Possible reasons for the appreciable decrease in abundance estimates for Antarctic minke whales from the IDCR/SOWER surveys between the second and third circumpolar sets of cruises

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Estimates of abundance obtained for Antarctic minke whales using the 'standard methods' of Branch and Butterworth (2001a) are appreciably lower for the third circumpolar set of surveys (CPIII) than for the second set (CPII). *When based on the complete CPIII data (1992/93–2003/04), the CPIII:CPII ratio, including like minkes, is 0.39 (SC/58/IA18). Ratios for individual Management Areas ranged from 0.18–0.52 except in Area VI where the CPIII:CPII ratio was 1.59 (SC/58/IA18). In contrast, results reported in SC/D06/J6 indicate that trends in JARPA abundance estimates over 1989/90–2004/05 are not significantly different from zero in Areas IV and V.* We present here a list of hypotheses updated from IWC (2003) that may explain (or exacerbate) the differences in estimates between CPII and CPIII, collected into (A) factors related to the population surveyed, (B) factors related to the survey process, and (C) factors that may be responsible for a real decline in abundance. The size of the effect on the ratio of CPIII:CPII is qualitatively indicated by 'small', 'medium' or 'large', where medium is of the order of 10% (i.e. would alter CPIII:CPII from 40% to 50%) and large is some tens of a percent. Sources of information on each of these factors is indicated, together with proposals for further addressing their impact. It should be noted that factors considered in these hypotheses may interact to produce effects that are greater or less than the sum of the effects of the hypotheses considered individually.

In this draft version, updated text since the last version is given in *italics*. Current date: 23 April 2007.

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Hypothesis	Likely effect on the ratio	Sources of information describing the hypothesis and the size of its effect on the ratio between the abundance estimates from CPIII to CPII	Proposals to account for effect or to further investigate effect
A. Factors related to the population surveyed			
A.1. Changes in coverage of Management Areas over years It is difficult to compare the results from the three CP surveys because CPI and CPII did not cover the full latitudinal range from the ice edge north to 60°S (Branch and Butterworth 2001a, Matsuoka *et al*. 2003).	Small	Branch (2003) indicates that abundance estimates for comparable regions that include the 1998/99 to 2000/01 data did not change the CPIII to CPII ratio compared to the ratio when less data from the CPIII survey were available. SC/57/IA16 showed that estimates from the completed CPIII surveys still have a low CPIII:CPII ratio (0.39), even though the full longitudinal range and 99.9% of the total area south of 60°S was surveyed. SC/55/IA11 assumed that the density in unsurveyed areas between the northern strata and 60°S was half of (instead of equal to) that in the corresponding northern strata and found this made virtually no difference to the CPIII:CPII ratio unless Area V is excluded; if Area V is excluded the ratio would increase by 4-6%. SC/56/IA8 used simulations to examine the effect of the unusual turret survey design in the south part of Area IV in CPII and concluded that this could result in an upward bias of 20-30%. Simulations suggested little difference in Area I because of survey design.	Spatial modelling has been proposed to extrapolate over unsurveyed regions. Analysis of existing data, simulation and field experiments can be used to further investigation.

Hypothesis	Likely effect on the ratio	Sources of information describing the hypothesis and the size of its effect on the ratio between the abundance estimates from CPIII to CPII	Proposals to account for effect or to further investigate effect
A.2. Changes in the location of the ice-edge and the proportion of animals south of the ice-edge Minke whale school density and school size drops off with distance from the ice-edge. The location of the ice-edge affects the proportion of the population within the survey region. Thus, an unknown, but conceivably large proportion of the SH minke whale population may be south of the ice edge, where vessels cannot go. This proportion is likely to change from year to year. The ice-edge extent and ice coverage are greatly affected by Antarctic and extra-polar climatological connections such as the Semiannual Oscillation (SAO), the Southern Oscillation Index (SOI) and the El Niño-Southern Oscillation (ENSO). Paper SC/54/IA7 provides information on interannual and long-term trends in Antarctic sea ice.	Uncertain, potentially large	SC/53/IA14 assumed that the density of minke whales in 0-60% ice was the same as in the southern strata and estimated that the circumpolar estimates should be increased by 64% (CPI), 24% (CPII) and 44% (CPIII, 1992/93 to 1997/98, calculated from tables) to account for minke whales inside the pack ice. SC/54/IA6 indicates there were minke whales in the pack-ice between 150°E and 77°E a month earlier than the IDCR/SOWER survey; however, no abundance estimates were possible. SC/54/IA18 notes that the low abundance estimate from Area IV in the 1998/99 IDCR/SOWER data (CPIII) as compared to that in 1989/90 (CPII) correlates with more ice coverage during 1998/99. Ishikawa (2003) notes that in 1997/98 the abundance estimate from Area IV based on JARPA data was low and ice coverage was high, in contrast to the next two occasions when this Area was surveyed, in 1999/2000 and 2001/02, when the abundance was high and ice coverage low. Murase *et al.* (2002) reports that an important feeding ground is the continental slope-shelf zone that is covered by ice during summer and not able to be surveyed by the survey vessels in some years. SC/54/IA19 indicates that the predicted number of minke whales in the pack-ice could vary from 18% to 159% of the open water abundance estimate, depending on the data used to estimate the relative density of minkes in the ice to that in open water. However, these data were generally collected at different times of the year than the IDCR/SOWER surveys. Hakamada *et al*. (2003) and Polacheck and Ensor (2003) note that mature females were sampled less frequently than usual due to higher coverage of pack-ice in the 1997/98 JARPA cruise, possibly because those animals were in the pack-ice. SC/56/IA10 notes that increased ice extent in CPIII in Areas I, III, and IV corresponded to lower abundance estimates relative to CPII, while decreased ice extent in Area Vi corresponded with high abundance estimates compared to CPII. Although ice extent was lower in Area II in CPIII, a large polynya was not surveyed by the vessels in 1997/98. SC/56/IA14 estimated the abundance in the unusually large unsurveyed Ronne polynya in Area II during the 1997/98 cruise. If the density in the polynya is assumed to be the same as in the southern strata, then the closing mode SOWER estimate would increase by 86%. The impact on IO estimates was not examined. SC/57/E1 presented an update on SC/56/E23 with results from six cruises totalling 126 survey days in the sea ice in the East Antarctic, Ross Sea and Weddell Sea. There were 232 minke schools (695 whales) sighted. Results indicate that sea ice habitat use by minke whales is highly variable and complex, but two main types of minke habitat are suggested. SC/57/IA6 reports on a GAM-based spatial analysis of the Ronne polynya in 1997/98. Extrapolations based on latitude, longitude and environmental variables suggested that 63,000 minke whales were in the polynya. SC/57/IA7 reports 23 schools (30 whales) sighted from a vessel and 10 (19) from helicopter during surveys in the pack ice in Areas III and IV. *SC/58/IA11 reports on simultaneous surveys by an ice-breaker within the ice and SOWER vessels outside the ice field; 19 schools were sighted within the ice field and densities were similar inside and outside the ice field.* *SC/58/IA12 found a negative correlation between the CPIII:CPII sea ice extent ratio (based on satellite data) and the CPIII:CPII abundance ratio at the half-Management Area level, suggesting that when ice extent was greater, abundance estimates were smaller.* *SC/58/IA17 found that estimated mean school size and sighting rate decreased from CPII to CPIII in Areas IIIW and IVE but increased in VIW, an opposite trend to sea ice extent in these three Management half-Areas.*	To account for the potential effects of sea-ice location, several methods have been proposed. For example, covariates could be used in the analysis (i.e. distance for ice-edge, school size, sea-ice coverage, sea-ice concentration). To investigate the percentage of the population in the pack ice, a work plan has been proposed that includes fully understanding existing published data, gathering all available recent data, and collecting additional data in the future, in collaboration with other national projects. Joint ice breaker and SOWER survey in 2004/05, data to be analysed.
A.3. Changes in the timing of the survey Compared to earlier IDCR/SOWER surveys, the timing of the surveys from	Small	SC/54/IA7 summarises information on satellite-imagery available to examine the change in ice extent/ice coverage between survey years, as well as the rate of retreat of the pack ice during the December-January period of most rapid ice retreat. SC/54/IA12 indicates that the peak migration in Areas III, IV and V in waters south of 60°S was in January during the 1970s and later during the 1990s, indicating that later timing in IDCR/SOWER surveys would not affect abundance estimates. However, the analysis	JARPA and JSV analyses.

Hypothesis	Likely effect on the ratio	Sources of information describing the hypothesis and the size of its effect on the ratio between the abundance estimates from CPIII to CPII	Proposals to account for effect or to further investigate effect
1994/95 to 2000/01 was later in the summer. This may have resulted in a smaller fraction of the population being present in the survey area during the 1994/95 to 2000/01 surveys.		combined JSV, JARPA and IDCR/SOWER datasets and recorded small samples, so that it is difficult to fully interpret these data. SC/54/IA28 indicates that when using the IDCR/SOWER data from 1978/79 to 1997/98, densities appear reasonably stable over the January to mid-February period, following which there was a decrease of about 20% in late February. The implications of this for abundance estimates given the later timing of some CPIII surveys were not investigated. SC/55/IA12 looked at the implications of a 20% decrease in densities after mid-February and showed that while some CPIII survey estimates would increase by >7%, the CPIII:CPII ratio would increase by only 2-3% if this factor was taken into account.	
A.4. Changes in the school size distribution The estimated mean school size appears to have decreased in CPIII. This may be due to the following: true mean school 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.	Small to medium	SC/54/IA13 reports a significant difference between the school size distributions in the North and South strata. Murase *et al.* (2004) reports that the school size distribution changed between the CP surveys. This is related to the changes in areas covered and sighting cues.	Incorporate the school size as a potential covariate in fitting the detection function.
A.5. Animals north of 60°S Some minke whales are north of 60°S during the IDCR/SOWER surveys. If the proportion south of 60°S has changed this would affect the CPIII:CPII ratio.	Likely small	Kasamatsu and Miyashita (1983) estimated 139,400 minke whales in the 40-60°S band from JSV data. Kasamatsu and Miyashita (1984) use line transect methods to analyse a survey covering 55-60°S in Area II (60°W-0°) in 1982/83 and estimate 14,730 minke whales in this region, compared to IDCR/SOWER estimates (SC/57/IA16) of 62,000, 141,000 and 35,000 for Area II in CPI, CPII and CPIII respectively. SC/42/SHMi18 compared IDCR CPI surveys and JSV data and found that IDCR CPI estimates should be increased by 41% or 52% (depending on the time period used for JSV data) to account for minke whales between 30°S and the northern boundary of the CPI surveys. Subsequent analyses (SC/47/SH20) suggested that JSV data was preferentially directed in areas with higher whale densities and that abundances north of 60°S for other species were generally less (range 39-118%) than obtained by SC/42/SHMi18. The consequences of this for minke whales was not explored.	Further investigate use of the JSV data to extrapolate to areas north of 60°S.
A.6. Additional variance not included in the abundance estimates	Uncertain, likely small to medium	Estimates of additional variance would increase the CVs associated with CPII and CPIII estimates, reducing the statistical significance of the lower CPIII estimate. Methods have previously been discussed (Cooke 1994, Punt et al. 1997, IWC 2004, SC/55/NAM1). Estimated additional variance from CPI to CPII was 0.36 if no change in abundance and 0.40 if change is estimated as a parameter (Punt et al. 1997). This factor would not impact the ratio itself but would affect whether it differed significantly from one.	Estimate additional variance using the methods in SC/57/IA5.
B. Factors related to survey process			
B.1. Changes in the proportion of schools classified as 'like-minke'	Small	Branch (2003) shows that the CPIII:CPII ratio increased by 3% when like-minke whale sightings are included.	Estimate abundance excluding and including sightings that are like-minkes to investigate the effects of this factor when using any of the proposed analytical methods.
B.2. Changes in the probability of observing animals on the track line *g*(0) *g*(0) is less than one for small schools and probably also for large schools.	Medium to large	SC/54/IA10 analyzes the 1989/90 (CPII) and 1993/94 (CPIII) Area I data from IDCR/SOWER with the new variant of the hazard probability analysis method. Estimates of g(0) are 0.59 and 0.54 (school size one), 0.76 and 0.70 (school size two) and 0.90 and 0.89 (school size >2), with an overall g(0) weighted by sample size of 0.68 for 1989/90 and 0.65 for 1993/94. Although g(0) differed by only a small amount, applying the analysis method resulted in a very different set of abundance estimates (39,301 for 1989/90 and 52,126 for 1993/94) compared to the 61,169 and 37,459 respectively in Branch and Butterworth (2001a).	Incorporate the following covariates into the analysis, if deemed necessary: school size, sightability (or Beaufort sea state), sighting cue, survey mode, or environmental

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Factors that affect the estimated mean school size include: sightability conditions, observer experience, sighting cue, and survey mode. Some of these changes may be due to increased surveying of more northerly waters where the weather is usually worst, and the true group size is smaller than that near the ice-edge. Greater numbers of inexperienced observers have been used in CPIII compared to CPI or CPII.		SC/54/IA16 indicates that the duplicate sighting probability was lower for small schools, schools detected in bad weather, and those schools that were sighted by inexperienced observers. For school sizes of two, the duplicate sighting probability was 1.56 times larger that for schools of size one, and the probability for school sizes >2 was 1.84 times larger. The duplicate sighting probability tended to be smaller for CPIII than for CPII by about 20%, with the effect being largest in the North strata. Murase et al. (2004) suggest that small school size and poor weather conditions found in northern strata may result in lower g(0) values in CPIII than CPII since surveys extended further north in CPIII. SC/54/IA30 reports that when using g(0) values from SC/54/IA10, the density estimates derived from the standard methods are negatively biased by 18% to 39%, depending on the survey mode (IO versus Closing mode) and circumpolar survey series. SC/55/IA12 notes that mean school size decreased from CPII to CPIII. If g(0) increases with school size, and is assumed to be 0.3 for school size of size one, adjusting for this factor would increase the closing mode CPIII:CPII ratio by 9%. SC/56/IA9 presents an updated model (including type of sighting cue) for estimating abundance from the IDCR/SOWER surveys which estimates g(0) for the 1989/90 survey to be 0.55 (CV=0.13). Abundance estimates in CPIII may have lower g(0) because they extended further north where most of the sightings are from cues other than blows. Mori et al. (2003) shows that the sighting rate was 42% lower for beginner observers than for experts. In CPIII all observers had >10 years experience but in CPIII half had been on <4 surveys. Thus g(0) might have been lower during CPIII because of observer experience. However, there was no significant trend in sighting rates when the three-observer combinations (two in the barrel, one in the IO platform) used in IDCR/SOWER surveys were examined. This might be an artefact of small sample size for some observer combinations, such as experts present in all platforms. *SC/58/IA9 and SC/58/IA10 extend the hazard probability model to account for measurement errors, resulting in similar CPII estimates but higher CPIII estimates, changing the CPIII:CPII ratio from 0.58 to 0.67. However, in this analysis, the CPII estimate was not increased to account for unsurveyed areas.*	indicators. The analytical methods will not assume *g*(0)=1. The performance of the analysis methods are being evaluated using simulated data that account for the effects listed above and incorporate a variety of heterogeneities. Analyses of existing data, simulation and field experiments can be used to further investigation. Visual dive time experiments from 2004/05 SOWER survey and earlier cruises. New methods of analyzing IDCR-SOWER will address this issue directly.
B.3. Changes in the bias of Closing mode estimates compared to IO mode estimates (R) Effect would be to increase the difference since closing:IO ratio higher in CPIII than in CPII.	Small (increases difference)	SC/54/IA26 indicates that the bias of Closing mode estimates relative to IO mode estimates from CPIII are different than that from CPII, though the estimates from CPIII appear to be less stable due to smaller sample sizes. An increasing trend in estimates of R (based on all surveys from 1985/86 to the most recent survey analysed) has been observed over time, as summarised in SC/57/IA11 and SC/57/IA16, from 0.751 (CV=0.152) in 1991 to 0.826 (CV=0.089) in 2001 to 0.880 (CV=0.076) in 2005.	Use different estimates of R for CPII and CPIII as suggested in SC/54/IA26.
B.4. Changes in the analysis options Alternative options for stratification, data truncation, school size estimation methods, and models for the detection function could lead to different school size and effective search half width estimates, and hence different abundance estimates.	Either direction, small	SC/54/IA5 indicates that when using the 1998/1999 IDCR/SOWER data, the abundance estimate from the closing mode could increase by up to 23%, and that from the IO mode could change by –3% to +18%, depending on the combination of alternative options used. Effects at the CP level were not investigated. SC/54/IA10 indicates that when using the 1989/90 and 1993/94 IDCR/SOWER data, the school size estimate can decrease to up to approximately 50%, depending on how the data were stratified, and school size estimated. SC/54/IA13 and SC/54/IA15 indicate that when using IDCR/SOWER data from 1985/86 to 1998/99, the annual abundance estimates changed by –6% to +47% of the previous estimates when the data were stratified by North and South instead of by vessel, where the 1995/96 to 1998/99 surveys show the largest positive differences. SC/54/IA32 indicated that using 1985/86 to 2000/01 IDCR/SOWER data to estimate abundance where data were stratified by North and South, instead of by vessel (Branch 2003), the abundance estimate from CPII increased by 4% and that from CPIII increased by 8%. Thus, the ratio of abundance from CPII to CPIII increased by about 2% when the data were stratified by North and South. SC/57/IA16 analyses the completed CPIII surveys using North and South stratification. While individual survey estimates changed by -24% to +34% compared to Branch and Butterworth (2001a), the CPIII:CPII ratios were 8% lower for closing mode and 9% lower for IO mode than in Branch and Butterworth (2001a) and 4% lower than in Branch (2003). These changes are also due to the addition of	Incorporate the following covariates into the analysis, if deemed necessary: school size, sightability (or Beaufort sea state), sighting cue, survey mode, or environmental indicators. The analytical methods will not assume *g*(0)=1. The performance of the analysis methods will be evaluated using simulated data that account for effects from above and incorporate a variety of heterogeneities. *Ensure that all abundance estimation methods use similar analysis options (SC/59/IA19).*

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		more surveys to the CPIII estimates.	
C. Factors that could cause a real decline in abundance			
C.1 Natural mortality Natural mortality may have increased due to increases in killer whale populations and/or killer whale prey preference.	Uncertain, likely small to medium	Estimates of natural mortality presented in SC/54/IA25 were 0.046 to 0.070 yr^{-1}; there are no estimates of changes over time as these would be confounded with recruitment trend estimates. Some reports of killer whales feeding on minke whales but no indication of trends, and the power of detecting a change based on observations is minimal. Abundance estimates of killer whales (predators) are higher in CPI, but similar in CPII and CPIII for comparable areas (Branch and Butterworth 2001b); differences between CPI and the other two sets may be caused by a change in the survey design. SC/55/IA11 applies a different extrapolation method to unsurveyed CPI areas but the killer whale estimates in CPI remained 3-4 times greater than those in CPII and CPIII. Springer et al. (2003) hypothesize that killer whales caused declines in North Pacific seals, sea lions and sea otters when they increased the proportion of these species in their diets after the substantial depletion of great whales by industrial whaling. SC/55/IA4 examined this hypothesis for the Antarctic and concluded that the decrease in minke whale estimates was far too great to be explained by increased killer whale predation, although there was great uncertainty in this analysis.	Analysing changes in age structure. Models estimating natural mortality (e.g. extending the analyses in SC/54/IA25). Refinement of killer whale abundance estimates, including stratification by Type A, B, and C (Pitman and Ensor 2003). Analysis of killer whale scars in JARPA data.
C.2 Mortality due to whaling Effect in the opposite direction since commercial whaling (which ended in 1987) caught many more minke whales than JARPA (1988 onwards).	Small (increases difference)	Branch and Butterworth (2001a) note that mortality from JARPA would need to be more than an order of magnitude higher to explain the observed decline. Catches have declined from CPII to CPIII so effect would be expected to be in the opposite direction.	None planned. Models could address this issue.
C.3 Incidental mortality from ship strikes, bycatch There may be increased mortality from ship strikes, and bycatch in CPIII.	Very small	No scars from ship contacts or net entanglement in JARPA samples. No ship strikes recorded during JARPA or IDCR/SOWER surveys. Very few minke deaths in passive shark nets off South Africa affect the Southern Hemisphere stock; the impact on the stock was considered minimal. Drift netting in the waters east of New Zealand in the 1980s has now ceased, so this minor source of mortality may be even lower in CPIII.	
C.4. Mortality due to pollution Increasing levels of marine pollution could cause greater mortality.	None to small	Air and sea water samples from IDCR-SOWER show relatively low pollution in Antarctic. Ingested plastic observations from JARPA cruises showed no evidence of an increase. Pollution residues (PCBs, DDT and mercury) are examined in Fujise (1997) and Fujise et al. (1997). Although there is an increasing trend in PCBs from 1984 to 1993, concentrations were much lower than in the Northern Hemisphere and are unlikely to result in increased mortality. Mercury concentration in younger animals decreased in the last decade (IWC, 1998, p388). Mercury concentrations increased in older individuals from 1980–82 to 1990, but decreased in younger individuals from the 1980s to the 1990s (Honda et al. 2006).	JARPA collection of pollution data continuing.
C.5. Increasing mortality due to disease	Unknown, no evidence	Very rarely reported from JARPA samples.	
C.6. Decrease in recruitment rate[1]	Unknown, little information	SC/53/IA13 showed that the apparent pregnancy rate did not change. Neonatal survival is likely a function of the condition of the mother. Blubber thickness data from JARPA showed that body fat is correlated to sea ice: when the ice extent was great, body condition was poor because krill was less available. Reported briefly in IWC (1998 p387), check in paper Ichii et al. (1997). Trends in blubber thickness are reported in Ohsumi et al. (1997) and Konishi et al. (2005).	Update and reanalyse the JARPA samples to develop a condition factor series by area and year.

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		Leaper et al. (2006) found a correlation between global climate processes and southern right whale calf production. They noted that the observed correlation between environment and failure late in pregnancy or early in lactation would not have been apparent based on observations of pregnancy rates.	
C.7. Phenomenon of overshooting	Medium	This could occur because minke whales may be capable of relatively rapid increase and may be expected to overshoot the carrying capacity levels and subsequently decline. Given indications in SC/54/IA25 that minke whales had been increasing towards the carrying capacity, some more recent decline might be expected.	Age structure, newborn to mature ratios, and modelling efforts could address the extent of implied density-dependence in the recruitment rate and include age-structure of the krill resources.
C.8. Decreases in carrying capacity due to lower krill populations (also related to natural mortality)	Unknown, possibly large either direction	The annual harvest by the krill fishery is very small compared to the estimated productivity of the krill population (e.g. SC-CCAMLR 2000). Brierley et al. (1999) provide estimates around South Georgia from 1981 to 1998; there is no consistent trend in these surveys, which in any case did not cover consistent areas. Brierley et al. (2002) show that the ice-edge length which is favoured by krill has decreased by perhaps 9% since the 1960s. Siegel et al. (2002) report krill estimates from the Elephant Island region from 1977 to 2000 but confidence intervals are broad and it is difficult to find any systematic trend in the data. Atkinson et al. (2004) report that >50% of Southern Ocean krill stocks are in the SW Atlantic Ocean where krill density has declined after 1976 with major declines after 1988. Declines in krill availability per capita are suggested by a decrease in blubber thickness in Areas IV and V since the 1980s (Ohsumi et al. 1997) and decreasing weights of stomach contents of mature minke whales since 1987 (Tamura and Konishi 2005). Honda et al. (2006) suggested that the food intake from young whales for the 1997-99 season group was 50% lower than for the 1980-82 group, based on indirect evidence from changes in hepatic mercury concentrations.	Review krill abundance estimates to decide whether there has been a change.
C.9. Decrease in carrying capacity due to increase in competition from other predators (e.g. baleen whales, seals) Some baleen whales may have increased in numbers since commercial whaling stopped. Increases might reduce the krill available to minke whales.	Unknown, possibly medium	Abundance of Southern Hemisphere humpback whales has increased at near maximal possible rates in a number of areas (e.g., SC/56/SH12, SC/57/SH12, SC/56/SH11), and there is also evidence that blue whales (Branch et al. 2004) and fin whales (SC/56/SH11) have increased. Antarctic fur seals increased at around 10% per annum over the 20th century (e.g. summarised in Hofmeyer et al. 1997). Mori and Butterworth (2004) model blue whales, minke whales and krill, showing that minke whale populations likely increased in the mid 20th century in response to increases in krill populations after the depletion of large whale stocks, followed by a recent decrease as the larger whales started to recover. *Mori and Butterworth (2006), extending Mori and Butterworth (2004) to include four baleen whale and two seal species, found that species interaction effects can (though with some difficulty) explain changes in minke abundance, and that crabeater seals may play an important role in these interactions.* SC/57/IA9 applies a statistical catch at age model to data in Areas IV and V allowing changes in carrying capacity over time, and found carrying capacity increased tenfold from 1930 to 1960 and then declined to between 2.5 and 5.2 times the 1930 level in 1980, although some scenarios suggested a different pattern in the historical trends. Abundance followed similar trends but the magnitude of changes was lower. *Similar trends are found in SC/58/IA2 for Areas IIIE, IV, V and VIW, with a tenfold increase to 1960 followed by a 70% decline after 1960.* SC/57/IA17 applies a VPA model to data from Areas IV and V and showed that minke abundance trends increased over the middle	Further investigations of multispecies models could address this issue. Investigate the sensitivity of the VPA models to different stock hypotheses.

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		decades of the 20th century, peaked in about 1970 and then declined for the next three decades. *Similar trends are found in SC/58/IA8.* SC/57/IA19 fit a population model to VPA-based minke whale recruitment estimates in Areas IV and V. The results suggest that carrying capacity increased four-fold between 1930 and the mid-1950s before declining 60% to the present. Recruitment estimates have been below the replacement line since the 1970s. SC/57/O21 modelled baleen whales, seals and krill and showed that species interaction effects alone can explain observed predator abundance trends, but not without difficulty. The model suggests that a krill surplus existed after other baleen whales were removed from the system, and that this resulted in an increase in abundance of minke whales to a maximum in the 1970s followed by a decline to the present. *SC/58/IA3 applied a growth model to commercial and JARPA data and found that the growth rate of younger minke whales declined rapidly just prior to the start of JARPA and then continued to decline slowly thereafter; however, the authors suggest that these results could also be artefacts of the model or due to ageing errors.* *SC/58/IA22 presented evidence showing that decreases in estimated size-at-age over time were due both to strong commercial selectivity for large animals compared to JARPA, and to bias in age readability in the commercial samples.*	
C.10. Climate oscillation and global warming	Unknown, positive or negative	Effects on sea-ice are complex. Changes could be directional or cyclic (see references in A.2). Episodic ice-induced mortality by closure of leads trapping animals (Mitchell, 1974). A directional climate effect seems unlikely since other species (humpback and right whales in some areas) are increasing at near to their maximal rates. Population dynamics of krill dependent predators (Antarctic fur seal, gentoo penguin, southern right whale have been related to global climate processes (Leaper et al., 2006; Trathan et al., 2006).	SC/57/IA20 suggests environmental variables that could be related to minke population dynamics.

[1] Recruitment rate is the product of the pregnancy rate and juvenile survival rate.