde's whale	N.D.									
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
Pygmy sperm whale	N.D.									
Dwarf sperm whale	N.D.									
Cuvier's beaked whale	N.D.									
Northern bottlenose whale	44,300	148,098	691,124	148,098	129,560	604,615	129,560	143,379	669,102	143,379
Blainville's beaked whale	N.D.									
Sowerby's beaked whale	N.D.									
Gervais' beaked whale	N.D.									
True's beaked whale	N.D.									
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
Short-finned pilot whale	N.D.									
False killer whale	N.D.									
Pygmy killer whale	N.D.									
Melon-headed whale	N.D.									
Atlantic hump-backed dolphin	N.D.									
Rough-toothed dolphin	N.D.									
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
Risso's dolphin	N.D.									
Bottlenose dolphin	N.D.									
Pantropical spotted dolphin	N.D.									
Atlantic spotted dolphin	N.D.									
Spinner dolphin	N.D.									
Clymene dolphin	N.D.									
Striped dolphin	N.D.									
Common dolphin *1	N.D.									
Fraser's dolphin	N.D.									
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**

*1: Including long-beaked common dolphin

7-4. 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	72,290,150	5,745,205	0	94,953,379	8,933,662	0	150,276,940
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**	**75,551,881**	**19,738,660**	**30,450,096**	**98,253,426**	**32,339,628**	**56,098,771**	**155,487,492**
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	27,725,633	26,797,479	1,661,972	19,293,415	22,040,161	1,428,515	16,590,790	27,422,366	1,888,806
Cetacean total	**29,914,518**	**26,872,320**	**15,556,639**	**21,673,440**	**22,135,464**	**18,123,594**	**20,669,430**	**27,640,517**	**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	101,504,463	14,735,218	95,303	130,469,087	23,909,733	218,151	225,822,626
Toothed whales	49,858,436	78,024,723	6,254,436	42,093,622	76,808,827	6,157,875	53,825,700	122,116,359	9,558,969
Cetacean total	**62,583,085**	**78,099,564**	**107,758,899**	**56,828,840**	**76,904,130**	**136,626,962**	**77,735,433**	**122,334,510**	**235,381,595**

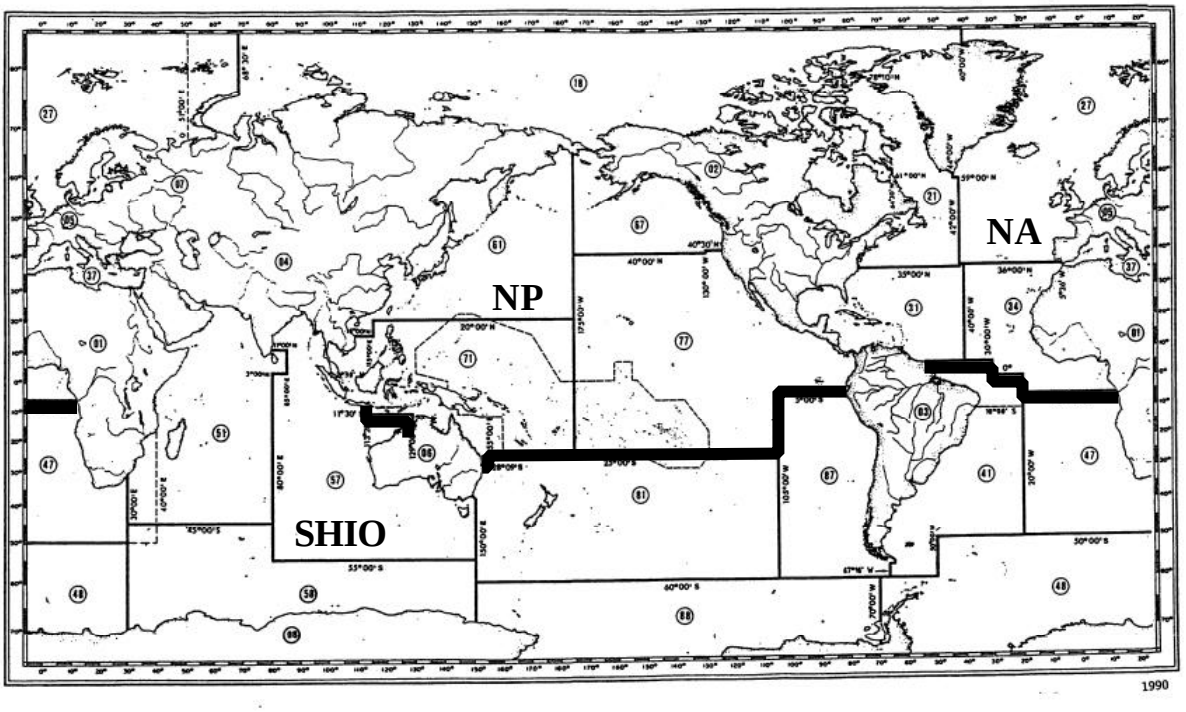

Fig.1. Map of major fishing areas for statistical purposes and ocean regions in this study, based on FAO (FAO, 1991).