A review of abundance, trends and foraging parameters of baleen whales in the Southern Hemisphere.

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1. INTRODUCTION

Large baleen whales were heavily depleted by commercial whaling in the Southern Hemisphere (Gambell, 1993; Clapham & Baker, 2002; Tønnessen & Johnsen, 1982), but since protection was afforded, many populations have shown different levels of recovery (Best, 1993). Despite the fact that baleen whales are major consumers of production in the Southern Ocean (occupying upper trophic levels), there remains considerable uncertainty about the role baleen whales play in this ecosystem especially given that many populations are currently recovering from severe overexploitation. Understanding this role is important because it provides a context within which to evaluate the potential impact of their predation on prey populations and community structure, and the impact of variation in prey populations, of harvesting by humans and environmental change on the their dynamics. Baleen whales feed almost exclusively on plankton and krill, and as the most abundant secondary producer in the Southern Ocean ecosystem, krill are also a key prey item for a number of other vertebrate predators. Hence in a food web context, the link between baleen whales and krill is an interaction likely to influence other dynamic interactions in the Southern Ocean as well as ecosystem structure and function. For this reason, their exploitation and recovery histories likely had, and continue to have important and unique effects to the Antarctic ecosystem. The ecosystem level effect of a large predator biomass removal followed by the recolonisation of historical and possibly new habitats is still poorly understood.

One way of exploring trophic relationships and their effects in the marine environment is through models of the ecosystem. Possible issues with this kind of analyses include the spatial and temporal scales of the models and the quality of the data. Recognising the importance of establishing appropriate models and data led the Scientific Committees of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the International Whaling Commission (IWC) to hold a workshop to review input data for Antarctic marine ecosystem models.

A summary of information on baleen whales was identified by the CCAMLR-IWC Workshop Steering Group as important for the models. The following types of data were identified as model requirements:

(1) Population: biomass/numbers, trends in abundance, population structure;

(2) Habitat utilisation: movement, key habitat and environmental variables, foraging areas;

(3) Population growth rates: growth of individuals, reproductive output, recruitment, mortality rates, carrying capacity;

(4) Foraging activities: diet, foraging success, consumption rate, competition;

(5) Catch: biomass/numbers taken and size structure in different regions over time.

This document provides a summary of these data for various large baleen whale species. In general there is substantial information on whale abundance, stock structure, biology and ecology in the Southern Hemisphere. Because most baleen whale species are migratory, this information may come from winter (breeding) or summer (feeding) grounds. In this study, emphasis was given to information obtained in the high latitude (feeding grounds), but in some cases data from low latitudes (winter/breeding) grounds was included to complement or contrast what is known from feeding grounds and include information on whales throughout their range.

2. SPECIES CONSIDERED AND MANAGEMENT AREAS

The following species were considered in this paper: humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whale (*B. borealis*), Antarctic minke whales (*B. bonaerensis*), and Southern right whales (*Eubalaena australis*). There is very limited information about population parameters for other baleen whale species that are mainly sub-Antarctic, but also occur in Antarctic waters (e.g. common [dwarf] minke whales [*B. Acutorostrata*], and pygmy right whales [*Caperea marginata*]). Therefore, they were not included here.

Broadly speaking, all the species discussed here have a circum-global distribution and all occur in the Antarctic, defined here as the region south of the Polar Front, during at least part of the year. Utilisation of Antarctic waters is species-specific. Some species are found close to ice-edge (*e.g.* Antarctic minke and blue whales), where it is expected most of its populations are found during the feeding season, while others remain further to the north (*e.g.* sei and Southern right whales), with only fewer individuals venturing in higher latitudes of the Antarctic Ocean.

The IWC and CCAMLR have divided the Southern Oceans into Management or Statistical Areas for the purpose of management. The distribution, abundance, rates of increase and habitat of various species of whales will be described with respect to these areas for the purposes of this manuscript. These areas are illustrated in Fig. 1. In some instances, parameters are either estimated across management units or as part of management units and are scaled accordingly.

3. SOURCES OF DATA

Sources of data used in this paper include whaling operations from various countries and, more recently, a number of research programs. The majority of the catch data are held in a database managed by the IWC secretariat and originated in the Bureau of International Whaling Statistics (BIWS). In a few cases (e.g. Southern right whales), records exist in sources that pre-date the BIWS (e.g. Townsend, 1935). More recent research programs can be broadly classified into (1) International Research Programmes, which were conducted by international organizations such as the IWC or CCAMLR or by multiple countries, and (2) National Research Programmes (e.g. government funded Antarctic Programs of individual countries), and (3) miscellaneous initiatives, including research conducted by individual research groups using platform of opportunity with limited or no government support (e.g. the Southern Hemisphere Humpback Whale Catalogue).

3.1 Distribution, Habitat, Abundance and Trend Estimates

3.1.1 The IDCR/SOWER cruises

The most comprehensive source of information on abundance and trends in the Antarctic Ocean are the three sets of circumpolar surveys (CP) conducted by the IWC under the International Decade for Cetacean Research (IDCR)/Southern Ocean Whale and Ecosystem Research (SOWER) Programmes (Branch & Butterworth, 2001a; Branch & Butterworth, 2001b; Joyce et al., 1988; Matsuoka et al., 2003). These annual surveys have been carried out in the austral summer almost exclusively south of 60°S. The IDCR/SOWER cruises have been divided into three circumpolar sets of cruises (CPI: 1978/1979-1983/1984, CPII: 1985/86–1990/91 and CPIII: 1991/92–2007/08[1]) and have covered 64.3% (CPI), 79.5% (CPII) and 99.7% (CPIII) of the region between 60°S and the ice edge. Some extrapolation has been implemented in order to compare estimates for the three sets of surveys. The IDCR/SOWER cruises have provided significant information on distribution and data to compute abundance and trend estimates for some baleen whale species. An overview of the survey objectives, areas and methods is provided by (Matsuoka et al., 2003). Abundance estimates using ‘standard methods’ from the three CP sets are reported by Branch and Butterworth (2001a; 2001d) and Branch (2006b; 2007a).

3.1.2 CCAMLR 2000 Survey

The CCAMLR 2000 Survey was a joint research cruise conducted by CCAMLR and IWC in January and February 2000. The primary objective of the survey was to obtain an up-to-date estimate of krill biomass for the region to use in setting a precautionary catch limit for the commercial krill fishery, but both commissions recognised this was as an ideal opportunity to couple whale sighting surveys with the krill surveys. Distribution

[1] The CPIII surveys cover 1991/92 to 2007/08, but the 2001/02-2003/04 repeats Area V covered in 1991/92; and the later surveys are mostly experimental and have so far been omitted when obtaining abundance estimates.

and abundance information was obtained for a number of species in an area extending across the Scotia Sea and around the Antarctic Peninsula (Hedley et al., 2001; Reilly et al., 2004).

3.1.3 Southern Ocean GLOBEC

The Southern Ocean Global Ocean Ecosystems Dynamics (SO-GLOBEC) program is an international, multidisciplinary effort to understand the physical and biological factors that influence the growth, reproduction, recruitment, and survival of Antarctic krill (*Euphausia superba*) with special emphasis on its overwintering mechanisms. In 2001, the IWC began to collaborate with SO-GLOBEC to provide studies of linkages between particular baleen whale species such as minke and humpback whales, and Antarctic krill populations. In collaboration with SO-GLOBEC two cetacean sightings surveys were also conducted (in 2004) on the AnSlope (Cross-slope exchanges at the Antarctic Slope Front) cruises (2002-2005). Large whale distribution and abundance data were collected for the Antarctic Peninsula (Marguerite Bay) (e.g. Thiele et al., 2004a), but these data have not yet been fully analysed, with the exception of the study by Friedlaender et al. (2006b).

3.1.4 National Research Programs

A number of National Research Programs have produced information on distribution and abundance of various cetacean species in the Antarctic. Notably, the following countries have conducted dedicated and/or opportunistic cetacean research: Australia, Brazil, Chile, Germany, Japan (see below), New Zealand, the United Kingdom, and the United States. Information from these programs for relevant baleen whale species is specified below.

3.1.4.1 JARPA

The Japanese Whale Research Program Under Special Permit in the Antarctic (JARPA) is the only research program among those mentioned above exclusively dedicated to the study of cetaceans. For this reason, it is treated separately here. JARPA constitutes a comprehensive set of studies, including sampling of whales, with potential to provide substantial information required for ecosystem models in the Antarctic. An overview of this research program, which has emphasis on Antarctic minke whales, is summarised by Nishiwaki et al. (2007).

JARPA was conducted every year from the 1987/88 to 2004/05 austral summer seasons. After two seasons of a feasibility study, full-scale research began in 1989/90. The program was designed to repeat surveys in the Indo-Pacific region (35ºE-145ºW) of the Antarctic (south of 60ºS), where IWC Management Areas IV and V were alternately sampled in each of the sixteen years of the research period. Area IV was divided into five strata and Area V into four strata. Although in each season work was conducted throughout November to March, repeated research in Areas IV and V was conducted mainly in January and February. A ‘Special Monitoring Zone’ was established to investigate seasonal variation of whale density during the 1992/93-1994/95 seasons. In 1995/96, the survey area was expanded into a part of Areas III and VI with the objective of improving the stock structure study. JARPA comprised a combination of sighting and sampling surveys. In general, a saw tooth shape track line at intervals of 4° longitude or IDCR/SOWER-style zig-zag tracklines were used in the southern strata and a zigzag trackline at intervals of 15° of longitude (or flexibly as in IDCR/SOWER) was used in the northern strata. In order to obtain biological samples representing whole population in the research area, a random sampling method coupled to line transect sighting surveying was adopted. Two or three sighting/sampling vessels (SSVs) conducted sighting and sampling survey on the predetermined track-line with parallel sub-track lines. A dedicated sighting vessel (SV) was introduced in 1991/92 and the SV preceded the SSVs by a distance of over 12 nautical miles, to avoid influence of sampling activity on the sighting survey. One or two Antarctic minke whales were sampled (killed) randomly from each primary sighted school within 3 n.miles of the trackline of each SSV. All the whales taken were subject to biological sampling. Some experiments were conducted to improve the methodology of the sighting/sampling survey. In parallel with the lethal sampling survey, a variety of non-lethal studies were conducted (e.g. oceanographic surveys, prey surveys, and photo-identification and biopsy sampling for large baleen whales).

3.1.5 JSV DATA

Information on baleen whale distribution and seasonal occurrence in the Southern Hemisphere was obtained by the National Research Institute of Far Seas Fisheries of Japan through sightings collected with the scouting vessels (JSV) attached to the Japanese whaling fleet (Butterworth et al., 1992; Miyashita et al., 1995; Miyashita et al., 1994; Ohsumi & Yamamura, 1982). These vessels operated during commercial whaling between the 1965/66 and the 1987/88 seasons and the data collected have been used in various studies. Notably, these data have supplemented those from the IDCR-SOWER cruises, particularly outside of the typical survey areas of these cruises (e.g. north of 60°S). The areas covered by the JSV’s was determined by the fleet commanders and typically corresponded to regions with expected high density of whales, where the whaling fleets operated. Tracklines were planned based on previous knowledge of whale abundance, habitat and the distribution of other higher trophic level predators (e.g. birds). Tracklines were not systematically designed and often changed throughout the survey according to local environmental (oceanographic) conditions and with whale distribution and abundance. Effort and sighting data was not recorded with the same scientific rigor implemented in more recent studies (e.g. IDCR-SOWER and JARPA) and temporal changes in sampling strategies were observed according to IWC management systems. For example, with the introduction of catch limits by species and areas the JSV's begun to operate in larger areas for shorter periods of time, which resulted in less detailed area coverage (Miyashita et al., 1994).

3.1.6 Miscellaneous Programs

A number of other studies (*e.g.* using research or cruise ships as platforms of opportunity and funded by private or non-governmental organisations) have provided information on cetacean distribution and abundance in various regions in the Southern Hemisphere. For example, this is the case in a number of studies conducted in the wintering grounds, which in many cases have likely provided more reliable information on population parameters than studies conducted in feeding grounds. Data relevant for baleen whales obtained under these research programs are mentioned below for each individual species.

3.2 Catch Data

Catch data were obtained from the official IWC catch database. This comprises two components: annual summaries of catches by species in broad areas, and for a large proportion of the catches, a second component containing specific information for individual whale catches, such as location, sex and pregnancy.

4. SPECIES ACCOUNTS

4.1 Humpback Whales

Humpback whales are one of the most studied whales among the Southern Ocean baleen whales. The species is highly migratory, moving seasonally between low latitude winter breeding areas and high latitude summer feeding grounds (Clapham & Mead, 1999). Their annual migration can cover up to 50^{o} of latitude in round trips that can reach over 11,000 km (Bannister, 2002; Rasmussen *et al.*, 2007)

The IWC currently recognises seven Breeding Stocks (BS) named 'A' to 'G' (IWC, 1998, 2004-2008). These populations winter off the east and west coasts of South and Central America (BSA and BSG), Africa (BSB and BSC), Australia (BSD and BSE) and islands and archipelagos of the southwest Pacific Ocean (F) (IWC, 1998). For the past few years, the IWC has been undertaking a Comprehensive Assessment of Southern Hemisphere humpback whales, which has generated substantial information for these different populations. Some stocks have been studied for several decades now (e.g. BSD and BSE) and are therefore relatively well known. On the other hand, research is still ongoing for other populations (BSF) and therefore not much information is yet available. Stock-specific data are presented below. For the purpose of summarising information in the feeding grounds, stock structure hypothesis follows the Naïve models proposed by the IWC (1998). New feeding ground boundaries (labelled the Core hypothesis) have been established for some stocks (e.g. BSA, BSD and BSG, IWC, 2006), but further discussions in that regards are ongoing for other groups (BSB, BSC, BSE and BSF); therefore the Naive model (IWC, 1998) was adopted for simplicity. The geographic correspondence of these areas with the IWC Management Areas in the Southern Hemisphere and the CCAMLR statistical areas are summarised in Table 1.

Overall, the abundance of humpback whales in the Southern Ocean is believed to be above 50,000 whales (Branch, 2006b). Mitochondrial DNA and microsatellite analyses suggest that substructure in the feeding grounds is consistent with the division of this species into breeding stocks (*e.g.* Pastene et al., 2006).

4.1.1 Breeding Stock A

4.1.1.1 DISTRIBUTION AND HABITAT UTILISATION

Breeding Stock A (BSA) corresponds to whales wintering off the eastern coast of South America. The majority of the population is found along the coast of Brazil mainly during winter and spring (June-November), within the continental shelf (depths < 500m) between 5^{o} and 24^{o}S (Andriolo et al., 2006; Martins et al., 2001). This population migrates through oceanic waters in the western South Atlantic Ocean to feeding grounds in the Scotia Sea (Zerbini et al., 2006a). The IWC assumes, for the purpose of catch allocation, that the feeding grounds associated with BSA range from the 40^{o}S to the pack-ice within 20 and 50^{o}W, within the IWC Management Area II and CCAMLR areas 48.2, 48.3, 48.4, and 48.5 (Table 1). Current sighting, photo-identification and telemetry data suggest that whales from this population concentrate in areas between 50^{o} and 60^{o}S and 20^{o} and 40^{o}W (Kasamatsu et al., 1996; Reilly et al., 2004; Stevick et al., 2006a; Zerbini et al., 2006a), with very few records west of 40^{o}W and south of 60^{o}S.

Historical data show that nearly 90% of the humpback whales catches in the Scotia Sea were taken within 100km of South Georgia from November to June with peaks in December and January (Matthews, 1937). Catches also occurred in smaller scales near the South Orkney, the Sandwich Islands and in pelagic waters (Tønnessen & Johnsen, 1982). More recent data suggest that humpback whales are rare near the former whaling grounds off South Georgia (Moore et al., 1999), but more common further offshore (300-500km) (Reilly et al., 2004; Zerbini et al., 2006a).

4.1.1.2 ABUNDANCE AND TRENDS

Abundance estimates for the feeding grounds are available from the IDCR/SOWER and the CCAMLR 2000 cruises and summarised in Table 2. Because IDCR/SOWER surveyed only waters south of 60^{o}S, the estimates resulting from these cruises certainly do not correspond to the true the size of BSA (Branch, 2006b). The estimate from the Scotia Sea obtained during CCAMLR 2000 corresponds to whales that inhabit a much greater portion of the BSA feeding grounds, but because not all the habitat occupied by these whales was sampled under this study, it should still be considered a partial estimate of the total stock size. The most reliable estimate of the size of this population (6,250 individuals, 95% CI = 4,500-8,800, Andriolo et al., 2006) comes from an aerial survey conducted in the wintering grounds off Brazil in 2005 (Table 2) (IWC, 2006). This estimate corresponds to nearly 28% of a pre-exploitation population of 24,500 (95% Bayesian interval = 22,800-31,200) individuals (Zerbini et al., 2006b)

Estimates of trends for BSA are available both from the feeding grounds and the breeding grounds (Table 2). The feeding ground estimate from the IDCR/SOWER CP cruises however, is not significantly different from zero and may be biased by poor coverage of the feeding grounds (see above); therefore it should not be used as an estimate of the rate of increase of BSA (Branch, 2006b). Estimates from wintering grounds resulted from sampling a much greater proportion of whales in this population, but the one obtained by Freitas *et al.* (2004) seems to be well above the maximum biologically plausible growth rate for humpback whales (Clapham et al., 2006) and therefore is not reliable (IWC, 2006). The best estimate of the growth rate of this population (7.4%/year, 95% CI = 0.5-14.6%/year) is the estimate of Ward *et al.* (2006) for the period 1995-1998 (Table 3).

4.1.1.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSA humpback whales under the IWC Core/Naïve model are presented, respectively, in Tables 4 and 5.

4.1.2 Breeding Stock B

4.1.2.1 DISTRIBUTION AND HABITAT UTILISATION

Breeding Stock B (BSB) corresponds to whales wintering off the western coast of Africa. It has been postulated that whales in this region can be divided into two separate groups. BSB1 which is thought to winter (June-October) along central West African coast (north of ~18^{o}S) and around the northern islands of the Gulf of Guinea (as far north as 4^{o}N); and BSB2 which is thought to winter off the west coast of South Africa and Namibia (south of ~18^{o}S), although the northerly extent of this remains undefined (IWC, 2006). There is evidence that the region within BSB2 also corresponds to a migratory route for animals breeding within BSB1 and a feeding ground for both individuals from BSB1 and BSB2. The latter is supported by photo-identification matches of whales from BSB1 seen in BSB2, and by observations of feeding and of whales summering in this area (Barendse et al., 2006; Best et al., 1995, IWC, 2006).

Limited telemetry data (two individuals) have indicated that whales from BSB1 have migrated along the coast of western Africa until nearly 18^{o}S, then along Walvis Ridge towards the Antarctic up to the 0^{o}W meridian (IWC, 2006). These individuals represent the only recorded connection between BSB and feeding grounds in high latitudes of the Antarctic. Feeding grounds associated with BSB correspond to the 20^{o}W-10^{o}E longitudinal sector of the Antarctic (IWC, 1998) within the IWC management areas IIE and IIIW and CCAMLR area 48.6 (Table 1).

4.1.2.2 ABUNDANCE AND TRENDS

Abundance in BSB feeding grounds was estimated for three seasons with data from the IDCR/SOWER surveys (Table 2). The latest estimate (CPIII: 1995/96, 595 individuals, CV=0.51) almost certainly corresponds to just a fraction of whales seen in the wintering grounds, where mark-recapture abundance estimates from photo-identification and genotype data resulted in estimates of ~3,800 with an upper limit of 5,000–6,000 individuals in 2001–04 (Collins et al., 2006). No estimates are available for B2, but a photographic catalogue from 2001–05 contains 260 individuals with a high inter-annual resighting rate of 16.5% that suggests the population is small (Barendse et al., 2006)

Assuming that the size of BSB2 is ~500, the total abundance for breeding stock B was ~4,300 in 2001–04 (Branch, 2006b). If the latest CPIII estimate is projected assuming a growth rate of 10%/year, then the abundance in the feeding grounds south of 60°S is just 28% of this estimate (Branch, 2006b). As for BSA, it is possible that a large proportion of humpback whales wintering off western Africa do not migrate into the areas covered by the IDCR/SOWER surveys. High densities of humpback whales north of 60°S in the summer have been previously observed between 25°W and 5°E (Miyashita et al., 1995) and between 5°E–20°E (Ensor et al., 2006).

The rate of increase estimated from the IDCR/SOWER series of abundance estimates is 5.9%/year (95%CI = -5.9%-17.9%/year, Branch, 2006b). This has broad confidence intervals and applies only to a portion of the population. No estimates are available for the wintering grounds. Therefore current trends in abundance of BSB are not well defined.

4.1.2.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSB humpback whales under the IWC Naïve model are presented, respectively, in Tables 4 and 5.

4.1.3 Breeding Stock C

4.1.3.1 DISTRIBUTION AND HABITAT UTILISATION

Breeding Stock C correspond to whales breeding off the eastern African coast in winter and spring months. Three sub-regions have been postulated for this stock: BSC1 (migrations along the east coast of South Africa up to breeding grounds off Mozambique and Tanzania); BSC2 (Mayotte Island, the Comoros Islands and other islands and reef systems of the Mozambique Channel); BSC3 (the coastal waters of Madagascar) (IWC, 2006). Recaptures of individuals provide potentially extensive connectivity between BSC2 and BSC3, and to a lesser extent (one individual) between BSC1 and BSC2. No evidence of connectivity exists for BSC1 and BSC2. One lost harpoon (Olsen, 1914-15) provides a link between East South Africa and Southern Mozambique. Genetic differentiation has been found between Antongil Bay (BSC3) and East South Africa/Southern Mozambique (BSC1), and between Mayotte (BSC2) and East South Africa/Southern Mozambique (BSC1), while no genetic differentiation is found between Mayotte (BSC2) and Antongil Bay (BSC3) (IWC, 2006).

Migration routes and migratory destinations of BSC whales are relatively poorly known. Best et al. (1998) suggested the existence of at least three main migratory routes: (1) along east Africa, (2) through the Madagascar Ridge and (3) through the central Mozambique Channel. The only direct evidence linking wintering grounds off eastern Africa and feeding grounds in higher latitudes came from two individuals marked in the Antarctic (~54°S, 10°E) and captured south of Madagascar (Rayner, 1940). Marking location was at the boundary between the feeding grounds associated with BSB and BSC, suggesting the possibility that whales from these two stocks mix in high latitudes.

Feeding grounds associated with BSC lie within 10°E and 60°E in the IWC Area III and overlap with a number of the CCAMLR areas (Table 1).

4.1.3.2 ABUNDANCE AND TRENDS

Feeding grounds associated with BSC correspond to the 10°E-60°E longitudinal sector of the Antarctic (IWC, 1998) (Table 1). Estimates of abundance were obtained in the summer grounds with data from the IDCR/SOWER surveys and the Australian Antarctic Division (AAD) BROKE Survey (Table 2). As for other stocks, the latest estimate (CPIII: 1993/94, 2391 individuals, CV=0.41, Branch, 2006b and BROKE: 2006, 4368 individuals, CV=0.28; Peel & Thiele, 2006) likely corresponds to just a fraction of whales seen in the wintering grounds because humpback whales are found north of 60°S in the summer (Ensor et al., 2006; Miyashita et al., 1995). In addition, the BROKE survey covered just a fraction of the longitudinal range of the stock (40°-70°E), between 62 and 68°S (Peel & Thiele, 2006).

Multiple estimates of abundance in the wintering grounds are available for different portions of BSC. For BSC1 a ship-based line-transect survey estimated abundance to be 5,965 (CV=0.17) in 2003 (Findlay et al., 2004), for BSC2 a total of 250 individuals were photo-identified from the eastern Comoros Archipelago but no abundance estimate is given (Ersts et al., 2006) and for BSC3 at Antongil Bay, Madagascar, photographic and genetic mark-recapture techniques provide estimates within the range of 5,000 to 7,000 for 1999–2004 (Cerchio et al., 2006). While some issues with sub-stock structure and possible interchange between regions are yet to be resolved, the total population for breeding stock C is approximately 12,000 in 1999–2004, assuming that the sub-stocks do not share individuals. The extrapolated CPIII abundance estimate is therefore only 20–44% of the total breeding ground estimate. Estimates in the feeding ground may include whales from BSB and/or BSD due to possible overlap in feeding grounds.

Feeding ground-based estimates of population growth is 6.6%/year (95% CI = -3.8-17.9%/year), but this applies only to a relatively small portion of the population (Branch, 2006b). An alternative estimated rate of increase

(9.0% or 12.3%/year) for this stock has been obtained from shore-based counts at Cape Vidal, South Africa (Findlay & Best, 2006), although the latter (12.3%) is beyond the biologically plausible for humpback whales (Clapham et al., 2006) and therefore likely not reliable.

4.1.3.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSC humpback whales under the IWC Naïve model are presented, respectively, in Tables 4 and 5.

4.1.4 Breeding Stock D

4.1.4.1 DISTRIBUTION AND HABITAT UTILISATION

Humpback whales migrate northwards during winter along the west coast of Australia towards a current breeding ground destination as far north as 15°S (Jenner et al., 2001) beyond North West Cape, Western Australia (*ca* 21°50'S, 114° 10'E). A few early northward migrating animals may reach the coast in April, but the main northbound stream arrives in June. The southerly migration takes place in late winter/spring. Off Perth, Western Australia (31°57'S, 115°51'E) southbound animals are found mostly in September and October, with cow-calf pairs most commonly seen in November (Burton, 1991).

BSD humpback whales migrate to feeding grounds in high latitudes of the Antarctic Ocean. Evidence from a variety of sources suggests that BSD mixes with BSE1 in these feeding areas. Analysis of catch returns taken in areas IV and V throughout the 1950's, supplemented by recoveries of Discovery marks, suggests an exchange of whales across both feeding areas, especially a movement of whales from breeding stock E to the feeding areas east of 115°E, in area IV (Chittleborough, 1965, Dawbin, 1966). More recently, genetic data also support this conclusion, where for instance a mark-recapture tag first sampled in the western part of area V was subsequently re-sampled in the eastern part of Area IV (IWC, 2002). Clues to the historic distribution of humpback whales in areas IV and V come from the recently updated IWC catch data series Allison (2006). It is clear from these data that the catch for areas V and IV is not uniformly distributed across these management areas. Sightings data from both the IDCR/SOWER circumpolar cruises and JARPA sightings surveys also suggest that whales are currently encountered more frequently at 20-40°E, 80°E-100°E, 150°E-180°E and 40°W-70°W (IWC, 2006). The current feeding grounds associated with BSD lie between 80^{o} and 110^{o}E (IWC, 2006), which corresponds to IWC Area IV and CCAMLR Area 58.4.1 (Table 1).

4.1.4.2 ABUNDANCE AND TRENDS

The most current estimate for BSD in the breeding grounds, 13,145 whales (95% CI 4,984–38,726) comes from aerial survey data from 2005 (Paxton et al., 2006, submitted). This population has been increasing steadily at 10.15% (SE = 4.6%) per year (Bannister & Hedley, 2001). At this rate of increase, the estimates from CPIII (Table 2) would have increased to about 38,000, i.e. 2.89 times the breeding ground estimate in 2005. Estimates of abundance from the Japanese Research Program in the Antarctic (JARPA) for Management Area IV south of 60^{o}S were of 33,010 (CV = 0.10) in 2001/02 and 31,750 (CV = 0.11) in 2003/04 (Matsuoka et al., 2006a) (Table 2) come from a similar longitudinal range (70–130°E vs. 60–120°E) and are consistent with the extrapolated IDCR/SOWER estimates (Branch, 2006b). Despite substantial effort during IDCR/SOWER transits, few humpback whales have been sighted north of the IDCR/SOWER survey region, suggesting that the majority is found south of 60°S. If the feeding ground surveys provide a more complete coverage of the entire population it is likely that the IDCR/SOWER and JARPA data provide a more complete abundance estimate than the breeding ground survey, and hence the current abundance of breeding stock D may be in excess of 30,000 (Branch, 2006b).

Rates of increase from both IDCR/SOWER and JARPA surveys are above biologically plausible levels and have wide confidence intervals; therefore the more precise 10.15% annual rate of increase from the wintering grounds (Bannister & Hedley, 2001) is preferred for this breeding stock (Branch, 2006b).

4.1.4.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSD humpback whales under the IWC Core/Naïve model are presented, respectively, in Tables 4 and 5.

4.1.5 Breeding Stock E

4.1.5.1 DISTRIBUTION AND HABITAT UTILISATION

Breeding Stock E corresponds to whales migrating primarily to the eastern coast of Australia, New Caledonia, Fiji, and Tonga (IWC, 2004). It has been suggested that this stock may be divided into three substocks: BSE1 (eastern Australia), BSE2 (New Caledonia) and BSE3 (Fiji and Tonga). Interchange across these areas as well as with other islands in Oceania (BSF) has been documented (Clapham et al., 2008; Garrigue et al., 2002).

Whales in eastern Australia migrate south along the coast towards feeding grounds in higher latitudes (IWC, 2004), while those in New Caledonia may move towards the Australian continent, through oceanic waters within Oceania, or past New Zealand (Clapham et al., 2008; Dawbin, 1966; IWC, 2004).

The feeding grounds of whales wintering in eastern Australia has been relatively well described (Dawbin, 1966). Discovery tagging revealed that 90% of the whales move to the IWC Management Area V. Nearly 10% of the whales moved to feeding grounds associated with BSD (IWC Area IV) and one individual went east into Area VI. The longitudinal range of the feeding grounds associated with BSE corresponds to 120^{o}E-170^{o}W (IWC, 1998).

4.1.5.2 ABUNDANCE AND TRENDS

Wintering ground abundance estimates are available for all sub-stocks of BSE. Multiple studies were conducted to estimate the size of population migrating/wintering off eastern Australia (BSE1) (e.g. Brown et al., 2003; Bryden et al., 1996; Noad et al., 2006; Paterson et al., 2004; Paton et al., 2006). The latest estimates, in 2005 and 2007, were, respectively 7,024 (95% CI = 5,163-9,685) (Paton et al., 2006) and 9,683 (95% CI = 8,556-10,959). Photographic mark-recapture estimates for 1999 to 2004 were 472 (CV = 0.18) for New Caledonia (BSE2) and 2,311 (CV = 0.22) for Tonga (BSE3) (SPWRC et al., 2006). Total breeding ground abundance for 1999-2005 is nearly 10,000 individuals.

Abundance estimates in the feeding grounds of BSE were obtained from the IDCR/SOWER cruises (Branch, 2006) and from the JARPA surveys (Matsuoka et al., 2006a) (Table 2). The most recent estimate from IDCR/SOWER (2001/02) indicated a population (13,300, 95% CI = 9,000-19,000) greater than the wintering ground abundances and greater than the latest JARPA estimate (2004/05) for Area V (9,800, 95% CI = 5,200-18,400). The IDCR/SOWER and JARPA estimates probably include most of the breeding stock given that few humpback whales are sighted north of the survey region during IDCR/SOWER transits (Branch, 2006b; Miyashita et al., 1995). Humpback whales migrating past the east coast of Australia have a male-biased sex ratio of 2.4:1 (Brown et al., 1995), suggesting that not all females leave the feeding grounds in winter (Paton & Kniest, 2006). However, feeding and wintering ground abundances for the same approximate years are not statistically different.

Rates of increase have also been computed in both feeding and wintering grounds. All sources suggest a high rate of increase for BSE: shore based surveys from Point Lookout (10.9%/year [95% CI = 10.5-11.4%], Noad et al., 2008) in the wintering grounds, and IDCR/SOWER (13.7% [95% CI 9.3–18.1%], Branch, 2006), and JARPA (6.4% [95% CI = -0.2-15.3%], Matsuoka et al., 2005). The IDCR/SOWER estimate is above biological limits and the JARPA estimate has wide confidence intervals. Therefore the Point Lookout surveys provide the most precise and reliable estimate of the rate of increase, which is near the maximum possible for humpback whales (Clapham et al., 2006)

4.1.5.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSE humpback whales under the IWC Naïve model are presented, respectively, in Tables 4 and 5.

4.1.6 Breeding Stock F

4.1.6.1 DISTRIBUTION AND HABITAT UTILISATION

Breeding Stock F corresponds to humpback whales wintering in western Oceania (IWC, 2004). Two possible sub-stocks have been identified, Cook Islands (BSF1) and French Polynesia (BSF2). This is likely the most poorly known humpback whale stock, with almost nothing known about seasonal distribution and movements. Photo-identification and satellite telemetry data has shown limited interchange of individuals with BSE and within areas of BSF (Clapham et al., 2008; Poole, 2006; IWC, 2006).

Migration routes for whales wintering within BSF are also unknown. Feeding grounds are thought to be within Antarctic Area VI (IWC, 2004), which is consistent with the movement of a whale tagged with a satellite transmitter from Rarotonga (Cook Islands) to the Antarctic Ocean (~65^{o}S, 126^{o}W) in Area VI (Hauser et al., 2007). Feeding grounds associated with this BS range between longitudes 170^{o}W and 110^{o}W (IWC, 1998)

4.1.6.2 ABUNDANCE AND TRENDS

There are no current estimates of abundance for BSF1. For BSF2, a photo-identification-based mark-recapture estimate for the period 1999-2004 indicated a population of 1,057 (95% CI = 700-1600) (Poole, 2006). Estimates from the feeding grounds (Table 2) showed that the population was nearly 3,800 whales (95% CI = 2,500-6,000). Feeding ground estimates are much higher than wintering grounds because no abundance was computed for the Cook Islands, not all habitats have been sampled (e.g. Poole [2006] reports that the estimate from French Polynesia was based on two islands but sightings have been reported in 23 other islands], and because not all females migrate to wintering grounds (sex ratio is male biased [1.5:1] in French Polynesia, Poole [2006]). Therefore, feeding ground estimates are likely more representative of the size of this stock. The most current estimate suggests as population of 3,852 whales (95% CI = 2,500-5,900) in 1997/98 (Branch, 2006b; Miyashita et al., 1995)

There are no estimates of rate of increase from wintering grounds of BSF. The existing estimate from the IDCR/SOWER is 1.6% (95% CI = -5.4% to 8.5%; Branch, 2006b) has wide confidence intervals and provides no evidence that this population is decreasing, stable or increasing.

4.1.6.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSF humpback whales under the IWC Naïve model are presented, respectively, in Tables 4 and 5.

4.1.7 Breeding Stock G

4.1.7.1 DISTRIBUTION AND HABITAT UTILISATION

Breeding Stock G correspond to whales wintering off the western coast of South and Central America, from northern Peru to Costa Rica (IWC, 2006b). There is no evidence of sub-stock structure in the wintering grounds although it seems that whales in this region migrate to two, possibly three separate feeding grounds. Migration routes are unknown for BSG whales, but feeding grounds are relatively well known. Several matches of whales from BSG and the Antarctic Peninsula have been reported (Rasmussen et al., 2007; Stevick et al., 2004; Stone et al., 1990). Humpback whales are found in this region at least during summer and autumn months (Friedlaender et al., 2006a; Secchi et al., 2001; Thiele et al., 2004).

In addition, a smaller feeding ground has been recently identified in the area of Magellan Strait, southern Chile and individuals from this region also winter within BSG (Acevedo et al., 2007). A third feeding aggregation occurs near Chiloé Island, Chile (Hucke-Gaete et al., 2006), but winter destinations of these whales have not yet been determined. The current feeding grounds associated with BSG in the Antarctic Ocean include waters between 110^{o}W and 50^{o}W (IWC, 2006b).

4.1.7.2 ABUNDANCE AND TRENDS

Wintering ground estimates of abundance from mark-recapture studies of photo-identified whales suggest that the size of BSG in 2006 was around 6500 individuals (95% CI = 4,300-9,900) (Felix et al., in review). This number is consistent with estimates from feeding grounds in the Antarctic Peninsula (Table 2), where humpback whales have been extensively studied. Feeding ground estimates in include those from the IDCR/SOWER CP surveys (Branch, 2006b), the CCAMLR 2000 cruise (Hedley et al., 2001; Reilly et al., 2004) and estimates from National Research Programs and miscellaneous studies (Secchi et al., 2006; Stevick et al., 2006b; Williams et al., 2006). Recent feeding ground estimates (1996-2006) ranged from 1,800 to 6,700 (Table 2). Most studies covered only a portion of the feeding grounds and therefore did not capture the entire population. The surveys with best coverage were the IDCR/SOWER and the CCAMLR 2000 and these estimates suggest that the number of BSG whales in the Antarctic could be around 9-12,000 today if the population is increasing at 5-10%/year. There are no estimates of abundance for the other feeding grounds in Chile, but populations are thought to be much smaller.

The only estimate of rate of increase for BSG is the one obtained from IDCR/SOWER (4.6% [95% CI = -3.4% - 12.6%/year; Branch, 2006b). This estimate has a wide confidence interval and provides limited information about current trends in this population. The pre-exploitation population size (assumed to be the pre-1900 population) was estimated at nearly 11,600 (95% Bayesian Interval = 10,500-13,800) individuals (Johnston & Butterworth, 2006).

4.1.7.3 CATCH

Post-1900 breeding ground and feeding ground catches of BSG humpback whales under the IWC Core/Naïve model are presented, respectively, in Tables 4 and 5.

4.2 Blue Whales

Two subspecies of blue whales exist in Southern Hemisphere: the Antarctic (or true) blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*) (Rice, 1998). The former attains greater maximum lengths, is longer at sexual maturity and has proportionately longer tail stock (Ichihara, 1966; Mackintosh & Wheeler, 1929). A complete review of spatial and seasonal distribution, densities and movements of blue whales is provided by Branch et al. (2007b). This study indicated that there is little evidence that pygmy blue whales migrate into high latitudes of the Antarctic. Fewer than 1% of the records south of 52^{o}S (Branch et al., 2007a; Branch & Mikhalev, accepted) were of this subspecies. For this reason, pygmy blue whales are not further considered in this study.

There is no current evidence of population structure in Antarctic blue whales.

4.2.1 Antarctic Blue Whales

4.2.1.1 DISTRIBUTION AND HABITAT UTILISATION

Nearly all blue whales in the Antarctic (south of 52^{o}S) are from the Antarctic (true) subspecies, where multiple lines of evidence, including distribution of biological data, catches, sightings, genetics, and acoustics indicate a continuous circumpolar distribution (Branch et al., 2007b and references therein). Discovery marks indicated wide longitudinal movements (sometimes in excess of 100^{o} in longitude) within and between seasons and clearly showed that blue whales often crossed the boundaries of the IWC Management Areas (Branch et al., 2007b; Brown, 1954; 1962). The majority of the historical catches of Antarctic blue whales were associated with the Antarctic Polar Front, but recent sightings indicate that current distribution is more associated with the pack ice. This difference may be partially explained by observation effort, which has been concentrated south of 60^{o}S in recent years. However, it is possible that the current small population (see below) prefers the ice edge, where krill abundance is higher (Branch et al., 2007b).

Occurrence of Antarctic blue whales in the Antarctic Ocean appears to peak in the summer. Almost all catches were taken between October and April (Branch et al., 2007b). In the winter, there is good evidence that this subspecies migrate to various low latitudes wintering grounds, including the west coast of South Africa, Namibia and Angola, the Eastern Tropical Pacific, the northern Indian Ocean, southwest Australia and northern New Zealand (e.g. Best, 1998; Branch et al., 2007b; Gedamke et al., 2007; Stafford et al., 2004; Stafford et al., 2005). However, whaling and acoustic data suggest that at an unknown component of the population may stay in high latitudes. Catches and sightings indicated the presence of blue whales in winter months near South Georgia (Hinton, 1915; Risting, 1928), albeit in low numbers, and calls have recently been recorded in the western Antarctic Peninsula and in East Antarctica throughout the year (Širovic´ et al., 2004, McKay et al., 2005).

4.2.1.2 ABUNDANCE AND TRENDS

The pre-exploitation abundance of Antarctic blue whales was estimated to be 239,000 (95% Bayesian interval 202,000-311,000) and the population was at about 1% (1700 individuals, 95% Bayesian interval 860–2,900) of its original abundance in 1996 (Branch et al., 2004). Recent estimates of Antarctic blue whale population size are available from the IDCR/SOWER cruises for the whole Antarctic Ocean (Branch, 2007a) and for IWC Areas III E, IV, V and VI W from the JARPA cruises (Matsuoka et al., 2006b) (Table 6). The most current circumpolar abundance estimate was 2,249 (95% CI = 1,140-4,400) (Branch, 2007a). Estimates of trends indicate that the population increased at 7.3%/year (95% CI = 1.4–11.4%/year) in the Antarctic Ocean south of 60^{o}S in the period 1978/79-2000/01 (Branch et al., 2004) and 7.4%/year for IWC Areas IV and V combined in the period 1989/90-2004/05 (Matsuoka et al., 2006b). The former estimate likely better represents the rate of increase of Antarctic blue whales in the past 30 years as it is obtained by fitting all the available data and therefore is more representative of the population.

4.2.1.3 CATCH

Catches of Antarctic blue whales are summarised in Table 7.

4.3 Fin Whales

Like most other baleen whales species, fin whales inhabit all major oceans in the Southern Hemisphere, where seasonal movements between breeding and feeding areas has been documented (Leatherwood & Reeves, 1983). The stock structure of this species is poorly known relative to humpback and, to a lesser extent, blue whales. Discovery Marks have shown north-south movements to wintering grounds directly above feeding areas and also some degree of site fidelity to feeding grounds (Rayner, 1940). However, inter-annual movements greater than 80 degrees of longitude have also been documented, suggesting that at least some exchange occur across the IWC Management Areas (Rayner, 1940). Although there is some evidence of stock separation from multiple lines of evidence (Best, 1974; Fujino, 1964; Mackintosh, 1965; Pastene, 2006), further research is needed to clarify population structure of Southern Hemisphere fin whales.

4.3.1 Distribution and habitat utilisation

Fin whales inhabit oceanic waters in low latitude wintering grounds between 20 and 35°S. Areas of concentration have been identified (1) off northern Chile and Peru, (2) east of South America, (3) west of South Africa, Angola and Congo, (4) off eastern Africa and Madagascar, (5) east of Madagascar, (6) west Australia, (7) east Australia (Coral Sea), and (7) Fiji sea and adjacent waters eastwards (Chapman, 1974). In the summer feeding grounds in the Antarctic, fin whales occur year-round but higher density is found from November to May (Kasamatsu et al., 1996; Mackintosh, 1965). Whales can be found as far south as 65-70°S, but the majority of the population seems to occur north of 60°S (Miyashita et al., 1995). Catches occurred throughout the Antarctic, but the majority of whales (~73%) were taken in the IWC Management Areas II and III. Sighting data suggest that spatial distribution varies across ocean basins (Kasamatsu et al., 1996). In the Atlantic and Indian Ocean sectors of the Antarctic density tends to be greater further to the north (50°-62°S) than in the Pacific Ocean sector (58°-70°S).

4.3.2 Abundance and trends

Recent estimates of fin whale abundance in the Antarctic were computed from the IDCR-SOWER set of circumpolar surveys (Branch & Butterworth, 2001a) and from JARPA for the IWC Areas IV and V (Matsuoka et al., 2006b) (Table 8). Because fin whales are most common north of 60°S (e.g. Miyashita *et al.*, 1995) the surveyed area does not represent the species complete range in the summer. The most current circumpolar abundance estimates range from 4,300 (CV=0.46) to 8,800 (CV=0.56), depending on assumptions about the data (Branch & Butterworth, 2001a, Table 8). These estimates are imprecise and not significantly different from each other.

Estimates of trends in Areas IV (25%/year, 95% CI = 8.8 – 43.5%/year) and V (10.4%/year, 95% CI = -2.9 – 25.6%/year) were computed by fitting a log-linear regression through the individual estimates of abundance from Matsuoka et al. (2006b). These estimates are relatively imprecise and point estimates are likely biologically implausible. In addition, they are most likely not representative of the whole population due to lack of coverage of the fin whale feeding grounds further to the north.

4.3.3 Catch

Fin whale catch data by IWC Area in wintering and feeding grounds are presented in Tables 9 and 10, respectively.

4.4 Sei Whales

Sei whales are found in all major oceans in the Southern Hemisphere, where migration between breeding and feeding areas has been documented (Leatherwood & Reeves, 1983). Biological data from whales captured in various whaling grounds in breeding and feeding areas, plus the recovery of Discovery Marks indicate some degree of isolation of sei whales within the six IWC Management Areas (Horwood, 1987).

4.4.1 Distribution and habitat utilisation

Like most other baleen whales, sei whales migrate from low-latitude breeding grounds, where they occur in the winter and spring, to summer feeding areas. The species in usually found south of 30°S during the breeding season (Leatherwood & Reeves, 1983), but lower latitude aggregations have been documented (Williamson, 1975). In the summer, the majority of the population occur between 40°S and 60°S, usually north of the Antarctic Convergence. Juveniles are found further north than mature individuals. Sei whales do not venture into higher latitude waters near the Antarctic continent as much as some other balaenopterid whales (Horwood, 1987; Miyashita et al., 1995).

Occurrence in low latitude wintering grounds has been recorded from March to December, but abundance peaks from June/July to August/September (Horwood, 1987). In late spring and summer, abundance peaks in November between 30°S and 50°S in November. As the season progresses relatively more whales are observed south of 40°S and abundance between 50°S and 60°S increases consistently until March (Horwood, 1987). In some regions (e.g. near South Georgia), sei whales have been regularly seen during autumn months (Leatherwood & Reeves, 1983).

4.4.2 Abundance and trends

Southern Hemisphere sei whales, once numbering perhaps 150,000 to 225,000 have been heavily exploited in and have suffered major declines throughout their range. There are no current estimates of population size or trends for this species.

4.4.3 Catch

Breeding and feeding ground catches per IWC Area are summarised in Tables 11 and 12, respectively.

4.5 Antarctic Minke Whales

Two species commonly called minke whales occur in the Southern Hemisphere: the Antarctic minke whale (*Balaenoptera bonaerensis*) and an as-yet unnamed subspecies of the common minke whale (*B. acutorostrata*) known as the dwarf minke whale. The dwarf minke whale has a white band on the flipper that distinguishes it from the Antarctic minke whale, but was only fairly recently identified as separate from Antarctic minke whales (Best, 1985). On available information, only a small percentage of minke whales in the Antarctic (south of 60°S) are dwarf minke whales. For example, in the IDCR/SOWER surveys from 1993/94–1997/98 only 0.2% of the identified sightings were dwarf minke whales (2 out of 906) (Branch & Butterworth, 2001b). No formal analysis has been conducted but it is probable that less than 1% of the minke whales south of 60°S are dwarf minke whales.

There is some evidence for population structure within Antarctic minke whales from mitochondrial and nuclear DNA between Area IIIE+IV (35–130°E) and Area VE+VIW (165°E eastward to 145°W), with an apparent stock division around 150–160°E (Pastene et al., 2006, and see IWC, 2008, page 422.); less is known about the region west of 35°E to 145°W.

4.5.1 Distribution and habitat utilisation

Most Antarctic minke whales follow a migration pattern similar to that of other baleen whales, being found mainly in Antarctic waters in the austral summer months, and in more northerly waters in the winter months (Best, 2007). Two minke whales tagged with Discovery marks south of 60°S were later recovered in the northern Brazilian whaling ground (Buckland & Duff, 1989). In winter they have a widespread pelagic distribution as far north as 10–20°S, are dispersed, and usually are not found in great concentrations close to land Best, 2007. Minke whales have been sighted in winter pack ice with sightings from Graham Land (Taylor, 1957), Prydz Bay and Enderby Land (Ensor, 1989), the Weddell and Scotia Seas (Ribic et al., 1991), East Antarctica (Thiele & Gill, 1999) and the Western Antarctic Peninsula (Thiele et al., 2004b). However, in the absence of data from tagged or re-sighted animals, it is not known whether these animals are transitory or remain in the ice for the whole winter season. In the austral summer the majority of Antarctic minke whales congregate in the Southern Ocean, with greatest densities close to and within the pack ice, and lower densities with increasing distance from the ice (Kasamatsu et al., 2000), including some north of 60°S. Antarctic minke whales are noticeably well adapted to living within the ice Ainley et al., 2007, but the exact proportion of Antarctic minke whales found within the pack ice, and in polynyas, is currently a source of great debate. It is possible that a large proportion of the population is found within the pack ice, out of reach of ship-based sighting surveys (Murase et al., 2005; Scheidat et al., 2007; Shimada & Kato, 2007).

4.5.2 Abundance and trends

The status of Antarctic minke whales is in a state of limbo, although the IWC is nearing the end of a comprehensive review of their status. The most recent IWC-accepted set of estimates sum to a total of 760,000 (CV = 0.098) and were based on IDCR/SOWER surveys to 1988/89 (Haw, 1993). Updated estimates have been produced using a "standard" method (Branch & Butterworth, 2001c) based on IDCR/SOWER surveys. The resulting circumpolar abundance estimates south of approximately 60°S were 645,000 (CV = 0.143) for 1978/79–1983/84, 786,000 (CV = 0.094) for 1985/86–1990/91, and 338,000 (CV = 0.079) for 1992/93–2003/04 (Branch, 2006a). Only the third set covers the full area south of 60°S; the first two sets did not survey 36% and 20% of this area respectively. These estimates are negatively biased because the surveys miss some minke whales inside the pack ice and north of 60°S, and because not all minke whales on the trackline are sighted. Abundance estimates by IWC Management Area are presented in Table 13. These estimates have not been adopted by the IWC, because these biases raise concerns about whether the appreciable difference in abundance estimates from the late 1980s to the 1990s, is due to changes in survey design or analysis methods, as summarised in Branch (2007b). Additionally, newer and better methods are being developed (such as the OK method below) which should address some of the sources of bias.

A newer method of analysing the IDCR/SOWER surveys, the OK method, has been developed by Okamura and others (Okamura & Kitakado, 2008a; Okamura & Kitakado, 2008c; Okamura et al., 2005) that does not assume that all minke whales on the trackline are sighted, and also accounts for some other factors not taken into account by the standard method. Preliminary abundance estimates were 1,049,000 (CV = 0.078) for 1985/86–1990/91 and 723,000 (CV = 0.089) for 1992/93–2003/04 (Okamura & Kitakado, 2008a), suggesting that the standard estimates may be negatively biased by 25–55%, particularly because of the assumption that all minke whales on the trackline are sighted. Abundance estimates by IWC Management Areas are presented in Table 13. However, the IWC, in reviewing these preliminary results, "stressed that caution should be used in interpreting the OK estimates… given the unresolved issues with the diagnostics" (SC report, 2008 meeting), and therefore the IWC was unable to endorse the OK abundance estimates. It is expected that final abundance estimates will, however, be agreed in 2009 or soon thereafter.

Abundance estimates are also available from the Japanese research program in the Antarctic (JARPA), from alternating surveys in IWC Areas IV and V south of 60°S during 1989/90 to 2004/05 (Hakamada et al., 2006a; Hakamada et al., 2006b), and are listed in Table 14. These estimates have not been adopted by the IWC because of the concerns summarised in Section 6.2.

Given the relatively low historical and current catches compared to their current abundance, the population might be expected to be stable. However, the IDCR/SOWER surveys (analysed using "standard methods", suggest an appreciable decline in abundance from the late 1980s to the 1990s (Branch, 2006a; Branch & Butterworth, 2001c). After accounting for the different areas surveyed, the most recent "standard" estimate is only 39% of the late 1980s estimate, and in five out of six management areas the most recent estimate is much lower than the early 1980s estimate or the late 1980s estimate (Branch, 2006a). The new preliminary OK method estimate is 63% of the corresponding late 1980s number (Okamura & Kitakado, 2008a). There has been considerable debate in the IWC about whether this difference is a real difference or a result of changes in the survey design and coverage, summarised in Branch, (2007). Currently, two of the more likely explanations are that the difference is due to a greater number of minke whales on the trackline being missed in recent years, or that there are more minke whales within the pack ice in more recent years. The JARPA data, however, show no trend in abundance in Area IV and V from 1989/90 to 2004/05 (Hakamada et al., 2006a), although nearly all of these surveys fall within the time period of the most recent set of IDCR/SOWER surveys. Overall, there is no current agreed assessment of trends in Antarctic minke whales and despite the issues raised above there is a real possibility of an appreciable decline in their abundance. The IWC-SC hopes to resolve these issues in 2009.

4.5.3 Catch

Breeding and feeding ground catches per IWC Area are summarised in Tables 15 and 16 respectively.

4.6 Right Whales

Breeding in winter in relatively warm waters, near continental or island coastlines, southern right whales migrate in summer to feed in colder waters, but generally not as far south as other baleen whales. They appear to occur near the subtropical convergence in summer (January to March) at around 40°-50°S (Ohsumi & Kasamatsu, 1985), but there are records of animals much further south (e.g. around 60-65°S south of Australia [Bannister et al., 1999] and southern Africa [Mate and Best, 2008; Tormosov et al 1998]).

Southern right whale numbers were drastically reduced by 'traditional', open-boat, whaling in the 18th and 19th centuries. More than 150,000 were killed between 1770 and 1900, with a peak of some 50,000 in the 1830s. As a result they were already rare by the early 20th century, and until legally protected in 1935 only about 1600 were taken in modern whaling. However, over 3000 were killed in illegal Soviet whaling in the 1960s (Tormosov et al, 1998, IUCN a, in prep). Numbers killed in traditional whaling are mostly estimated from production statistics and often cannot easily be assigned to a particular region or stock. They are likely to be underestimates, given that information is incomplete for some periods and some national operations. Adjustments for hunting loss also vary between fisheries: such 'struck and lost' (and presumed dead) rates range between 1.2-1.5 times the landed catch, but for the southern hemisphere as a whole an average value of 1.35 has been adopted for stock assessment. Catch information available to 1997 was collated at the most recent right whale IWC assessment meeting, in 1998.

Breeding populations occur off eastern South America (Argentina, Brazil and Uruguay), South Africa, Australia/New Zealand, and to a lesser extent Chile. In 1998 a population assessment was only attempted on a hemisphere-wide basis, largely because of difficulties in apportioning historical catches to individual populations (IWC, 2001). Nevertheless, 11 management units were recognised at that time; the summary of estimates of demographic parameters and abundance levels agreed then is reproduced here as Table 17. For the Southern Hemisphere as a whole, the original (ca. 1770) population was estimated at 55,000-70,000, reaching its lowest level – perhaps no more than 300 individuals - in the 1920s. Population size by 1997 was estimated as 7,500 (IWC 2001); with a doubling time of some 10 years it should now number at least 15,000 today. However, caveats associated with the estimates of historical population size included a) the need to develop hypotheses to allow allocation of catches to breeding stocks; and b) that the estimation models should take account of disaggregation by sex (in particular, the effect of selective removal of females in shore-based operations), as well as by age (IWC, 2001). Since this assessment, further information, summarised below, has accrued for all breeding populations.

4.6.1 Eastern South America

4.6.1.1 DISTRIBUTION AND HABITAT UTILISATION

Southern right whales are found off Argentina and Brazil, with a major calving site at Peninsula Valdes, Argentina (42° 30'S). There is evidence of substantial interchange between Argentina and Brazil (Groch et al., 2005). The feeding grounds are poorly defined but movement has been recorded between Argentina and South Georgia (IWC 2001, Rowntree et al., 2001). There were 'modern' whaling catches mainly to the north of South Georgia in the early 20th century and by Soviet whalers in the 1960s (Tormosov, 1998; IWC 2001). Right whales have been the most frequent species recorded recently at South Georgia, with a peak of sightings between January and May (Moore et al., 1999). There may be some sporadic, limited feeding at Peninsula Valdes, Argentina (42°30'S) particularly on sparse krill in October, and en route further south, in highly productive waters along the Patagonian shelf, as spring advances (Rowntree et al., 2008). Recent evidence from the south west Atlantic has shown that calving in animals wintering off Argentina can be affected by sea surface temperature anomalies on the South Georgia feeding grounds; as Antarctic waters warm up, the average calving rate can be expected to decline (Leaper et al., 2006).

4.6.1.2 ABUNDANCE AND TRENDS

The most recent population estimate, for animals wintering at Peninsula Valdes, Argentina, is 2577 in 1997 (IWC 2001) including 547 mature females (based on extrapolation from an estimated 328 in 1990 [Cooke et al., 2001]). Annual growth rate, 1971-1990, was estimated as 6.9% (SE = 0.7%) per year (Cooke et al., 2001).

4.6.1.3 CATCH

As tabulated during the 1998 assessment, historical catches referable to this breeding population (Brazil shore 14904, Brazil/Falklands pelagic 14666, Brazil/Falklands French pelagic 1807) total 31377 individuals. In addition, a total of 26534 taken in US open boat whaling ('US pelagic S. Atlantic') can be allocated in the proportion 2.5:3.5 based on an inspection of the relevant Townsend Chart (Townsend, 1935), which shows discontinuities in catch distribution between various whaling 'grounds', used in obtaining those catch figures. On that basis, an additional 11100 (to the nearest 100 animals) would be allocated to the western South Atlantic (and 15500 to the eastern half). Modern whaling catches (Brazil shore 360, S. Georgia/S. Shetlands 548, illegal Soviet 1408) total 2316.

4.6.2 South Africa

4.6.2.1 DISTRIBUTION AND HABITAT UTILSATION

Winter concentrations have been recorded at various locations along the southern African coast, between Angola in the west and Mozambique in the east, but currently the most significant occur on the South African coast between Port Elizabeth and Cape Town (Best, 2007). Recent satellite telemetry has shown animals travelling from the South African coast to the south west, between 13°E and 16°W as far south as 60°S (Mate and Best, 2008). Pelagic catches have indicated concentrations between 30° and 40°S from Cape Town to Tristan da Cunha (and there is one record of movement between Gough Island (south of Tristan) and the South African coast (Best et al, 1993). An apparently unique instance of regular, coastal, probable warmer-water feeding has recently been recorded at *ca* 32°S in September-January near St. Helena Bay and Saldanha Bay, just north of Cape Town (Mate and Best 2008), apparently reoccupying a historically important feeding area (Best 2006). There were nineteenth century and modern (illegal Soviet) catches at the Crozet Islands (46°S, 52°E), presumably a feeding area, and possibly a destination for animals from the South African east coast (Best 2007).

4.6.2.2 ABUNDANCE AND TRENDS

The most recent estimate of population increase for animals wintering on the South African coast, 1971-2003, is an instantaneous annual rate of 0.073 (95% CI 0.066, 0.079), with population size in 2003 of some 3400 (Best et al., 2006).

4.6.2.3 CATCH

As tabulated during the 1998 assessment (IWC 2001), catches that can be assumed referable to this breeding population (S African shore whaling 1580 + 106, S African Bay whaling 12000, French pelagic (Tristan da Cunha) 382, and illegal Soviet whaling 767) total 14835. The figure includes some catches from Delagoa Bay and Natal. As indicated above, 15500 can be added from South Atlantic US pelagic catch, plus an unknown proportion of unspecified French pelagic catches (total 624). If animals found at the Crozet Islands are also referable to this population, the illegal Soviet catch there of 309, as well as some proportion of the Indian Ocean US pelagic catch of 12493 (IWC 2001, Annex L, Table 3) should be included. An inspection of Townsend's chart suggests approximately one sixth (i.e. 2100) of the Indian Ocean US pelagic catch could be thus apportioned. Townsend's chart also shows considerable catching activity north east of the Crozet Is as well as at and north of Kerguelen. If those catches are also referable to this population, five-sixths (to include catches at the Crozet Is) of the Indian Ocean pelagic total, i.e. 10400, could be included here. The overall total would then be 43100 (not including the 624 unspecified French pelagic catch).

4.6.3 Australia/New Zealand

4.6.3.1 DISTRIBUTION AND HABITAT UTILISATION

Wintering right whales are currently recorded on the Australian south coast, mainly between Cape Leeuwin, Western Australia and Ceduna, South Australia, and less frequently on the Australian south east coast (Victoria and New South Wales) and around Tasmania. There are occasional records on the west coast as far as north West Cape, Western Australia (*ca* 21°S) and on the east coast as far north as Hervey Bay, Queensland (25°S) (Bannister, 2008a). Historically, there were large catches in the south west Pacific, including from shore in south east Australia, Tasmania, and New Zealand (Dawbin, 1986), and near the Kermadec Islands (Richards, 2002; Townsend, 1935). Currently few right whales are seen in mainland New Zealand waters, but a substantial number winters in sub-Antarctic New Zealand (Auckland and Campbell Islands, 51-52°S). Low-level gene flow between sub-Antarctic New Zealand and Australia (Baker et al., 1999) has led to the suggestion that Australian and New Zealand animals belong to two separate breeding populations, separated at Tasmania. There are however three records of movement between Campbell Island and southern Australia, including two instances of females calving in each of two calving grounds (Anonymous, 2004), and it may be that Australia/New Zealand animals should be regarded as belonging to one metapopulation, with differential reduction of maternally philopatric lineages within it.

4.6.3.2 ABUNDANCE AND TRENDS

The most recent annual trend estimate for calving right whales wintering off the southern Australian coast, 1993-2006, was 8.10% (95% CI, 4.48-11.83%) (Bannister, 2008b). The figure excludes data for 2007, where the number of cow/calf pairs was the lowest in the series since 1994, and is clearly an outlier. Whether calving in 2007 was affected by temperature anomalies on the feeding grounds in earlier years (as recorded for animals off Argentina, see Leaper *et al*. 2006) is currently unclear. The population estimate for the same area is 2400 in 2006 (Bannister, 2008b).

4.6.3.3 CATCH

Catches for the Australia/New Zealand region have been estimated (IWC, 2001) for Western Australian Bay whaling (266), early shore/bay whaling in South Australia, New South Wales, Tasmania and Victoria (11045), New Zealand Bays (5360), French whaling off New Zealand/Australia (3871) and illegal Soviet whaling in the south west Pacific (372), totalling 20914. In addition, one sixth of the US pelagic Indian Ocean catch could be included (2100), together with a proportion of US pelagic Pacific Ocean catches; on the basis of Townsend's chart, that proportion could amount to some two-thirds of the total of 14652, i.e. 9800. The overall total would then be 32800.

4.6.4 Western South America (Chile/Peru)

4.6.4.1 DISTRIBUTION AND HABITAT UTILISATION

Wintering animals are recorded between southern Peru and central Chile, with the northernmost sighting nearly at 15°S in Bahia San Fernando: Peru/Chilean coastal waters seem to be used as migratory corridors. Females with calves have been recorded in southern Peru (15-17°S), and to the south as far as 40°S off Chile, with one record at Punta Arenas (53°S) (IUCN, in prep). There is little other information available on animals from this presumed separate breeding population. Three feeding grounds have been postulated (IWC, 2006a), one north of 40°S, another offshore of Chiloe I (*ca* 42°S) and a third at the south west corner of Tierra del Fuego (but possibly including animals from the eastern South American population). In addition, there were catches in the early 1900s off the western Antarctic Peninsula and around the South Shetland Islands.

4.6.4.2 ABUNDANCE AND TRENDS

Despite a lack of known major catches off Chile in the past or off Peru in the 20th century, and no post WWII Soviet pelagic catches, no increase has been observed in this population. The paucity of sightings over the past 50 years suggests that numbers are still very low, with the mature population perhaps fewer than 50 animals (IUCN, in prep).

4.6.4.3 CATCH

2839 whales are listed as taken from the coast of Chile between 1815 and 1969, including early 19th Century French pelagic catches (peaking at 2211 in 1830-39) and 20th Century modern coastal whaling (IWC 2001). On the same basis as above (see Item 4.6.3.3) one third of the US South Pacific pelagic catch could be allocated here, i.e. 4900. There were no Soviet operations in this area. The total would then be 7700.

5. FEEDING ECOLOGY AND CONSUMPTION RATES

There are numerous accounts of baleen whale diet from commercial whaling operations, extensively reviewed in Kawamura (1980; 1994), and more recently a number of non-lethal techniques including genetic methods have also been used to determine principal prey species in some baleen whales (e.g. see Jarman et al., 2006).

At large scales (100's-1000's km), the spatial distribution of baleen whales is a product of the gross distribution of their dominant prey and physical and oceanographic features and these relationships are now well established from both historical and contemporary accounts (Kasamatsu, 2000; Kasamatsu et al., 1996; Kasamatsu et al., 2000; Matsuoka et al., 2000; Murase et al., 2002; Thiele et al., 2000; Tynan, 1997; Tynan, 1998). Gaskin (1982) summarised three types of feeding habitat in terms of oceanographic structure: oceanic fronts between water masses; eddy grounds, both dynamic and topographic, and: upwelling zones, both dynamic and topographic. Within these habitats, patterns of distribution are almost certainly mediated through mechanisms of both prey productivity and aggregation. There are, however, few large-scale studies in the Southern Ocean that have estimated baleen whale and krill distribution and abundance simultaneously (Nicol et al., 2000; Reilly et al., 2004). With some overlap, baleen whale populations are generally spatially segregated by both latitude and longitude when at their peak concentration (see Fig. 2). Blue and minke whales are generally regarded as Antarctic krill, *Euphausia superba*, specialists (Kawamura, 1994), but both species do consume other euphausid species on occasion. The distribution of minke whales is essentially circumpolar, but particularly high densities have been observed in some years in high Antarctic areas such as Prydz Bay, the Weddell Sea and the Ross Sea (Kasamatsu et al., 1997). Where blues and minkes consume several species of planktonic crustaceans, the relative amount consumed is likely related to local availability. For example, minke whales can also feed on *E. crystallorophias* (ice krill) particularly in major embayments, *E. frigida*, and *T. macrura* (Tamura & Konishsi, 2006). The sole species of schooling pelagic fish, *Pleuragramma antarcticum* can also be an important prey item in addition to *E. crystallorophias* in far southern waters (e.g. the southeast shelf of the Ross Sea) in years of low sea ice extent (Ichii et al., 1998).

Like blue whales, humpback and fin whales are also generally regarded as Antarctic krill specialists (Kawamura, 1994), but are much less associated with sea ice habitats and continental shelf areas (Murase et al., 2002). Sei whales exhibit a greater variety in diet than other baleen whales, but tend to feed on only one or two types of prey at a time, including copepods and amphipods, as well as krill (Nemoto & Kawamura, 1977). There is relatively little direct evidence on the feeding of right whales, but north of 40°S the diet consists mainly of copepods, south of 50°S mainly krill, and varying proportions of the two food items at intermediate latitudes (Hamner et al., 1988; Matthews, 1938; Tormosov et al., 1998).

Although only a handful of studies have been conducted at smaller scales (10’s-100’s km), (Friedlaender et al., 2006b; Reid et al., 2000) there appears to be complex spatial structuring of baleen whales in relation to their prey and environment at meso- and micro-scales. In a study of minke and humpback whales in the Western Antarctic Peninsula, Friedlaender et al. (2006b) found that at meso-scales, the interplay of physical features (e.g. marginal ice edge and increasing bathymetric slope) and dynamic oceanographic processes that enhance prey aggregation, led to a predictable distribution and abundance of whales over a number of years. Measurements of whale distribution and abundance, prey field attributes such as swarm size and density and environmental data collected concurrently, also provided the motivation to examine fine-scale spatial structuring of minkes and humpbacks; species that share the same dominant prey species, and that overlap in time and space. Minke whales were consistently associated with significantly deeper krill aggregations and targeted aggregations with larger individual krill and smaller area than humpback whales (Friedlaender et al., 2006a). Integrated studies such as this have given new insights into the linkages between baleen whales and their environment, but we are only just beginning to understand these complex relationships and for no more than a few populations in the Southern Ocean ecosystem.

Leaper and Lavigne (2007) provide a recent review of estimates and methods for estimating consumption rates in large whales. They reviewed methods based on estimates of energy requirements based on allometry, respiration rates and energy storage; estimates of prey consumption based on stomach contents; and direct observations of feeding. There is considerable uncertainty in these estimates resulting in an order of magnitude difference between some estimates of consumption by large whales. Estimates of energy requirements based on allometry have been used most often and face a number of challenges (1) estimates of metabolic rates in large whales need to be extrapolated well beyond the range of available data; (2) estimates of Basal Metabolic Rate (BMR) need to be adjusted to Field Metabolic Rate (FMR) or Average Daily Metabolic Rate (ADMR) and to allow for the energy requirements of growth and reproduction; (3) large whales may make long migrations and feed for only a proportion of the annual cycle; and (4) energy content of prey needs to be estimated and adjusted for assimilation efficiency (i.e. the amount of energy that becomes available to the whale). Given the uncertainty, Leaper and Lavigne (2007) suggested that ecological models should use a range of values for prey consumption by individual whales and suggest some bounds for this range. In particular, they note a lack of theoretical or empirical evidence to support scaling prey consumption linearly with body mass and argue that 0.75 should be considered as an upper bound for the scaling exponent with body mass.

In 2007, the Scientific Committee discussed estimates of prey consumption for minke whales based on stomach contents analysis from JARPA and noted a number of issues that needed to be resolved before it were possible to move beyond broad estimates. In particular, further information is needed on (1) the length of feeding season; (2) to what extent consumption rate is sensitive to digestion rate (which is largely unknown); and (3) the extent of feeding at night

6. POSSIBLE BIASES IN PARAMETER ESTIMATION

In addition to presenting a review of various baleen whale population parameters for the upcoming CCAMLR-IWC workshop on Antarctic ecosystem models, one of the primary tasks given to this group is to provide a commentary on the uncertainties and limitations in the use of estimates of abundance and trends for baleen whales. This section attempts to address some of these issues.

Nearly all surveys designed to obtain estimates of abundance will likely have multiple sources of bias. The degree to which bias occur depends on a number of factors related to experimental design and data analysis, target species, environmental variability and others. If surveys implement an appropriate sampling design, and data are rigorously collected and analysed, biases tend to be reduced or at least parameters can be robustly estimated. Yet, estimates can still be affected by other factors that are beyond the control of those conducting the study. For example environmental (e.g. weather or presence of sea ice) conditions may preclude the appropriate sampling of certain areas. Environmental factors can also lead to shifts in distribution of the target species over time, resulting in different components of the population being sampled in each year if surveys are carried out over several years. Multi-species surveys may be also be problematic because while there are usually one or two target species, data may be collected for many others that themselves have different distributions or seasonal occurrences in the survey area at the time of the study. All surveys that estimated abundance of baleen whales mentioned in this paper probably suffer from one or more of these issues. However, in spite of these problems, the information collected can be valid if the appropriate caveats are taken into consideration.

Most of the information on abundance and trends obtained for baleen whales in the Southern Hemisphere originate from ship surveys conducted in the Antarctic using line transect sampling techniques (Buckland et al., 2001; Buckland et al., 2004). Such surveys can be referred to as design unbiased line-transect surveys along regular tracks. With such surveys, analyses of data are possible using traditional distance methodology (Buckland et al., 2001) or spatial modelling (Hedley et al., 1999; Williams et al., 2006). The main examples of such surveys are the IDCR/SOWER and the JARPA cruises in the Southern Ocean. The possible problems these studies have faced and the implications for abundance and trend estimation have been a concern of the IWC SC for a number of years and have extensively been discussed (e.g. IWC, 2005-2008a, b). Other smaller scale research efforts (e.g. those from various national Antarctic programs) likely suffer from the same problems, but are generally best categorised as either (1) design biased line-transect surveys along ship tracks where population estimates are possible using spatial modelling; or (2) design biased opportunistic surveys along ship tracks, where analyses of data is much more difficult.

6.1 – IDCR/SOWER cruises

In a comprehensive analysis of the abundance estimates derived from the three sets of CP cruises for Antarctic minke whales Branch (2007) examined a number of factors that could pose caveats and therefore need to be considered in interpreting estimates of baleen whale population size and trends in Antarctic waters. The factors relevant for the present manuscript are those associated with survey design and sampling procedures and are further discussed below.

6.1.1 – Geographic and Temporal Coverage of Surveys

IDCR/SOWER covered the Southern Ocean south of 60^{o}S (Branch & Butterworth, 2001a; Branch & Butterworth, 2001b; Matsuoka et al., 2003), but spatial coverage was not consistent across CP's. CPI, CPII and CPIII covered 64.3%, 79.5% and 99.7% of the area between the ice-edge and the 60^{o}S parallel, respectively (Branch, 2007a). Because areas near the ice-edge received greater coverage, it is likely that the majority of the feeding habitat was sampled only for Antarctic minke and Antarctic blue whales. For other species, for example fin and sei whales, much of their feeding habitat lies north of 60°S. A large proportion of the fin whale population is distributed far north than 60^{o}S and therefore abundance estimates for this species from either research programs likely do not correspond to the total stock size. For humpback whales, while there is little evidence that some stocks migrate further south than 60^{o}S (e.g. BSA), there is enough evidence indicating that the majority of whales move into higher latitudes for other stocks (e.g. BSD and BSE). Therefore, estimates of abundance from IDCR/SOWER should not be considered estimates of the total stock sizes for most species other than perhaps minke and blue whales.

Lack of, or inconsistent spatial coverage is not necessarily a problem for parameter estimates for ecosystem models if for example, feeding ground abundance estimates are available for the geographic area of interest or if the proportion of whales occupying this area is known and abundance estimates from breeding grounds are available. However, some correction is frequently required to account for differences in survey area for estimates of trends in abundance. It may be difficult to ascertain how robust such corrections are as there is often not *a priori* basis on which to do this. In an attempt to deal with the issue of spatial scaling of abundance estimates, Branch and Butterworth (2001d) and Branch (2006b) computed estimates of abundance for comparable areas. However, as these authors pointed out, this approach could still lead to biased estimates of trends. They found that the direction of the bias depended on the how much the true density of whales in the unsurveyed areas differed from the assumed density in those areas.

The IDCR/SOWER surveys were conducted in the summer (Dec-Feb), which roughly corresponds to the peak of abundance of most species in Antarctic waters (Kasamatsu et al., 1996). Shifts in the timing of surveys (from earlier to later in the summer season) between 1994/5 and 2000/01 may have caused a smaller fraction of Antarctic minke whales to be sampled. Such temporal shifts in survey are thought however, to have a small effect on abundance estimates (Brandão et al., 2002; Branch, 2007). While it may be supposed that this temporal effect is similarly small for other baleen whale species, there is some evidence to suggest that it might not be (e.g. humpbacks). It is likely that this temporal effect may introduce a bias to estimates of trends that is more difficult to discern than for abundance estimates.

6.1.2 – Changes in Location of the Ice-Edge and Whales South of the Ice-Edge

Group density and school size decreases with distance from the ice-edge for some species (e.g. Antarctic minke whales). If a proportion of whales remain south of the ice edge in some years, then the location of the ice-edge affects the proportion of the population within the survey region. Because the IDCR/SOWER survey vessels do not venture into the pack ice, abundance estimates of species associated with the ice will be negatively biased. This most affects Antarctic minke whales and perhaps, to a limited extent, Antarctic blue whales, but probably does not influence estimates of the other species.

6.1.3 – Distribution of Group Sizes

The estimated mean group size of Antarctic minke whales appears to have decreased in CPIII (Branch, 2007). Other than a true decrease in mean group size, this may also be due to the following: true mean group size tends to increase with latitude, observed school size tends to decrease with increased Beaufort conditions, and more inexperienced observers were used in CPIII compared to CPII. Effects of latitudinal changes in the abundance estimates of other baleen whales will be species-specific, while the other two factors will likely affect all species in a similar fashion. Use of more inexperienced observers may have also resulted in difficulties with species identification.

6.1.4 – Detection Probability on the Trackline (g[0])

Probably the most important potential bias for abundance estimates from line transect surveys is the assumption that all whales on the survey trackline are detected (Buckland et al., 2001), an assumption often known as "*g(0)*=1". This is almost always violated in cetacean studies because these animals tend to spend most of their time underwater, reducing chances of detection. The effects of violating this assumption for baleen whales vary across species. Blue, fin and humpback whales have conspicuous cues and are relatively easy to detect; therefore the proportion of groups missed is expected to be small. For example, studies conducted off the western coast of the United States indicated that 1-10% of blue and humpback whales are missed in the trackline, depending on visibility conditions and group size (e.g. Barlow, 1995; Barlow & Gerrodette, 1996; Calambokidis & Barlow, 2004). This problem is much more important for minke whales and possibly sei whales because these species are smaller and less conspicuous. For example, it has been estimated that *g(0)* for Antarctic minke whales during the IDCR/SOWER surveys averaged over group size and environmental conditions, was 0.47–0.53 (Okamura & Kitakado, 2008b).

Most of the baleen whale abundance estimates from the IDCR/SOWER cruises were computed using 'standard' methods (Branch, 2006b; Branch, 2007a; Branch & Butterworth, 2001a; Branch & Butterworth, 2001b). These assume 100% detection probability on the trackline and therefore result in estimates being biased downwards. If *g(0)* varies across sampling seasons, then trend estimates from time series of abundance estimates may also be biased and/or have poorer precision.

6.1.5 – Group Size Estimation

In CPI all surveys were conducted in closing mode, where the vessel left the trackline to confirm species and school size. In CPII and CPIII, closing mode and passing mode (vessels did not leave trackline to approach groups detected) alternated. Previous analyses showed that minke whale school size estimates in passing mode were negatively biased compared to closing mode by about 30% (Branch, 2007). A similar effect may be expected for other species when abundance estimates are solely based on passing mode methods.

6.2 – JARPA

The JARPA surveys include a component dedicated to estimation of abundance (and consequently trends) using the line transect methodology, with similarities to the IDCR/SOWER cruises regarding some of the survey procedures. Therefore, many of the caveats listed above also apply to the JARPA cruises. On the other hand, JARPA differs from IDCR/SOWER in a number of aspects. Unlike the latter, which covered all IWC Management Areas south of 60°S over a period of several years, JARPA focused on IWC Areas IV and V, and more recently Areas III east and VI west (Nishiwaki et al., 2007), with more frequent repetition of survey areas. It has been pointed out that this could better facilitate estimation of inter-year variability in local abundance and improve estimation of trends (IWC, 2007). JARPA uses two types of vessels: sighting vessels (SV) and sighting and sampling vessels (SSV). The former are exclusive sighting platforms, while the latter is a sighting platform, but becomes engaged in sampling of whales whenever applicable. Abundance estimates have been obtained with data collected from both of these platforms.

A great deal of information with regard to abundance and trends in abundance for many baleen whale species have been generated from JARPA (Hakamada et al., 2006b; Matsuoka et al., 2006b) and a number of issues with respect to sampling methods and analyses have been raised (IWC, 1998; 2006b; 2007b). Some of these issues were recently reviewed in a Workshop to Review Data and Results from Special Permit Research on Minke Whales in the Antarctic (IWC, 2007, p. 4-12) and in the following SC meeting (IWC, 2008). Discussions focused on estimation of abundance and trends of Antarctic minke whales, but it was noted that the potential problems raised for these analyses were likely applicable to other large whale species for which estimates from JARPA are available. The main issues discussed by the IWC-SC and their effects on estimates of abundance and trends were the following:

(1) Skipping – missing tracklines due to (A) night steaming, (B) catching up with survey schedule, (C) closing and chasing of targeted whales, and (D) poor weather conditions (Hakamada et al., 2007);
(2) Estimation of detection probability on the trackline (g[0]);
(3) Effects of closing mode and sampling mode in estimates of density;
(4) Extrapolation of density estimates to unsurveyed areas;
(5) Detection function estimation (in particular in regards to small sample sizes);
(6) Estimation of effect strip width, group size and variance from SSV;
(7) Order in which different strata were sampled;
(8) Reaction of whales to chasing and sampling – effects on detection probability of other sighting/sampling vessels;
(9) Different trackline designs – saw-tooth, N-S and transects parallel to the ice-edge;

In discussing abundance and trend estimates for baleen whales resulting from JARPA, the IWC SC (IWC, 2007; 2008) noted that a large dataset had been accumulated by sighting surveys and appreciated that a considerable amount of work had been undertaken to address previous recommendations from the Committee. The SC made a number of points that required further consideration, but recognised that abundance estimates presented, in particular for blue, fin and humpback whales, represented useful steps forward in working towards acceptable estimates.

6.3 – Other

Although they have not been considered in the context of in-depth assessment at the IWC/SC, feeding ground abundance estimates for various species provided by other platform of opportunity (POP) based studies such as BROKE, CCAMLR and SO-GLOBEC (e.g. Reilly et al., 2004; Peel and Thiele, 2006; Secchi et al., 2006; Williams et al., 2006) covered only a relatively small portion of the stock ranges in the Southern Ocean and also do not correspond to stock size estimates. These estimates also likely present some of the biases pointed out above for the IDCR/SOWER and JARPA cruises (e.g. g(0)=1 assumption). In addition, biases specific to data from POP surveys include: (1) closing mode not used (i.e. for species identification and school size confirmation, (2) non-standardised platform design among different survey vessels, (3) design biased line-transect surveys. At this stage the abundance estimates from such studies should be treated with caution until these estimates are discussed in the context of an In-depth assessment in IWC/SC.

A few aerial surveys were conducted in the wintering grounds for estimating abundance of humpback whales (e.g. Andriolo et al., 2006; Paxton et al., 2006). Estimates from some of these studies are also negatively biased because g(0) calculations accounted only for availability, but not perception bias.

Estimates of mark-recapture for humpback whales have in general poor geographic coverage and therefore probably refer to a small portion of the population. In addition, the number of recaptures is relatively small for many of these studies (e.g. Cerchio et al., 2006; Collins et al., 2006; Félix et al., 2006.). For this reason, only simple models can be implemented to estimate abundance, likely resulting in biased estimates due to lack of appropriate modelling of heterogeneity in capture probabilities (see Hammond et al., 1990; Hammond, 1986). Estimates of trends in abundance from mark-recapture data must also be seen with caution as an expansion of the sampling area over time can occur, resulting in different components of the population being sampled. This can inflate estimates of trends, producing unreliable results (e.g. IWC, 2005).

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Table 1 – Geographic correspondence of feeding grounds associated with various humpback whale breeding stocks, the IWC Management Areas in the Southern Hemisphere and the CCAMLR statistical areas.

Breeding Stock	Feeding Grounds (Naïve Model)	IWC Management Areas	CCAMLR Areas
A	20W-50W	II	48.2, 48.3, 48.4, 48.5
B	20W-10E	II E and III W	48.6
C	10E-60E	III	48.6, 58.4.2, 58.4.4a, 58.4.4b, 58.6, 58.7
D	60E-120E	III E, IV	58.4.1, 58.4.2, 58.4.3a, 58.4.3b, 58.5.1, 58.5.2
E	120E-170W	IV E, V and VI W	58.4.1, 88.1
F	170W-120W	VI	88.2
G	120W-50W	I and II E	48.1, 88.3

Table 2 – Southern Hemisphere humpback whale abundance estimates[1]

Breeding Stock/Region	Year/Cruise	*N*	CV	Source
Breeding Stock A				
Feeding grounds (50°W–20°W)	1981/82 (CPI)	45	0.88	Branch (2006)
Feeding grounds (50°W–20°W)	1986/87 (CPII)	259	0.62	Branch (2006)
Feeding grounds (50°W–20°W)	1997/98 (CPIII)	200	0.64	Branch (2006)
Scotia Sea	2000 (CCAMLR 2000)	2,493	0.55	Hedley *et al., (*2001); Reilly *et al.*, (2004)
Low latitude wintering grounds	2005	6,251	0.17	Andriolo *et al.* (2006)
Breeding Stock B				
Feeding grounds (20°W–10°E)	1980/81 (CPI)	692	0.84	Branch (2006)
Feeding grounds (20°W–10°E)	1986/87 (CPII)	70	0.63	Branch (2006)
Feeding grounds (20°W–10°E)	1995/96 (CPIII)	595	0.51	Branch (2006)
Wintering ground (BSB1)	2001-2004	~3,800		Collins *et al.* (2006)
Breeding Stock C				
Feeding grounds (10°E–60°E)	1979/80 (CPI)	1,043	0.62	Branch (2006)
Feeding grounds (10°E–60°E)	1987/88 (CPII)	926	0.57	Branch (2006)
Feeding grounds (10°E–60°E)	1993/94 (CPIII)	2,391	0.41	Branch (2006)
Feeding grounds (40º-70ºE)	2006 (BROKE)	4,368	0.28	Peel *et al.*(2006)
Wintering ground (BSC1)	2003	5,965	0.17	Findlay *et al.* (2004)
Wintering ground (BSC3)	1999-2004	5-7,000		Cerchio *et al.*(2006)
Breeding Stock D				
Feeding grounds (60°E–120°E)	1978/79 (CPI)	1,219	0.46	Branch (2006)
Feeding grounds (60°E–120°E)	1988/89 (CPII)	4,202	0.52	Branch (2006)
Feeding grounds (60°E–120°E)	1997/98 (CPIII)	17,959	0.17	Branch (2006)
Feeding grounds (IWC Area IV)	1989/90 (JARPA)	5,230	0.3	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	1991/92 (JARPA)	5,350	0.19	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	1993/94 (JARPA)	2,740	0.15	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	1995/96 (JARPA)	8,850	0.14	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	1997/98 (JARPA)	10,874	0.17	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	1999/2000 (JARPA)	16,211	0.15	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	2001/2002 (JARPA)	33,010	0.11	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area IV)	2003/2004 (JARPA)	31,750	0.11	Matsuoka *et al.* (2006)
Wintering ground	2005	13,145	0.59	Paxton *et al.* (2006)
Breeding Stock E				
Feeding grounds (120°E–170°W)	1980/81 (CPI)	1,913	0.6	Branch (2006)
Feeding grounds (120°E–170°W)	1985/86 (CPII)	622	0.5	Branch (2006)
Feeding grounds (120°E–170°W)	1992/93 (CPIII*)[2]	3,484	0.33	Branch (2006)
Feeding grounds (120°E–170°W)	2001/02 (CPIII)	13,300	0.2	Branch (2006)
Feeding grounds (IWC Area V)	1990/91 (JARPA)	1,354	0.2	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area V)	1992/93 (JARPA)	3,837	0.63	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area V)	1994/95 (JARPA)	3,567	0.31	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area V)	1996/97 (JARPA)	1,543	0.28	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area V)	1998/99 (JARPA)	8,301	0.31	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area V)	2000/2001 (JARPA)	4,720	0.22	Matsuoka *et al.* (2006)
Feeding grounds (IWC Area V)	2002/2003 (JARPA)	2,735	0.16	Matsuoka *et al.* (2006)

Feeding grounds (IWC Area V)	2004/2005 (JARPA)	9,765	0.33	Matsuoka *et al.* (2006)
Wintering grounds (BSE1)	2004	7,090	0.05	Noad *et al.* (2006)
Wintering grounds (BSE1)	2005	7,024	0.14	Paton *et al.*(2006)
Wintering grounds (New Caledonia, BSE2)	1999-2004	472	0.18	SPWRC (2006)
Wintering grounds (Tonga, BSE3)	1999-2004	2,311	0.22	SPWRC (2006)
Breeding Stock F				
Feeding grounds (170°W–110°W)	1982/83 (CPI)	3,240	0.47	Branch (2006)
Feeding grounds (170°W–110°W)	1990/91 (CPII)	2,976	0.51	Branch (2006)
Feeding grounds (170°W–110°W)	1997/98 (CPIII)	3,852	0.22	Branch (2006)
Wintering ground (BSF2)	1999-2004	1,057	0.24	Poole *et al.*(2006)
Breeding Stock G				
Feeding grounds (110°W–50°W)	1982/83 (CPI)	1,452	0.65	Branch (2006)
Feeding grounds (110°W–50°W)	1989/90 (CPII)	2,817	0.38	Branch (2006)
Feeding grounds (110°W–50°W)	1996/97 (CPIII)	3,310	0.21	Branch (2006)
Feeding grounds (Antarctic Peninsula)	2000 (CCAMLR 2000)	6,691	0.32	Hedley et al., (2001); Reilly et al., (2004)
Feeding grounds (Antarctic Peninsula)	1997	3,851	0.05	Stevick *et al.* (2006b)
Feeding grounds (Antarctic Peninsula)	2006	1,981	0.23	Secchi *et al.* (2006)
Feeding grounds (Antarctic Peninsula)	2000/01	1,829	0.33	Williams *et al.* (2006)
Wintering grounds	2006	6,500	0.21	Felix *et al.*(in review)
IWC Area II (120°W-60W°)				
CPI	1982/83	1,405	0.66	Branch (2006)
CPII	1989/90	3,048	0.41	Branch (2006)
CPIII	1997/98	3,549	0.20	Branch (2006)
IWC Area II (60°W-0°)				
CPI	1982/83	421	0.92	Branch (2006)
CPII	1986/87	464	0.40	Branch (2006)
CPIII	1997/98	1,005	0.38	Branch (2006)
IWC Area III (0°-70°E)				
CPI	1979/80	1,017	0.49	Branch (2006)
CPII	1987/88	890	0.46	Branch (2006)
CPIII	1993/94	2,504	0.40	Branch (2006)
IWC Area IV (70°E-130°E)				
CPI	1978/79	1,102	0.46	Branch (2006)
CPII	1988/89	4,167	0.53	Branch (2006)
CPIII	1997/98	17,938	0.18	Branch (2006)
IWC Area V (130°E-170°W)				
CPI	1980/81	1,876	0.60	Branch (2006)
CPII	1985/86	622	0.50	Branch (2006)
CPIII*	1991/92	3,310	0.34	Branch (2006)
CPIII	2002/03	13,246	0.20	Branch (2006)
IWC Area VI (170°W-120°W)				
CPI	1983/84	3,240	0.47	Branch (2006)
CPII	1990/91	2,976	0.51	Branch (2006)
CPIII	1998/99	3,098	0.27	Branch (2006)

[1]Estimates from the IDCR/SOWER cruises presented here are those computed for comparable areas to account for unsurveyed regions in CPI and CP II (see Branch, 2006 for details). [2]Two estimates of abundance were computed for CPIII, one for 2001/02-2003/04 from complete coverage south of 60oS and another, denoted by CPIII*, for the survey with incomplete coverage in 1991/92 (Branch, 2006).

Table 3 – Rates of increase of Southern Hemisphere humpback whales

BS	Period	ROI (%/yr)	95% CI	Observation	Reference
A	1996-2001	30.6	2.6-60	wintering grounds, biologically unrealistic	Freitas *et al.* (2004)
A	1995-1998	7.4	0.5-14.5	wintering grounds, sighting data	Ward *et al.* (2006)
A	1981/82-1997/98	5.3	-6.9-17.4	feeding grounds, IDCR-SOWER cruises	Branch (2006)
B	1979/80-1995/96	5.9	-5.9-17.6	feeding grounds, IDCR-SOWER cruises	Branch (2006)
C	1979/80-1993/94	6.6	-3.8-16.9	feeding grounds, IDCR-SOWER cruises	Branch (2006)
C	1991-2003	7.9	-	wintering grounds, sighting data	Findlay *et al.* (2004)
D	1978/79-1997/98	14.4	9.6-19.2	feeding grounds, IDCR-SOWER cruises, biologically unrealistic	Branch (2006)
D	1977-1991	10.1	5.5-14.7	wintering grounds, sighting data	Bannister and Hedley (2001)
E	1978/79-2001/02	13.7	9.3-18.1	feeding grounds, IDCR-SOWER cruises, biologically unrealistic	Branch (2006)
E	1984-2007	10.9	10.5-11.1	wintering grounds, sighting data	Noad *et al.* (2008)
F	1982/83-1997/98	1.6	-5.4-8.5	feeding grounds, IDCR-SOWER cruises	Branch (2006)
G	1982/83-1996/97	4.6	-3.4-12.6	feeding grounds, IDCR-SOWER cruises	Branch (2006)

Table 4 – Catches of Southern Hemisphere humpback whale breeding stocks (BS) in the wintering grounds (north of 40°S, from Allison, 2006)

Year	BSA	BSB	BSC	BSD	BSE	BSF	BSG	Total
Total	1836	29833	20807	28281	14513	0	2345	97615
1900	0	0	0	0	8	0	0	8
1901	0	0	0	0	8	0	0	8
1902	0	0	0	0	8	0	0	8
1903	0	0	0	0	8	0	0	8
1904	0	0	0	0	8	0	0	8
1905	0	0	0	0	8	0	0	8
1906	0	0	0	0	8	0	0	8
1907	0	0	0	0	8	0	0	8
1908	0	0	104	0	8	0	16	128
1909	0	576	149	0	16	0	44	785
1910	0	962	632	0	77	0	62	1733
1911	102	2603	1580	0	77	0	92	4454
1912	342	4692	2338	234	224	0	86	7916
1913	352	5962	1805	993	440	0	45	9597
1914	317	2873	830	1968	93	0	195	6276
1915	82	169	334	1297	106	0	30	2018
1916	68	70	94	388	82	0	15	717
1917	62	10	7	0	94	0	15	188
1918	62	10	9	0	90	0	23	194
1919	29	17	91	0	119	0	24	280
1920	0	40	148	0	107	0	21	316
1921	0	0	251	0	89	0	21	361
1922	0	626	285	155	57	0	19	1142
1923	0	899	183	166	79	0	16	1343
1924	0	662	187	0	107	0	34	990
1925	0	842	372	669	96	0	248	2227
1926	0	442	124	735	78	0	277	1656
1927	0	47	86	996	127	0	40	1296
1928	0	68	62	1035	105	0	36	1306
1929	0	50	99	0	102	0	26	277
1930	0	614	134	0	78	0	33	859
1931	0	0	72	0	109	0	53	234
1932	0	0	307	0	18	0	21	346
1933	0	0	162	0	44	0	11	217
1934	0	723	514	0	52	0	13	1302
1935	0	1238	418	0	57	0	31	1744
1936	0	869	300	3076	69	0	18	4332
1937	0	327	1465	3250	55	0	28	5125
1938	0	0	1929	917	75	0	6	2927
1939	0	0	1440	0	80	0	7	1527
Table 4	continued							
1940	0	0	176	0	107	0	0	283

1941	0	0	79	0	86	0	0	165
1942	0	0	156	0	71	0	0	227
1943	0	0	80	0	90	0	0	170
1944	0	0	115	0	88	0	0	203
1945	0	0	116	0	107	0	0	223
1946	0	0	93	0	110	0	15	218
1947	11	5	89	2	101	0	19	227
1948	23	14	182	4	92	0	5	320
1949	17	1371	1523	190	144	0	6	3251
1950	26	1411	865	388	79	0	5	2774
1951	28	1114	103	1224	111	0	26	2606
1952	9	280	111	1187	721	0	27	2335
1953	8	9	89	1300	809	0	29	2244
1954	18	0	28	1320	898	0	106	2370
1955	9	0	49	1126	832	0	7	2023
1956	17	0	36	1119	1013	0	10	2195
1957	3	3	34	1120	1041	0	5	2206
1958	5	2	39	967	1039	0	0	2052
1959	8	168	38	700	1294	0	3	2211
1960	13	4	36	545	1357	0	2	1957
1961	13	23	36	580	997	0	3	1652
1962	11	15	39	543	209	0	4	821
1963	12	9	39	87	9	0	1	157
1964	0	1	7	0	0	0	38	46
1965	0	1	9	0	0	0	147	157
1966	0	9	62	0	0	0	264	335
1967	189	3	66	0	0	0	13	271
1968	0	0	0	0	0	0	3	3
1969	0	0	0	0	0	0	1	1
1970	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	0	0	1	0	3	0	0	4
1974	0	0	0	0	4	0	0	4
1975	0	0	0	0	8	0	0	8
1976	0	0	0	0	4	0	0	4
1977	0	0	0	0	4	0	0	4
1978	0	0	0	0	11	0	0	11

Table 5 – Catches of Southern Hemisphere humpback whale breeding stocks (BS) in the feeding grounds (south of 40^{o}S, from Allison, 2006)

	BSA	BSB	BSC	BSD	BSE	BSF	BSG	Total
Total	29334	5056	8128	20352	35971	8147	15056	122044
1900	0	0	0	0	0	0	0	0
1901	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	1	1
1904	180	0	0	0	0	0	0	180
1905	288	0	0	0	0	0	23	311
1906	240	0	0	0	0	0	498	738
1907	1261	0	0	0	0	0	366	1627
1908	1849	0	0	217	0	0	1246	3312
1909	3391	0	0	118	0	0	1481	4990
1910	6468	0	0	83	0	0	2527	9078
1911	5730	0	0	0	0	0	2039	7769
1912	2539	0	0	0	0	0	976	3515
1913	647	0	0	0	0	0	1038	1685
1914	838	0	0	0	0	0	656	1494
1915	1615	0	0	0	0	0	219	1834
1916	379	0	0	0	0	0	21	400
1917	59	0	0	0	0	0	69	128
1918	67	0	0	0	0	0	81	148
1919	82	0	0	0	0	0	181	263
1920	102	0	0	0	0	0	149	251
1921	9	0	0	0	0	0	0	9
1922	364	0	0	0	0	0	189	553
1923	133	0	0	0	0	0	96	229
1924	266	0	0	0	0	0	102	368
1925	254	0	0	0	0	0	163	417
1926	7	0	0	0	82	0	101	190
1927	0	0	0	0	16	0	2	18
1928	19	0	0	11	17	0	15	62
1929	51	16	4	11	775	0	0	857
1930	107	63	150	27	235	0	1	583
1931	18	3	2	161	0	0	0	184
1932	23	18	37	82	0	0	0	160
1933	132	85	54	601	0	0	0	872
1934	57	38	543	1343	0	0	0	1981
1935	48	300	1870	940	4	0	0	3162
1936	105	250	2683	1435	0	0	1	4474
1937	242	189	778	836	32	0	0	2077
1938	0	0	0	835	48	0	0	883
1939	2	0	4	0	0	0	0	6
1940	36	242	0	0	2394	0	1	2673
1941	13	0	0	0	0	0	0	13

Table 5 continued

1942	0	0	0	0	0	0	0	0
1943	4	0	0	0	0	0	0	4
1944	60	0	0	0	0	0	0	60
1945	238	0	0	0	0	0	0	238
1946	30	1	0	0	0	0	0	31
1947	24	1	0	1	0	0	0	26
1948	25	84	34	0	0	0	0	143
1949	66	465	395	675	1017	0	0	2618
1950	672	229	73	1115	171	317	272	2849
1951	17	428	211	900	591	38	0	2185
1952	25	201	208	193	517	13	0	1157
1953	132	101	66	259	14	136	0	708
1954	26	317	49	26	940	340	0	1698
1955	87	143	29	1165	2373	334	14	4145
1956	150	96	3	0	0	37	665	951
1957	58	61	66	1909	220	198	59	2571
1958	11	87	119	3679	2065	0	0	5961
1959	7	60	153	259	12363	513	208	13563
1960	14	117	71	650	9236	2758	89	12935
1961	0	18	28	363	1571	2332	1210	5522
1962	13	14	74	1712	473	303	297	2886
1963	0	2	39	359	284	0	0	684
1964	0	0	48	89	86	0	0	223
1965	52	914	75	93	354	477	0	1965
1966	0	147	196	122	56	237	0	758
1967	0	365	66	82	34	111	0	658
1968	0	0	0	1	1	0	0	2
1969	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	3	0	3
1972	2	1	0	0	2	0	0	5

Table 6 - Abundance estimates of Antarctic blue whales south of 60°S

Year/Cruise	*N*	CV
Area I (120°W-60°W)		
1982/83 (CPI)[1]	25	0.8
1989/90 (CPII)[1]	178	1.03
1997/98 (CPIII)	88	0.85
Area II (60°W–0°)		
1981/82 (CPI)	26	0.81
1986/87 (CPII)	158	0.71
1997/98 (CPIII)	268	0.58
Area III (0°–70°E)		
1979/80 (CPI)	219	0.61
1987/88 (CPII)	111	0.79
1993/94 (CPIII)	166	0.6
1995/96 (JARPA)[2]	192	0.43
1997/98 (JARPA)[2]	234	0.48
1999/2000 (JARPA)[2]	546	0.58
2001/02 (JARPA)[2]	80	0.62
2003/04 (JARPA)[2]	546	0.34
Area IV (70°E–130°E)		
1978/79 (CPI)	9	1.06
1988/89 (CPII)	0	0
1997/98 (CPIII)	419	0.51
1989/90 (JARPA)	65	0.48
1991/92 (JARPA)	18	1.08
1993/94 (JARPA)	66	0.62
1995/96 (JARPA)	8	0.9
1997/98 (JARPA)	145	0.6
1999/2000 (JARPA)	225	0.39
2001/02 (JARPA)	300	0.46
2003/04 (JARPA)	78	0.73
Area V (130°E–170°W)		
1980/81 (CPI)	110	0.73
1985/86 (CPII)	218	0.75
1991/92 (CPIII*)[3]	534	0.61
2002/03 (CPIII)	765	0.43
1990/91 (JARPA)	183	1.01
1992/93 (JARPA)	257	0.64
1994/95 (JARPA)	270	0.63
1996/97 (JARPA)	10	0.75
1998/99 (JARPA)	206	2.15
2000/01 (JARPA)	317	0.5
2002/03 (JARPA)	143	0.53
2004/05 (JARPA)	489	0.75
Area VI (170°W–120°W)		

Table 6 - continued

1983/84 (CPI)	177	0.81
1990/91 (CPII)	21	0.9
1998/99 (CPIII)	500	0.68
1996/97 (JARPA) [2]	90	0.45
2002/03 (JARPA) [2]	28	0.93
2004/05 (JARPA) [2]	152	0.38
All areas		
1980/81 (CPI)	592	0.4
1987/88 (CPII)	686	0.47
1997/98 (CPIII)	2,249	0.36

[1]Estimates from the IDCR/SOWER cruises presented here are those computed for comparable areas to account for unsurveyed regions in CPI and CP II (see Branch, 2007a for details).
[2]Estimates from JARPA surveys covered only the eastern (35^{o}E-70^{o}E) and western (170^{o}W -145^{o}W) portions of Areas III and VI, respectively, and therefore are not to be taken as an estimate for the whole IWC Management Area.
[3]Two estimates of abundance were computed for CPIII, one for 2001/02-2003/04 from complete coverage south of 60^{o}S and another, denoted by CPIII*, for the survey with incomplete coverage in 1991/92 (Branch, 2006).

Table 7 - Annual catches of Antarctic blue whales. The year is the start year of the Antarctic summer season, i.e. 1904 refers to the 1904/05 season, and include annual winter land station catches if most of the catches at that station were taken after 1 July of that year (Branch et al., 2008).

Year	Catches	Year	Catches	Year	Catches	Year	Catches
1904	11	1922	6,694	1940	4,973	1958	1,082
1905	51	1923	4,829	1941	63	1959	534
1906	111	1924	6,629	1942	126	1960	481
1907	201	1925	6,028	1943	346	1961	611
1908	244	1926	8,143	1944	1,047	1962	395
1909	176	1927	10,006	1945	3,603	1963	183
1910	422	1928	14,130	1946	9,234	1964	129
1911	1,477	1929	18,608	1947	6,936	1965	164
1912	2,391	1930	30,365	1948	7,641	1966	155
1913	3,113	1931	6,577	1949	6,196	1967	58
1914	5,125	1932	18,961	1950	7,057	1968	95
1915	5,503	1933	17,413	1951	5,111	1969	47
1916	4,356	1934	16,578	1952	3,851	1970	37
1917	3,061	1935	17,815	1953	2,704	1971	23
1918	2,143	1936	14,414	1954	2,171	1972	3
1919	1,987	1937	15,019	1955	1,578	Total	345,775
1920	2,955	1938	14,110	1956	1,504		
1921	4,552	1939	11,772	1957	1,667		

Table 8 - Abundance Estimates of Antarctic fin whales south of 60°S

Year/Cruise	*N*	CV
All areas[1]		
1980/81 (CPI)	2,410	0.36
1987/88 (CPII)	1,370	0.46
1997/98 (CPIII)	4,850	0.54
Area IIIE (35°E-70°E)		
1995/96 (JARPA)	2,066	0.24
1997/98 (JARPA)	74	0.58
1999/2000 (JARPA)	5,199	0.28
2001/02 (JARPA)	3,389	0.52
2003/04 (JARPA)	5,288	0.32
Area IV (70°E–130°E)		
1989/90 (JARPA)	103	0.85
1991/92 (JARPA)	342	0.59
1993/94 (JARPA)	186	0.45
1995/96 (JARPA)	1021	0.31
1997/98 (JARPA)	624	0.34
1999/2000 (JARPA)	1565	0.49
2001/02 (JARPA)	5861	0.29
2003/04 (JARPA)	1226	0.28
Area V (130°E–170°W)		
1990/91 (JARPA)	732	0.30
1992/93 (JARPA)	1623	0.38
1994/95 (JARPA)	6937	0.37
1996/97 (JARPA)	1224	0.32
1998/99 (JARPA)	4259	0.39
2000/01 (JARPA)	5321	0.25
2002/03 (JARPA)	3210	0.32
2004/05 (JARPA)	4556	0.44
Area VI (170°W -145°W)		
1996/97 (JARPA)	655	0.26
1998/99 (JARPA)	164	0.74
2000/01 (JARPA)	1,071	0.30
2002/03 (JARPA)	495	0.32
2004/05 (JARPA)	685	0.30

[1]Estimates from the IDCR/SOWER cruises presented here are those computed for comparable areas to account for unsurveyed regions in CPI and CP II (see Branch and Butterworth, 2001a and Branch, 2007a for details).

Table 9 – Catches of Southern Hemisphere fin whales in the feeding grounds (south of 40°S) by IWC Management Area.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Total	59448	15560	106295	29160	13275	1753	223738
1913			18				18
1914			65				65
1918			427				427
1919			334				334
1920			764				764
1922			579				579
1923			903				903
1924			1253				1253
1925			1649				1649
1926			1732				1732
1927			1780				1780
1928			1716				1716
1929			1068				1068
1930			1560				1560
1931			602				602
1932			603				603
1933	36		901				937
1934		41	1024				1065
1935	56	4	1129				1189
1936	2608		1981	10	10		4609
1937	3425		2099	4			5528
1938	581		959				1540
1939	168		5				173
1941	1653						1653
1942	3604						3604
1943	3295						3295
1946			804				804
1947	3549		1081				4630
1948	3223		1511				4734
1949	1180	2	1555				2737
1950	1043		1298				2341
1951	9287		2117				11404
1952	231	1	1441				1673
1953	979	1	1172	1			2153
1954	5421	4	918				6343
1955	1105	41	1093	7			2246
1956	944	4	1112	62			2122
1957	2368	30	2158	162	48		4766
1958	2134	21	2376	283			4814
1959	1846	21	2463	139			4469
1960	1608	152	2792	282			4834
1961	2100	167	3151	454			5872

Table 9 - continued

1962	2313	1776	3700	899	164		8852
1963	1505	506	5273	2365	1219		10868
1964	1146	467	4705	2564	1747	32	10629
1965	532	37	4674	4465	1126		10834
1966	546	671	3491	2172			6880
1967	282	306	3177	1326	58		5149
1968		284	1965	732	325		3306
1969		307	3601	1606			5514
1970		287	4501	1923	885		7596
1971		889	4551	1416	820		7676
1972		2060	4718	1081	2468		10327
1973		809	3096	1030	1389		6324
1974	577	2223	2370	1553	1441		8164
1975	103	1586	2513	1822	811	304	6835
1976		1478	1108	1465	244	888	4295
1977		343	1705	628	273	179	2949
1978		392	954	709	26	223	2081
1979		620			221	127	841
1980		30					30

Table 10 – Catches of Southern Hemisphere fin whales in the breeding grounds (north of 40°S) by IWC Management Area.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Total	40173	273607	239205	102061	63024	38129	718070
1913		335					335
1914		978					978
1915	2	1350					1352
1916	62	2164					2226
1917		981					981
1918	517	1200					1717
1919	846	1279					2125
1920	661	2274					2935
1921	2006	2512					4518
1922	1072	1141					2213
1923	1281	2454					3735
1924	1491	1822					3313
1925	1710	2790					4500
1926	2126	5708					7834
1927	1750	3050					4800
1928	1668	2618			6		4292
1929	1602	5459	53		123		7237
1930	839	6055	654	27	1231		8806
1931	448	2853	1991	565	374		6231
1932	91	2135	126	417			2769
1933	97	2612	2089	1406			6204
1934	222	2861	2578	2471	1		8133
1935	95	3189	8653	1049	17		13003
1936		4218	5658	765			10641
1937		7823	6200	3457			17480
1938		12317	9501	7584	541		29943
1939	66	7471	7011	4796	1539		20883
1940		9952	1855	829			12636
1941		3305	20				3325
1942		757					757
1943		800					800
1944		1718					1718
1945		2231	69				2300
1946		6530	4258	485	40		11313
1947		7140	5252	4631	725		17748
1948		7803	8755	5304	2005	47	23867
1949		8520	7315	3497	2818	59	22150
1950	41	8974	5831	5073	2594	1118	22513
1951	520	6952	5895	4425	3052	1324	20844
1952		7614	7091	2454	3118	2329	20277
1953	18	6757	10776	1805	2108	2108	21464
1954	101	10795	12089	3292	1116	2774	27393

Table 10 - continued

1955	265	6074	15643	4040	3818	1219	29840
1956	4606	8631	8232	3991	1441	2900	26901
1957	6133	12216	5642	1358	880	5553	26229
1958	2018	6775	11172	3422	1800	4752	25187
1959	180	6516	11268	6986	2745	2193	27695
1960	509	6687	11293	7150	1938	347	27577
1961	1116	8428	15653	2904	1007	1926	29108
1962	2442	8819	13725	2918	883	664	28787
1963	382	7100	9668	2203	1197	114	20550
1964	48	9274	4662	1510	3894	22	19388
1965	66	4483	916	206	2500		8171
1966	118	1391	1829	976	1186	226	5500
1967	6	265	2467	600	2745	1182	6083
1968		391	960	1314	3331	285	5996
1969	247	86	930	1638	661	456	3562
1970		206	2161	1762	2117	90	6246
1971	24	1910	2236	1035	2205		7410
1972	359	1366	2601	1123	810	25	6259
1973	515	767	1651	966	1083	671	4982
1974	675	702	411	175	2715	1169	4678
1975	497	241	559	389	1561	1953	3247
1976	282	807	305	422	452	616	2268
1977	10	187	474	201	196	845	1068
1978	153	305	853	419	198	617	1928
1979	190	483	174	11	250	545	1108
2006				10			10
2007					3		3

Table 11 – Catches of Southern Hemisphere sei whales in the breeding grounds (north of 40°S) by IWC Management Area.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Total	1061	11203	29825	10105	97	0	52291
1913			59				59
1914			27				27
1918			93				93
1919			174				174
1920			72				72
1922			128				128
1923			193				193
1924			670				670
1925			184				184
1926			405				405
1927			457				457
1928			639				639
1929			212				212
1930			212				212
1931			28				28
1932			23				23
1933			11				11
1934		2	54				56
1935	2	1	97				100
1936	10		296				306
1937	3		121				124
1938			64				64
1946			75				75
1947	2		158				160
1948	3	10	192				205
1949			220				220
1950			426				426
1951	3	151	617				771
1952		158	1037				1195
1953	24	161	391				576
1954	47	183	71				301
1955	32	200	177				409
1956	24	196	101		14		335
1957	39	115	323		2		479
1958	16	118	577				711
1959	6	294	913		2		1215
1960	9	750	682				1441
1961	3	974	772		1		1750
1962	9	1046	927	2			1984
1963	6	383	2154	22			2565
1964	38	286	1078	812			2214
1965	439	412	1244	324	28		2447
1966	207	1077	694	3272	1		5251

Table 11 - continued

1967	139	1299	2704	2251			6393
1968		1017	2989	1	5		4012
1969		673	2725	2037			5435
1970		611	1901	1320	2		3834
1971		1052	1076	64	6		2198
1972		11	164		36		211
1973		7	494				501
1974		3	453				456
1975		3	266				269
1976		5	5				10
1977		5					5

Table 12 – Catches of Southern Hemisphere sei whales in the feeding grounds (south of 40^{o}S) by IWC Management Area.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Total	8183	57901	20468	21471	16982	11089	125005
1914		8					8
1918		43					43
1919		7					7
1920		55					55
1921		35					35
1922		81					81
1923		11					11
1924	2	193					195
1925	1	1					2
1926	4	11					15
1927	2	370					372
1928	699	97					796
1929	410	373					783
1930		227					227
1931	1	143					144
1932	10	16					26
1933	15	2					17
1934	3						3
1935	1	263					264
1937		490					490
1938		161					161
1939	1	21			1		23
1940		81					81
1941		104					104
1942		46					46
1943		73					73
1944		197					197
1945		78					78
1946		85					85
1947		393					393
1948		624		2	10		636
1949		578		1			579
1950		1283					1283
1951		606		11			617
1952		526			2		528
1953		516	12	3	92	2	623
1954		939	11	1		1	951
1955		450	9	5	3		467
1956	16	391	6	1	2	8	416
1957	270	1068	15	1	1	132	1355
1958	542	1095	16	90	422	969	2165
1959		1079	80	233	373	535	1765

Table 12 - continued

1960	159	1548	231	528	470	230	2936
1961	225	2007	341	103	163	1571	2839
1962	1672	1968	511	621	347	241	5119
1963	579	1843	1388	322	409	64	4541
1964	28	4942	1579	88	1903		8540
1965	40	18628	350	117	2257		21392
1966	56	10459	5129	85	614	562	16343
1967		713	4690	3525	1274	447	10202
1968		362	1791	2110	3135	2778	7398
1969	30	869	603	1123	1093	607	3718
1970		266	1248	3192	295	104	5001
1971		748	662	2646	690		4746
1972	5	105	712	2070	992		3884
1973	480	20	600	1780	850	77	3730
1974	1369	3	391	862	570	940	3195
1975	874	4	93	891	378	1032	2240
1976	80	513		423	626	251	1642
1977	298	83		399	10	538	790
1978	311			238			549

Table 13 – Minke whale abundance estimates south of 60°S from the IDCR/SOWER surveys based on the standard method (Branch, 2006a) and preliminary estimates from the OK Method (Okamura & Kitakado, 2008b).

	Branch (2006)		Okamura and Kitakado (2008)	
Year/Cruise	*N*	CV	*N*	CV
Area I (120°W-60°W)				
1982/83 (CPI)[1]	118,605	0.239	–	–
1989/90 (CPII)[1]	104,455	0.192	140,760	0.186
1997/98 (CPIII)	38,087	0.211	54,329	0.151
Area II (60°W–0°)				
1981/82 (CPI)	115,908	0.371	–	–
1986/87 (CPII)	182,622	0.231	159,651	0.135
1997/98 (CPIII)	35,067	0.196	70,388	0.184
Area III (0°–70°E)				
1979/80 (CPI)	183,918	0.263	–	–
1987/88 (CPII)	222,304	0.341	131,329	0.207
1993/94 (CPIII)	49,960	0.147	95,742	0.152
Area IV (70°E–130°E)				
1978/79 (CPI)	141,465	0.188	–	–
1988/89 (CPII)	86,776	0.291	100,597	0.157
1997/98 (CPIII)	13,015	0.281	95,742	0.329
Area V (130°E–170°W)				
1980/81 (CPI)	269,084	0.294	–	–
1985/86 (CPII)	278,693	0.136	414,278	0.136
2002/03 (CPIII)	140,336	0.162	224,801	0.095
Area VI (170°W–120°W)				
1983/84 (CPI)	101,976	0.232	–	–
1990/91 (CPII)	47,384	0.253	94,039	0.259
1998/99 (CPIII)	68,651	0.201	111,627	0.143
All areas				
1980/81 (CPI)	930,955	0.155	–	–
1987/88 (CPII)	969,811	0.109	1,040,654	0.071
1997/98 (CPIII)	338,653	0.079	652,612	0.077

[1]Estimates from the IDCR/SOWER cruises presented here are those computed for comparable areas to account for unsurveyed regions in CPI and CP II, although different methods were used to adjust the estimates. The standard method excludes like minke sightings, while the OK method includes like minke sightings.

Table 14 – Minke whale abundance estimates south of 60°S from the JARPA research cruises Source for Areas IV and V (Hakamada et al., 2006a); for Areas IIIE and VIW (Hakamada et al., 2005).

Year/Cruise	*N*	CV
Area IIIE (35°E–70°E)		
1995/96	13,793	0.282
1997/98	8,153	0.400
1999/00	12,314	0.686
2001/02	58,302	0.410
2003/04	34,887	0.294
Area IV (70°E–130°E)		
1989/90	54,772	0.231
1991/92	56,774	0.258
1993/94	41,895	0.211
1995/96	42,882	0.245
1997/98	29,683	0.266
1999/00	49,922	0.168
2001/02	67,954	0.169
2003/04	47,818	0.358
Area V (130°E–170°W)		
1990/91	189,887	0.238
1992/93	126,590	0.232
1994/95	164,121	0.269
1996/97	169,878	0.265
1998/99	195,991	0.251
2000/01	174,904	0.222
2002/03	225,796	0.162
2004/05	93,989	0.174
Area VIW (170°W–145°W)		
1996/97	13,373	0.259
1998/99	40,743	0.268
2000/01	23,237	0.224
2002/03	13,807	0.250

Table 15 – Minke whale catches in the breeding grounds (north of 40°S). A small proportion of these catches may correspond to common (dwarf) minke whales.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Total		0	14361	1186	36	18	15601
1949		1					1
1953		9					9
1955		2		1			3
1959		2					2
1963		2	7	1			10
1964		47	2				49
1965		67	5	1			73
1966		352	5	10			367
1967		495	7	8			510
1968		456	100				556
1969		621	114	5			740
1970		706	175	9			890
1971		912	223	1			1136
1972		702	139		2		843
1973		650	178				828
1974		765	119				884
1975		1039	112				1151
1976		776					776
1977		1000			16	6	1022
1978		690					690
1979		739					739
1980		902					902
1981		749					749
1982		854					854
1983		625					625
1984		600					600
1985		598					598

Table 16 – Minke whale catches in the feeding grounds (south of 40°S). A small proportion (<1%) of these catches may correspond to dwarf minke whales.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Total	12260	5236	26957	37348	17080	5624	104505
1918	5						5
1922		1					1
1955			1				1
1957		1	1				2
1958			6	2			8
1960			3				3
1962		2					2
1963			3	10	14		27
1964		1	1	98	1		101
1965		1	2	1	4		8
1966		2	1	4	6	1	14
1967		3	4	581	7	1	596
1968		1	5	18	3	2	29
1969	7	1	1	41	2	3	55
1970				8	18		26
1971		3	4	1318			1325
1972	3	1	932	4842			5778
1973	300	13	884	5647			6844
1974	1102	169	2314	2231	734	13	6563
1975	2378	800	2028	881	420		6507
1976	545	1164	2083	1522	1221	159	6694
1977	943	865	2176	710	1109	382	6185
1978	463	362	2487	742	216	288	4558
1979	653	397	1989	1675	910	135	5759
1980	944	301	2978	2002	848		7073
1981	768	172	1392	2088	1248	429	6097
1982	930	299	1892	2230	1393	951	7695
1983	694		263	2449	1735	776	5917
1984	624		1670	451	1390	1005	5140
1985	624		1221	1488	910	252	4495
1986	670	256	1404	1921	1110	162	5523
1987	607	421	533	950	916	414	3841
1988				273			273
1989				139	236		375
1990				188	5		193
1991				47	304	14	365
1992				241	77		318
1993				94	226	24	344
1994				236	89		325
1995			69	61	241		371
1996			40	269	2	94	405
1997			94		283	62	439

1998	17	327			344
1999	109	9	328	61	507
2000		321		110	431
2001	82	22	300	30	434
2002	28	308		103	439
2003	110	19	330	7	466
2004		311	3	110	424
2005			423	36	459
2006	130	573	18		721

Table 17 – Summary of estimates of certain demographic parameters and current abundance levels for different breeding stock population units used for assessment modelling of Southern Right whales (IWC, 2001). A dash indicates no information.

Breeding unit	Growth rate *r*	Annual survival *S*	Age at first parturition *tm*	Most recent population estimate of mature females	'1997' estimate of mature females used in the model [1]	'1997' total population (i.e. all animals) estimate used in the model
New Zealand	-	-	-	69 (1997)	70	330
Australia	0.0825	-	-	220 (1995)	254	1197
Central Indian Ocean	-	-	-	-	0	0
Mozambique	-	-	-	<10	0	0
South Africa	0.072	0.98-0.99	9.1	613 (1996)	659	3104
Namibia		-	-	<10	0	0
Tristan da Cunha	-	-	-	20 (1985)[2]	48	226
Brazil	-	-	-	25 (1995)	29	137
Argentina	0.071	0.98	9.0	330 (1990)	547[3]	2577
Chile/Peru	-	-	-	<10	0	0
NZ/Kermadec	-	-	-	-	0	0
Total					1607	7571

1. Estimates calculated assuming a growth rate of 0.075 for all areas.
2. Upon review later in the meeting, it was felt that this number was probably too high.
3. This is entirely extrapolation based, as data are only available to 1990.

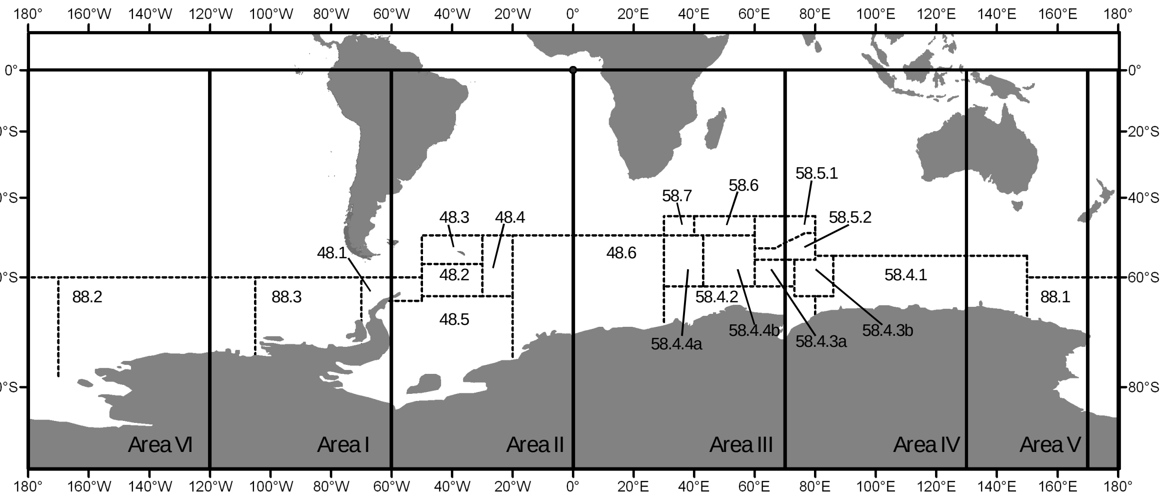

Fig. 1 – IWC Management Areas in the Southern Hemisphere (Areas I-VI; Donovan, 1991– solid lines) and the CCAMLR statistical areas (dotted lines).

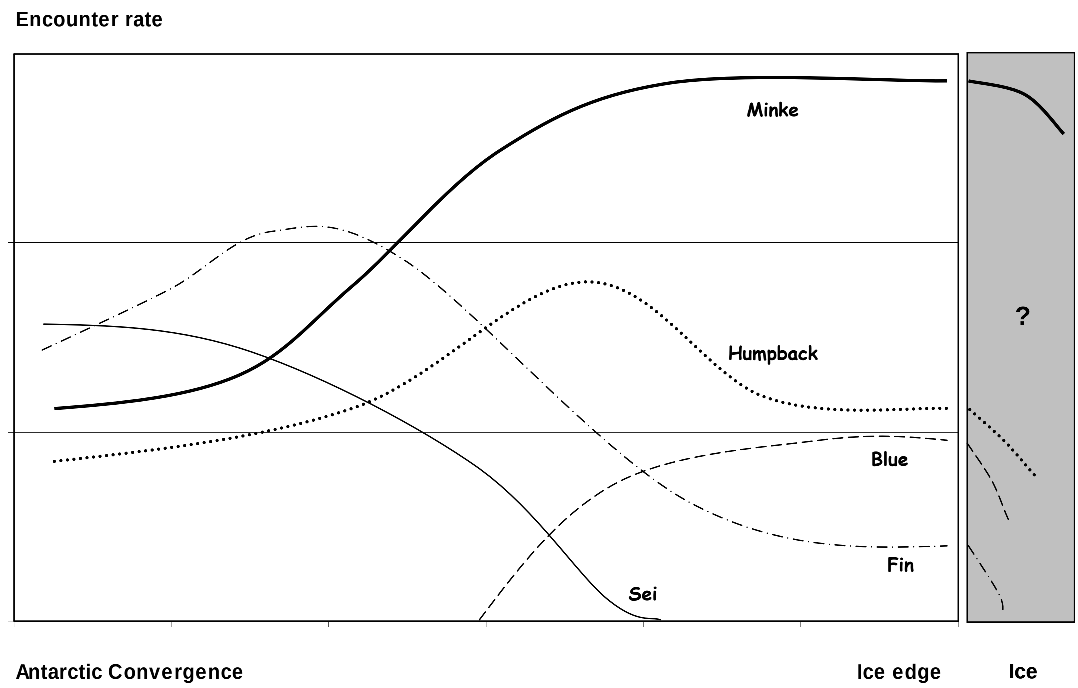

Fig. 2 – Latitudinal occurrence of Antarctic baleen whales (adapted from Kasamatsu, 1996)