Estimates of abundance and abundance trend of the Antarctic minke whale in Areas IIIE-VIW, south of 60ºS, based on JARPA and JARPAII sighting data (1989/90-2008/09)

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ABSTRACT
The Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) and its second phase (JARPA II) conducted sighting surveys during the 1989/90 to 2008/09 austral summer seasons (mainly in January and February), alternating between western and eastern sectors of the research areas, both south of 60°S in each year. These data are analyzed to obtain abundance estimates for Antarctic minke whales (*Balaenoptera bonaerensis*) in Areas IIIE-VIW. The estimates are calculated by standard line transect analysis methods using the program DISTANCE under the assumption that g(0)=1. Annual rates of increase in abundance are estimated using log-linear models. The analyses take several recommendations from the 2006 JARPA Review Meeting into consideration. Log-linear models are used to adjust for different strata being surveyed at different times of year over the duration of JARPA and JARPAII, with model selection being based on AICc. Abundance estimates for each Area during the JARPA and JARPAII period were as follow:

	Average	Minimum		Maximum	
Area	Estimate	Estimate	CV	Estimate	CV
IIIE	18,569	5,566	0.367	44,801	0.582
IV	32,474	14,739	0.570	62,979	0.334
V	114,550	69,771	0.228	170,621	0.129
VIW	15,603	7,530	0.226	26,364	0.218

The estimates that took into account the model error were as follow:

	Average	Minimum		Maximum	
Area	Estimate	Estimate	CV	Estimate	CV
IIIE	18,759	4,478	0.911	48,540	0.711
IV	32,714	15,088	0.645	63,794	0.509
V	101,106	67,661	0.308	151,072	0.326
VIW	15,486	8,434	0.601	27,790	0.507

For the estimates that took the model error into consideration the annual rates of increase in abundance were 1.1% with a 95% CI of [-2.3%, 4.5%] for Area IIIE+IV and 0.6% with a 95% CI of [-2.2%, 3.3%] for Area V+VIW. Estimates of these trends were robust to the effects of changes in survey timing, the shapes of the shoulders of detection functions, portions of survey tracklines following the ice edge, parts of the Areas in which no survey took place and poor coverage within some strata. Adjustments to allow for the g(0) being less than 1 were made by the application of a regression model, developed from the results of the Okamura-Kitakado (OK) method estimate of Antarctic minke whale abundance from the IDCR-SOWER surveys, which provided estimates of g(0) from the statistics of the Antarctic minke whale school size distribution in a stratum. With this adjustment, abundance estimates increased by an average of 23,984 (88%) for Area IV and 105,906 (109%) for Area V, while the estimates of annual rates of increase and their 95% CIs changed to 2.5% [-1.3%, 6.3%] for Areas IIIE+IV and -0.6 % [-3.9%, 2.6%] for Areas V+VIW.

KEYWORDS: ANTARCTIC; ANTARCTIC MINKE WHALE; SIGHTING SURVEY; SURVEY-VESSEL; ABUNDANCE ESTIMATE; TREND

INTRODUCTION

Based on sighting data collected during the International Whaling Commission Scientific Committee (IWC SC)'s International Decade of Cetacean Research (IDCR) (Matsuoka *et al*., 2003) from 1982/83 to 1988/89 (the second circumpolar set of surveys – CPII), the circumpolar abundance of Antarctic minke whales south of 60ºS was estimated at 761,000 (IWC, 1991) under the assumption that all schools on the trackline are seen ($g(0)=1$). Subsequently, the methodology used in 1990 has been refined in a number of ways, in particular to make use of models which allow for the possibility that $g(0)<1$ (Okamura and Kitakado, 2012; Bravington and Hedley, 2012). Using results from these approaches, the so-called OK and SPLINTR approaches, the IWC SC subsequently agreed that 720,000 for CPII (1985/86-1990/91) and 515,000 for CPIII (1991/92-2003/04) represent the best available abundance estimates of the Antarctic minke whales in the areas surveyed during the IDCR and Southern Ocean Whale and Ecosystem Research (SOWER) programmes (IWC, 2013).

The main objective of this paper is to produce revised estimates of abundance and trends of Antarctic minke whales based on the JARPA and JARPAII sighting data which take into consideration the recommendations from the JARPA review meeting (JRM) conducted by the IWC SC in 2006 (see IWC 2008a pp349). Approaches in Hakamada *et al* (in press) are applied for the estimates.

MATERIALS AND METHODS

Details for the survey procedure during JARPA were explained in Hakamada *et al* (in press).

Sighting survey procedure during JARPAII

Survey area and geographical stratification

The main sectors for the full scale research that are surveyed in alternate years were Areas IIIE, IV and V (35°E - 175°E) and Area V and VIW (130°E - 145°W), south of 60°S; each of these Areas was divided into smaller strata (Figure 1). Specifications of the stratification are given in Figure 1. Distributions of the primary sightings of minke whales and of efforts in Areas IIIE, IV, V and VIW for each year are shown in Figure 2a-2d.

Monthly coverage and order of the surveys

The JARPAII research period ranged from the end of December to March in each year, regular research in Areas IV and V was concentrated in January and February in most years, which coincides with the peak period for migration of minke whales to their Antarctic feeding grounds (Kasamatsu *et al*., 1996). The order in which the strata were surveyed within the research period (December-March) each year is shown in Figure 3 for both Areas. Start and end dates in JARPAII surveys are shown in Figure 4. The end date was earlier than usual in 2006/07 due to a fire accident on the research base *Nisshin-Maru* (Nishiwaki *et al*., 2007). Abundance estimates are based on single coverage of the blocks shown in Figure 1 in the year concerned.

Trackline design

The trackline was designed to cover the whole research area and was followed consistently throughout the JARPA and JARPAII surveys (Figure 2a-2d). The starting points of the trackline were selected at random from 1 n.mile intervals on lines of longitude. Trackline way points (where the trackline changes direction) were systematically allocated on the ice edge and on the locus of points 45 n.miles from that edge in southern strata, and on this locus and the 60°S latitude line in the northern strata. There were two modifications in trackline design in JARPAII surveys considering the recommendations at the JRM to improve abundance estimation. One is that the saw-tooth type trackline for the southern strata was chosen to allow for wide area coverage in JARPA but was not chosen in JARPAII. Another is that northern and southern strata were surveyed in the same period (Nishiwaki *et al*., 2014) to avoid that temporal gaps occurring in the survey period of southern and northern strata during JARPAII period.

Sampling and Sighting Vessels (SSVs) and Sighting Vessels (SVs)

JARPAII comprised a combination of sighting and sampling surveys. SSVs and SVs were surveyed independently. Researchers search for schools until a school is detected, and then proceed to confirm its species and school size. The procedure they use is identical to that of a SV in closing mode (Nishiwaki *et al*., 2006), except that once this confirmation has been achieved SSVs attempt to catch minke whales targeted within the school in terms of specified procedures (Nishiwaki *et al*., 2006). During the JARPAII period, SSVs covered south of 62°S whereas SVs covered south of 60°S. Therefore sighting data obtained by SSVs were not used for abundance estimation.

Closing and passing mode

Fundamentally, the survey protocols of JARPAII follow those of IDCR (Nishiwaki *et al*., 2014). A SV surveyed in passing mode (SVP) for the first 8 hours of the day and in closing mode (SVC) during the rest of the day. Therefore, the allocation of effort between passing mode and closing mode was systematic. By comparing abundance estimates for SSV and SVC modes to SVP (which in principle gives less biased results because it avoids the "end effects" introduced by closure), the effect of survey mode on the abundance estimates can be examined.

Unsurveyed area
Some small parts of Area IV were not surveyed on four of the cruises in the JARPA period. These geographical "gaps" arose because of the southward retreat of the ice edge after the survey of the more northerly of the two strata concerned had been completed, necessitating re-location of the trackline for the more southerly stratum. For more details on the "gaps", see Hakamada *et al*. (in press). Because northern and southern strata were surveyed in the same period (Nishiwaki *et al*., 2014), such "gaps" did not occur during the JARPAII period.

Due to violent action by an anti-whaling non governmental organisation in the research area, the SVs and SSVs could not carry out the research in the planned track line in Area III East (35°E - 70°E), a part of Area IV (90°E - 130°E) and a part of Area V West (130°E - 132°E) in 2009/10 (Nishiwaki *et al*., 2010). Due to violent action by an anti-whaling non governmental organisation in the research area, a sighting survey by SV was not conducted in 2010/11 (IWC, 2012). Therefore, abundance in these years could not be estimated.

Tracklines following contours of the ice edge
At the IWC SC meeting in 2006, there was a discussion as to whether some lengthy intermediate transects which run nearly parallel to the ice edge might introduce bias, particularly for design-based abundance estimation approaches. For more details on this was provided in Hakamada *et al*. (in press). Having some segments of the tracklines not parallel to lines of longitude could lead to an overestimate of abundance because some of these segments run virtually along the ice edge in strata where saw-tooth shape tracklines designs were used. As mentioned above, saw-tooth type tracklines were not adopted in any strata in the JARPA II period so that such tracklines rarely occurred.

Pre-determined daily distance coverage
A pre-determined distance for daily movement along the research track line was calculated so as to cover the survey area within the schedule for JARPA from the 1989/90 to the 1992/93 seasons. Explanation of the pre-determined distance was provided in Hakamada *et al*. (in press). Pre-determined daily distance was not set during JARPA II period.

Analytical procedure
Before explaining the analytical procedures applied in this paper, it is useful to list the six fundamental steps which these involve. The procedure is same as that in Hakamada *et al*. (in press) except that the step 2) below was added in order to interpolate the abundance estimate to unsurveyed areas in the JARPA II period.

1) Estimate the abundance in stratum for each survey mode using the "standard methodology" of Branch and Butterworth (2001) for IDCR-SOWER line transect data.
2) Abundance estimated using approach using a log-linear model (Kitakado *et al*., 2012) for strata which survey coverage was incomplete.
3) Conduct sensitivity tests to investigate whether different treatment of the sighting data might affect the abundance estimates obtained in step 1) substantially.
4). Apply a model selection criterion to choose amongst different log-linear models to examine the effects of survey mode and survey timing, and to estimate abundance trends.
5) Examine the sensitivity of estimates of abundance trends by analyzing the abundances estimated in step 3.
6). Estimate corrected abundances using the correction factors for the survey mode effect estimated in step 4).

Note that abundances were estimated by survey mode because it has been suggested that these may differ depending on the survey mode (Haw, 1991).

Smearing
The data recorded for radial distance and angle are smeared using the method II of Buckland and Anganuzzi (1988). The smearing parameter values used in this study are shown in Table 1. After the smearing, the perpendicular distances are truncated at 1.5 n.miles. This treatment is the same as the one employed in abundance estimation from the IWC IDCR-SOWER data (Branch and Butterworth, 2001; Branch, 2006). The number of sightings remaining after smearing and truncation includes sightings with both confirmed and unconfirmed school sizes.

Correction of observed angle and distance
To be able to correct for biases in distance and angle estimation, a distance and angle estimation experiment was conducted on each vessel each year (Nishiwaki *et al*., 2006). The correction factors estimated for observed angles and distances for each vessel are listed in Table 1 of Hakamada and Matsuoka (2014) have been used for these analyses. More details of the methodology for estimation of these correction factors may be found in Branch and Butterworth (2001).

Abundance estimation
The methodology for abundance estimation used in this study is described by Branch and Butterworth (2001) and Branch (2006), and has been termed the "standard methodology" in the IWC SC. The program DISTANCE ver 6.0 (Thomas *et al*., 2010) was used to provide abundance estimates corresponding to each track line[1]. The following equation was used for abundance estimation in each stratum:

$$P_i = \frac{AE(s)n_i}{2wL_i}, \qquad (1)$$

where
P_i is the abundance in numbers as estimated from the i th trackline,
A is the open ocean area of the stratum,
$E(s)$ is the estimated mean school size,
n_i is the numbers of primary sightings of schools on the i th trackline,
w is the effective search half-width for schools and
L_i is the primary search effort on the i th trackline.

For SSVs, the total abundance in each stratum is calculated as:

$$P = \frac{\sum_i L_i P_i}{L} \quad . \qquad (2).$$

where L is sum of the L_i for each of the SSVs in the stratum.
The CV of the total abundance estimate P, is then calculated for each stratum using the equation:

$$\mathrm{CV}(P) = \sqrt{\left\{\mathrm{CV}\left(\frac{n}{L}\right)\right\}^2 + \{\mathrm{CV}(E(s))\}^2 + \{\mathrm{CV}(w)\}^2}, \qquad (3)$$

where n is the sum of n_i for all the SSVs. Estimation of the CV of n/L is as specified in equation (5) below.

Detection function
A hazard rate model with no adjustment terms was used for the detection function:

$$f(y) = 1 - \exp\left\{-\left(\frac{y}{a}\right)^{-b}\right\} \qquad (4)$$

where y is perpendicular distance, and a>0 and b≥1 are parameters of the model to be estimated. It is assumed here that $g(0)$=1 (i.e. the detection probability of a school on the track line is 1). Detections with

[1] The reason why "track line" was used rather than "vessel" here is because the location of each SSV among the two or three parallel tracklines was changed each day (see Appendix 2 of Hakamada *et al*, (in press)).

perpendicular distances of more than 1.5 n.mile were truncated when estimating effective search half-width (ESW) *w*. More details of this detection function are given in Buckland *et al.* (1993; 2001).

Stratification of data to estimate ESHW (effective search half width)
In line with the IWC (2008a) recommendation AE9, ESHWs were estimated by stratum. In cases where the sample size was smaller than 15, the sighting data were pooled among strata to estimate the detection function in line with the the IWC (2008a) *recomm.* AE5. In such cases, data were pooled across West-East strata because sighting conditions and school size distributions are expected to be more similar than for North-South strata. In instances where there were less than 15 detections in southern/northern strata, data were aggregated over the whole of each Area.

Estimated mean school size
Again in line with the IWC (2008a) recommendation AE9, mean school sizes were estimated by stratum. Only the primary sightings for which the school size was confirmed were used for the estimation. The method for estimation of the mean school size described in Buckland *et al.* (1993; 2001) was used. More specifically, regressions of the log of observed school size against *f*(*y*) was conducted for this purpose. If the regression coefficient was not significant at the 15% level, the observed mean school size for sightings within a distance of 1.5 n.miles was substituted instead in the equation (1). If the consequent mean school size estimated was less than 1, then the observed mean school size was substituted instead in the equation (1) even if the regression coefficient was statistically significant at this 15% level. Similarly to the analyses for the IDCR-SOWER data (Branch and Butterworth, 2001; Branch 2006), for SVP the mean school size estimated from SVC data was used instead of estimating this from SVP data, for which school size estimates are known to be negatively biased as a result of not approaching all schools closely (Butterworth and McQuaid, 1986).

Combined encounter rate taking account of correlation among two or three SSV track lines (IWCb, 2008a recommendation AE6)
The survey by the SSVs comprised two or three parallel tracklines. There may be a positive correlation in the encounter rates along these lines, which would cause a negative bias in the estimate of the CV of the overall encounter rate if the results from each vessel were assumed to be independent. To take this possible covariance into account, the CV of the encounter rate when combined over the two or three SSVs with their parallel tracklines was estimated as:

$$\mathrm{CV}\left(\frac{n_i}{L_i}\right) = \frac{\sqrt{\left\{\mathrm{var}\left(\frac{n_i}{L_i}\right)\right\}}}{\frac{n_i}{L_i}} \tag{5}$$

where $$n_i = \sum_j n_{i,j} \quad L_i = \sum_j L_{i,j}$$

with $n_{i,j}$ and $L_{i,j}$ being the number of primary sightings of minke whale schools and the primary effort on the *i* th transect as surveyed on the *j* th tracklines,. The variance of (*n*/*L*) is calculated as:

$$Var\left(\frac{n}{L}\right) = \sum_{i=1}^{k} \frac{1}{(k-1)} \left(\frac{L_i}{L}\right)^2 \left(\frac{n_i}{L_i} - \frac{n}{L}\right)^2 \tag{6}$$

where *k* is the number of transects on each trackline.

Log-linear models to estimate abundance trend considering the effect of survey times
In order to examine the effect of survey timing, the four models shown below were considered.

Model i): $\log(P_{obs}(y,a)) = \log(P_{true}(0,a)) + \alpha y + \varepsilon_{y,a} + \eta_{y,a}$, (7)

Model ii): $\log(P_{obs}(y,a)) = \log(P_{true}(0,a)) + \alpha y + M + \varepsilon_{y,a} + \eta_{y,a}$, (8)

Model iii): $\log(P_{obs}(y,a)) = \log(P_{true}(0,a)) + \alpha y + M + T + \varepsilon_{y,a} + \eta_{y,a}$, (9)

Model iv): $\log(P_{obs}(y,a)) = \log(P_{true}(0,a)) + \alpha y + M + T + a * T + \varepsilon_{y,a} + \eta_{y,a}$, (10)

where
y is the year,
a is the stratum,
$P_{obs}(y,a)$ is the observed abundance estimate in stratum a and in year y as obtained from the line transect analyses,
$P_{true}(y,a)$is the underlying abundance (i.e. free from the effect of survey mode) which is to be estimated in year y and in stratum a,
M is the survey mode factor,
T is the categorical variable related to survey time as defined below,
$a*T$ is an interaction between strata and survey timing,
$\varepsilon_{y,a}$ is an error reflecting the sampling error of the survey abundance estimate in year y and stratum a and
$\eta_{y,a}$ is a normally distributed error with mean of 0 and variance of σ^2 associated with "model error".

To assess sensitivity, models that replace abundance estimates with density estimates were also evaluated to estimate abundance trends.

The middle day of the survey period in each stratum was calculated and categorized into groups as a basis to specify T. Because the estimate of trend α might be sensitive to the definition of T, four grouping were considered:
1) T=1: Dec 1-Jan 15, ***T*=2: Jan 16-31**, T=3: Feb 1-15, T=4 Feb 16-Mar15 (Grouping $T1$)
2) T= 1: Dec 1-Jan 15, ***T*=2: Jan 16-Feb 15** and T=3: Feb 16-Mar 15 (Grouping $T2$)
3) T= 1: Dec, ***T*=2: Jan**, T=3: Feb and T=4: Mar (Grouping $T3$)
4) ***T*= 1: Dec and Jan** and T=2: Feb and Mar (Grouping $T4$)
The groups in bold letters were included in the intercept of the alternative models considered (i.e. the effect of those groups is set to zero in the calculations). $T1$ – $T4$ were used as categorical covariates in Models iii) and iv) (equations (9) and (10)) above. The best grouping was selected by comparing the Akaike Information Criterion (AIC) (Akaike, 1973) for each model.

Log likelihoods for these models are provided by,

$$LL(\theta,\sigma^2) = \left(-\frac{n}{2}\right)\log(2\pi) - \frac{\log\{\det(V+\sigma^2 I)\}}{2} - \frac{{}^t(x-\hat{x})(V+\sigma^2 I)^{-1}(x-\hat{x})}{2} \quad (11)$$

where
θ is the vector of parameters to be estimated,
n is the number of data available to fit the model,
V is the variance-covariance matrix of the abundance estimates,
I is the identity matrix,
X is a vector of log of the observed abundance (density) estimates,
$\hat{x}$ is a vector of log of predicted abundance (density) by one of the models i) to iv) (equations (7)-(10)) above and
t indicates transpose of the vector

The variance-covariance matrices for the estimated parameters $V(\theta)$ were derived from the Information matrix. It should be noted that "additional variance" as estimated by maximum likelihood (ML) using equation (11) is negatively biased

In cases where sample size is small or the number of parameters is large compared to the sample size, it is known that AIC over- estimates the appropriate number of parameters to be estimated (i.e. AIC has tendency to select a model that is too complex). Because there may be many such parameters when compared to samples size for Model iv), an adjusted value, corrected AIC (AIC_c) (Sugiura, 1978; Hurvich and Tsai, 1989; 1991), which can be applied to linear models with normal errors, is used instead of AIC. As AIC_c and AIC are asymptotically equivalent, AIC_c can also be applied in cases of large sample size. AIC_c is defined by:

$$AIC_C = 2\log(LL(\hat{\theta},\hat{\sigma})) + 2(p+1) = AIC + \frac{2(p+1)(p+2)}{n-p-2} \quad (12)$$

where $(\hat{\theta},\hat{\sigma})$ are the parameter values that maximize the log-likelihood, p is the number of parameters estimated in the model concerned. On implementation of models (7) – (10), nominal abundance estimates in Areas IIIE and IV together and those in Area V and VIW together.

Correction of nominal abundance estimates and their variance-covariance matrices

When model i) was selected under AIC_c, the observed abundance estimates from the line transect analyses can be utilised as they stand to calculate estimates averaged over survey modes in the manner described below. Their variance-covariance matrices were derived from a bootstrap approach using equation (13) below. When one of the models ii) to iv) was selected however, the nominal abundances from the line transect analyses first needed to be adjusted using factors estimated from the model selected. If models that include the survey time covariate were selected, the nominal abundance estimates were adjusted to correspond to January. This provides total abundance estimates for Areas IIIE, IV, V and VIW for each survey mode. To estimate variance and covariance for these adjusted abundances, resampling techniques were used rather than to attempt to estimate them analytically, because the correlation between adjustment factors and the nominal abundance estimates made the latter approach difficult. A total of 1000 resamples of abundance were generated for each stratum using a parametric bootstrap approach, and parameters estimated for the selected model to in turn estimate the variance-covariance matrix, as follows:

$$x_{pseudo} \sim N\left(\bar{x}, V + \sigma^2 I\right) \quad (13)$$

$$(\theta,\sigma)_{psudo} \sim N((\bar{\theta},\bar{\sigma},\Sigma_{(\theta,\sigma)}) \quad (14)$$

where $\Sigma_{(\theta,\sigma)}$ is variance-covariance matrix of the estimated parameters of models i) to iv).

Weighted average of abundance over survey modes

Weighted averages of abundance estimates over survey modes were calculated, where the weights were chosen to minimize the associated variances. Thus the weighted average P_{wa} and its variance $V(P_{wa})$ were obtained from:

$$P_{WA} = wP_{SSV} + (1-w)P_{SVC} \quad (15)$$

$$V(P_{WA}) = w^2 V(P_{SSV}) + 2w(1-w)Cov(P_{SSV},P_{SVC}) + (1-w)^2 V(P_{SVC}) \quad (16)$$

where

w=0 if $V(P_{SVC}) \le Cov(P_{SSV},P_{SVC})$

w=1 if $V(P_{SSV}) \le Cov(P_{SSV},P_{SVC})$

$w = \dfrac{V(P_{SVC}) - Cov(P_{SSV},P_{SVC})}{V(P_{SSV}) - 2Cov(P_{SSV},P_{SVC}) + V(P_{SVC})}$ otherwise

for 1992/93-1996/97 and

$$P_{WA} = \frac{aP_{SSV} + bP_{SVC} + cP_{SVP}}{a+b+c} \quad (17)$$

$$V(P_{WA}) = \frac{a^2V(P_{SSV}) + b^2V(P_{SVC}) + c^2V(P_{SVP}) + 2\{abCov(P_{SSV},P_{SVC}) + bcCov(P_{SVC},P_{SVP}) + caCov(P_{SSV},P_{SVP})\}}{(a+b+c)^2} \quad (18)$$

where

$$a = \{V(P_{SVC}) - Cov(P_{SSV},P_{SVC})\}\{V(P_{SVP}) - Cov(P_{SSV},P_{SVP})\}$$
$$-\{Cov(P_{SVC},P_{SVP}) - Cov(P_{SSV},P_{SVC})\}\{Cov(P_{SVC},P_{SVP}) - Cov(P_{SSV},P_{SVP})\}$$
$$b = \{V(P_{SSV}) - Cov(P_{SSV},P_{SVC})\}\{V(P_{SVP}) - Cov(P_{SVC},P_{SVP})\}$$
$$-\{Cov(P_{SSV},P_{SVP}) - Cov(P_{SSV},P_{SVC})\}\{Cov(P_{SSV},P_{SVP}) - Cov(P_{SVC},P_{SVP})\}$$

$$c = \{V(P_{SSV}) - Cov(P_{SSV}, P_{SVP})\}\{V(P_{SVC}) - Cov(P_{SVC}, P_{SVP})\}$$
$$- \{Cov(P_{SSV}, P_{SVC}) - Cov(P_{SVC}, P_{SVP})\}\{Cov(P_{SSV}, P_{SVC}) - Cov(P_{SSV}, P_{SVP})\}$$

for 1997/98 – 2004/05. If any of *a*, *b* and *c* was negative, that value would be substituted by 0.

For 2005/06-2008/09, equations (15) and (16) replacing P_{ssv} by P_{svp} were applied to estimate P_{WA} and its variance because there were no abundance estimates for SSV during the period.

Sensitivity tests for abundance and trend estimates

There are various possible sources of bias in abundance estimates and their trends, the more important of which were discussed at JRM and at the IWCb SC meeting in 2007 (Table 2) (see IWC 2008a pp349). In order to examine their possible magnitudes, sensitivity analyses were conducted.

The effect of a' shoulder' in the detection functions

For SSVs, the detection function has a clear shoulder in most cases Hakamada *et al*. (in press). For cases where *b* in equation (4) is estimated to be 1, however, the detection function would hardly show a shoulder. Estimates of ESHW in those strata were replaced by the average of ESHW for same strata in other years as in this test, which assumed that the CV of the estimated ESHW was same as before the replacement.

For SVs, though some of the detection functions show a good fit to the data, others do not have a clear shoulder, perhaps related to smaller samples sizes than are typical for the SSVs. In order to examine the detection functions for the SVs further, the MCDS (Multiple Covariates Distance Sampling) module in DISTANCE was used (Thomas *et al*., 2010). MCDS can incorporate covariates other than perpendicular distance to estimate the scale parameters of detection functions. The data were stratified into Northern strata, Southern strata, Prydz Bay, Area IIIE and Area VIW separately, because the ESHW estimate is expected to differ in relation to distance northwards. AIC_c values were compared to select covariates to include in the detection function model below. The hazard rate function was utilized, with the full model described by:

$$f(y) = 1 - \exp\left\{ -\left(\frac{y}{a \exp(EW + year)} \right)^{-b} \right\} \qquad (19)$$

where *y* is perpendicular distance, a>0 and b≥1 are estimable parameters, and *EW* and *year* are categorical covariates for whether the stratum is to the East or the West, and for the year when the survey was conducted, respectively.

Treatment of segments of tracklines following contours of the ice edge (IWC, 2008a recommendation AE 12)

To examine the effect of alternative treatments, analyses were conducted for the SE and SW strata in Area IV and the SW stratum in Area V where saw-tooth tracklines designs were used during JARPA period. Abundances were estimated excluding trackline segments that were essentially along the ice edge (Option B), and also for exclusion of tracklines not parallel to lines of longitude (Option C). The results are compared to the base case for which the complete tracklines are used. Saw-tooth tracklines were not used during JARPA II period, and therefore nominal abundance estimates to apply models (7)-(10) were same as those used for the base case.

Unsurveyed areas (IWC, 2008a recommendation AE 10)

For the cases such "gaps" occurred during JARPA period, two approaches were pursued to attempt to bound the uncertainty associated with the treatment of "gaps" in coverage as defined above for the base case estimates. On the conservative side, the abundance contributions from these gaps were set to zero (i.e. whales in such gaps at the time of surveying the more southerly strata were considered to be ones already effectively counted in the earlier survey of the more northerly strata, as these whales would subsequently likely have moved further south). On the liberal side, the density in a gap was assumed to be the same as the higher density in the stratum immediately to the south, rather than that immediately to the north as in the base case. No "gaps" occurred during the JARPA II period, and therefore nominal abundance estimates to apply models (7)-(10) were same those used for the base case.

Incomplete coverage (IWC, 2008a recommendation AE 11)
For the base case estimates of abundance, the interpolated density for the (virtually) unsurveyed portion of a stratum was taken to be the same as that in the surveyed portion. To check sensitivity to an alternative to this assumption, the average of the ratio of the densities in these two portions of the stratum on surveys in other years was evaluated, and this was used instead to extrapolate the density in the surveyed portion to that for the (virtually) unsurveyed portion for the year in question. The development of such averages did not include data from every other cruise, as consideration was also given to similarities of ice-edge configurations amongst the cruises. For JARPA surveys, the strata for which such alternative computations were conducted in Hakamada *et al.* (in press). Table 3 listed strata which considered incomplete coverage occurred during 2005/06 – 2008/09 JARPA II surveys. For these areas, generalized linear model (GLM) were applied to extrapolate abundance estimate as follows;

$$\mathrm{Log}(P_{obs}(y,i)) = \mathrm{Log}(P_{true}(y,i)) + M + \tau_i + \varepsilon_{i,y} \qquad (20)$$

where
y is the year,
i is the survey block,
$P_{obs}(y,i)$ is the observed abundance estimate in survey block i and in year y as obtained from the line transect analyses,
$P_{true}(y,i)$is the underlying abundance (i.e. free from the effect of survey mode) which is to be estimated in year y and in block i,
M is the survey mode factor,
$\varepsilon_{i,y}$ is an error reflecting the sampling error of the survey abundance estimate in year y and survey block i and
τ_i is a normally distributed error with mean of 0 and variance of ρ^2 associated with additional variance.

Survey block are defined in Areas IIIE, VW and VW, respectively as follows;

Area IIIE (4 blocks): (a part of IIIEN stratum west of 55^{o}E), NW2 (a part of NW stratum east of 161^{o}E), SW1 (a part of SW stratum west of 159^{o}E) and SW2 (a part of SW stratum east of 159^{o}E)
Area IVW (3 blocks): NW, SW and PB (Same as strata shown in Figure 1).
Area VW (4 blocks): NW1 (a part of NW stratum west of 161^{o}E), NW2 (a part of NW stratum east of 161^{o}E), SW1 (a part of SW stratum west of 159^{o}E) and SW2 (a part of SW stratum east of 159^{o}E)

Table 4 shows which block were surveyed or unsurveyed in each year. Abundance estimates were interpolated abundance estimate for strata including unsurveyed blocks by applying equation (20).

The effect of "skipping" to cover the pre-determined daily distance
The approach of specifying a pre-determined distance for travel each day was discontinued after 1992/93. In order to eliminate any impact that possible consequent biases in the associated estimates of abundance might have had on the estimated abundance trend, estimates prior to the 1993/94 survey were omitted when implementing models i) to iv).

Sensitivity of abundance trend
Models i) to iv) were applied to abundance estimates obtained in the sensitivity tests above under the assumption that the variance-covariance matrix for the abundances was same as that for the base case. Again, the best model was selected using AIC_c.

Adjustment for g(0) less than 1
The Okamura and Kitakado (2012) and the Bravington and Hedley (2012) approaches (known respectively as the "OK" and "SPLINTR" methods) for estimating minke whale abundance from the IDCR-SOWER data resulted in estimates of g(0) which were less than 1 for minke whales, especially so for schools of size 1. Furthermore, since school sizes tended to be less for later surveys, it was important to take this into account when estimating the extent of possible changes in minke whale abundance over

time. Because neither the SSVs nor the SVs participating in the JARPA and JARPA II surveys had Independent Observer Platforms, whose observations are needed to identify the duplicate sightings upon which the OK and SPLINTR methods rely, they cannot be applied directly here.

Instead, noting that the key (albeit not exclusive) dependence of the g(0) estimates from these methods on school size, a regression approach conducted in Hakamada *et al*. (in press), was updated. This uses the estimates of g(0) provided by the OK approach for each survey block in their analyses to fit to a linear model whose covariates include the mean and standard deviation of the school size for each block, together with other factors readily available such as (Management) *Area* and whether the block concerned adjoined the ice-edge (*S*) or the northern boundary (*N*) of the survey (these co-variates are serving as proxies for the environmental conditions, such as Beaufort sea state, taken into account in the OK analyses). As the JARPA and JARPA II surveys did not include Independent Observers as in IO mode for the IDCR-SOWER surveys, for comparability the OK estimates from those latter surveys which are used here are for closing mode survey which does not have Independent Observers involved in searching for whales. The school size distribution statistics were based on primary sightings in closing mode whose school size had been confirmed; furthermore to curb undue influence of outlier values arising from the occasional very large school, means above 8 were treated as equal to 8, and similarly standard deviations above 4 were treated as equal to 4. Because the resulting equation was to be applied JARPA and JARPA II results for Areas III, IV, V and VI only OK estimates of g(0) for these four Areas (a total of 43 estimates) were used in the regression. A number of models were investigated, considering also interactions amongst the factor mentioned above and whether to treat the two Areas separately or jointly; these possibilities included introducing quadratic terms in mean school size and its standard derivation. On the basis of AIC_c, the following model was selected:

$$g(0)= a + b.E(s) +c.sd(s)+NS +Area+NS*Area \qquad (21)$$

where *a*, *b* and *c* are parameters estimated in the model fit, *sd(s)* is the standard deviation of the school size distribution for the block, and *NS, Area* and their interactions are categorical variables.

Figure 5 compares the values of g(0) predicted by this model to the OK estimates; given that school sizes tended to be smaller for the third circumpolar set of surveys (CPIII) than for the second, it is unsurprising that the CPIII points shown in this Figure tend to reflect higher values of g(0) than do the CPII points. Table 5 lists the estimates of the parameter values of equation (21); given that the relationship between g(0) and school size *s* must asymptote at g(0)=1 and therefore be non-linear with a negative second derivative, the negative value obtained for the *c* parameter is to be expected, as larger values of *sd(s)* reflect the influence of a greater proportion of singleton schools.

RESULTS

Abundance estimates

Table 6a-6j show abundance estimates by strata in Areas IIIE and VI during JARPA and JARPA II and in Areas IV and V during JARPA II for each survey mode estimated in this analysis. Detection functions to estimate ESHW for abundance estimation are shown in Figures 6a-6b. By pooling strata where the number of detections is less than 15, the shape of the detection functions seem improved, especially as regards displaying a shoulder. Table 7 shows interpolated abundance estimate by the equation (20) for strata which survey coverage was incomplete listed in Table 3. On implementation of models (7) – (10), abundance estimates in Table 6a-6j were replaced by those in Table 7 for such strata. Abundance estimates for Areas IV and V for SSV, SVC and SVP survey modes during the JARPA period to apply log-linear models (7) – (10) were referred from Hakamada *et al*. (in press).

Log-linear models and abundance trend estimates taking "model error" into account

Table 8 shows AIC_c and its difference from the selected model for each model, and the instantaneous annual rates of increase and "model error" estimates for Areas IIIE+IV and V+VIW together with their 95% confidence intervals. Model i) was selected for both Areas IIIE+IV and V+VIW. These rates of increase (ROI) are 1.1% with a 95% CI of [-2.3%, 4.5%] for Area IIIE+IV and 0.6% with a 95% CI of [-2.2%, 3.3%] for Area V+VIW (Table 8). The point estimates from the other models range from 1.1% to 4.4% for Area IIIE+IV and from -2.1% to 0.6% for Area V+VIW, so that all lie within the 95% CI for the abundance trend estimate for the model selected (Table 8). Previous analyses of these data (Haw, 1991; Branch and Butterworth 2001; Branch 2006; Hakamada *et al*. 2006) have suggested that a survey mode calibration factor should be taken into account in developing composite abundance estimates, but that option was not selected by AICc in this instance, possibly as a result of now allowing also for additional variance (model/process error) in the models of equations (7) to (10); including survey mode in the analysis would not change the point estimate of trend in abundance for Area IIIE+IV, though that for Area V+VIW would decrease by about 1% pa. Estimated coefficients for the log-linear model selected for each Area are shown in Table 9. The model errors (ML estimates of the additional variance parameter σ) and their associated standard errors are 0.755 (SE=0.069) for Area IIIE+IV and 0.575 (SE=0.059) for Area V+VIW. These estimates are negatively biased because they were obtained using a standard ML rather than a restricted maximum likelihood (REML) approach (Patterson and Thompson, 1971).

Abundance estimates averaged over survey modes
Because model i) was selected for Areas IIIE+IV and V+VIW for the base case, adjustment factors were not applied to abundance estimates in Tables 6a-6f.

Table 10 shows adjusted abundance estimates for each year and survey mode together with their CVs when taking model error estimates into account. The inverse variance weighted averages of abundance estimates over survey modes are shown in Table 11a. The CVs for these abundance estimates are all higher than those from a previous analysis (Hakamada *et al*., 2006) because model error is now taken into account.

Table 11b shows the inverse variance weighted averages of abundance estimates over survey modes without taking model errors into account[2].

Table 12 shows the correlation matrices for the logarithms of the abundance estimates given Areas IIIE, IV, VW, VE and VIW, respectively. Correlations amongst these estimates are low because no common correction factor was applied.

Adjustment for g(0) less than 1
The regression model of equation (21) was applied to school size information for the JARPA and JARPA II survey strata, treating these in exactly the same way as for the OK estimates when developing that regression equation. The resultant values are listed in Table 13. The abundance estimates in Tables 6a-6i were then divided by these $g(0)$ values to provide the $g(0)$-adjusted abundance estimates and their trends which are shown in Tables 14 and 15. However, to avoid extrapolation when applying equation (21), in the few cases where the regression estimate lay outside the range of the OK estimates of $g(0)$ used to fit the regression, those estimates were increased or decreased to equal to the lowest or highest value in the set of OK estimates. In computing variances estimates for the $g(0)$-adjusted abundance estimates and trends given in Tables 14 and 15, appropriate account was taken of the co-variances introduced by the use of the common regression relationship of equation (21), though for simplicity the variances and co-variances for the OK estimates of $g(0)$ were overlooked and these were treated as known without error in estimating the regression parameter values.

Abundance estimates and trends for the sensitivity tests
Table 14 compares abundance estimates and their trends for the sensitivity tests examined. Different from the results in previous analysis (Hakamada *et al*., in press), models which allows for the effects of survey mode and survey time together, was selected in all sensitivity test. For Areas IV, abundance estimates are not always robust (-10.5% - 24.0% in average) among the sensitivities besides the $g(0)$ adjusted scenario,

[2] It should be noted here that the abundance estimates in Table 11b were recommended for their use in other studies such as in the development of ecosystem models (Kitakado *et al*., 2014a); SCAA (Punt *et al*., 2013) and prey consumption estimation (Tamura and Konishi, 2014), because those estimates had lower CVs than some initial estimates that took into consideration the model error (the latter estimates had particularly high CVs -data not shown-). Improved recent analyses allowed that the CVs of the estimates that took into consideration model error became much smaller (see Table 11a). Because of a timing problem, the studies on ecosystem model development, SCAA and prey consumption were still using the estimates in Table 11b and could not be updated for the use of the estimates in Table 11a.

because survey mode and survey time effect in the selected model affect on the abundance estimate. model. For Area V, abundance estimates are not always robust (-7.7% - 18.8%) among the sensitivities besides the *g*(0) adjusted scenario, because of the survey mode and survey timing effect of the selected model. Table 15 shows estimated instantaneous annual rates of increase for Areas IIIE+IV and V+VIW using the model selected by AICc for all the sensitivities examined in this paper. Using density instead of abundance estimates for these calculations does not change the trend estimates substantially. These annual abundance rate of increase estimates range over [0.1%, 3.7%] for Area IIIE+IV and [-1.7%, 0.6%] for Area V+VIW for the various sensitivity tests.

When the abundance estimates are g(0)-adjusted, as would be expected the estimates increase by an average of 23,984 (88%) for Area IV and 105,906 (109%) for Area V (Table 14). The estimates of annual rates of increase and their 95% CIs change to 2.5% [-1.3%,6.3%] for Areas IIIE and IV and -0.6 % [-3.9%,2.6%] for Areas V and VIW (Table 15), reflecting 1.5% increase for the former and 1% decrease for the latter, and slightly less precision (a increase in standard error of about 0.02) than when g(0) is assumed to be 1 because of the further variance introduced in estimating the g(0) values.

DISCUSSION AND FUTURE WORK

This paper has provided new estimates of abundance and trends for the Antarctic minke whales in Areas IIIE, IV, V and VIW which take into account the recommendations made at the JRM. The CVs of the estimated abundances and trends were obtained with the incorporation of "model errors". Information on stock structure in Areas IIIE, IV, V and VIW has been provided based on both genetic and non-genetic data from JARPA (Pastene *et al*., 2006). The JRM agreed that this showed there were at least two stocks of Antarctic minke whales present in the JARPA/JARPA II research area, and that the data suggests an area of transition around 150 ºE -165ºE within which there is a yet undetermined level and range of mixing (IWC, 2008b). Recently, the longitudinal extent of the transition area and the annual changes in stock proportions in this region are being investigated using both genetic and non-genetic markers (Kitakado *et al*., 2014b). Because the distributions of these two stocks are not identical to the Management Areas, it will be desirable to estimate abundance trends at the stock level, taking account this recent information on the stock structure.

Clearly the estimates of abundance of this paper are subject to the same uncertainties as those from the IDCR-SOWER surveys with regard to Antarctic minke whales in the unsurveyed areas south of the ice edge. At the IWC SC meeting in 2012, it was recognized that reliable absolute abundance estimates of Antarctic minke whales in these ice regions (which are comparable in space and time for JARPA/JARPA II and IDCR-SOWER surveys) would be impossible to produce. Accordingly, the recommendation was made that relatively simple analyses be conducted to generate abundances using aerial survey data (IWC, 2013). Such abundance estimate using aerial survey data will be available in future. To the extent that it might prove possible to use these to adjust the IDCR-SOWER abundance estimates, such an adjustment process could also be applied to the abundance estimates based on JARPA and JARPAII.

Log-linear models

Because the extent of a same stratum varies from year to year as a result of different ice edge locations, it is not immediately obvious whether such modelling approaches should be based on the density or on the abundance in a stratum, and arguments can be offered to support either approach. Matsuoka *et al*. (2011) found little difference in results for the two approaches for humpback whales. This is also the case for the Antarctic minke whale abundances and their trends as indicated in Table 15. For the selected model, the estimates of abundance trends would not change substantially if abundance were replaced by density in the analyses.

Unlike the results of sensitivity analysis in Hakamada *et al*. (in press), models iii) or iv) were selected in all cases of sensitivity test in this study, which may suggest that the abundance estimates are affected by the survey mode and the survey timing effect. This may caused by an increased power to detect the effect due to further survey data used. This may suggest that the effect of survey timing on abundance exists. Even if the effect exists, abundance trend estimate varies within the 95% CI of abundance trend of the selected model for the base case for Areas IIIE+IV and V+VIW (Table 8).

Under estimation of additional variance

In principle, additional variance (the size of model error) should be estimated using REML rather than MLE to avoid negative bias, but this would lead to difficulties in model selection. This is a matter merits future investigation.

Abundance trend estimates from JARPA

Figure 7 compares the exponential trend estimated by model i) with the estimates of abundance by year for the base case model for each of Area IV and V. The exponential trend estimates are given in Table 8 and abundance estimates by year are given in Table 14.

For all the models and sensitivities examined, the point estimates of the abundance trend in Areas IIIE+IV and V+VIW fall within the 95% confidence intervals for the model selected, even though different log-linear model was selected in sensitivity test. This suggests the robustness of the abundance trend in both Areas IIIE+IV and V+VIW.

Adjustment for g(0) < 1 and comparison with the minke whale abundance estimate derived from IDCR-SOWER

Figure 8 repeats Figure 7 with the base case estimates of abundance replaced by $g(0)$-adjusted estimates. Other than an approximate doubling of abundance in absolute terms, these Figures are very similar. Figure 8 also shows the IWC-SOWER estimates for Areas IV and V from the second and third circumpolar cruises as agreed by the 2012 IWC SC meeting (IWC, 2013). In three of the four cases there is very good agreement between the IWC-SOWER point estimates and the exponential trend estimated from applying model i) to the JARPA and JARPA II data. The exception is the point estimate for the 1985/86 CP II estimate for Area V which is appreciably larger than the following JARPA, JARPA II and CP III estimates. However, when the confidence intervals for both the CP II estimate and the exponential trend are considered (see Figure 8), together with the fact that considerable backward extrapolation of that trend is needed for comparison with the IDCR-SOWER estimate during a period when the actual (log-) population trend might not have been linear, it is evident that there is no obvious inconsistency.

Nevertheless, comparison of Area V estimates on a finer spatial scale to identify the main source of this difference would seem desirable to aid understanding. Both the JARPA/JARPA II and IDCR-SOWER CIs shown in Figure 8 incorporate additional variance (σ^2 – see equations (7)-(10) and the text following). The CIs for the JARPA and JARPA II surveys are notably larger, arising from a σ value of about 0.76 (Areas IIE+IV) and 0.58 (V+VIW), which are larger than that for the IDCR-SOWER surveys. This additional variance arises from differing proportions of the overall population in a particular region surveyed from one season to another; the reasons for the larger values for the JARPA and JARPA II surveys merit further investigation, but may relate to the fact that these surveys extended over a longer period than the IDCR-SOWER surveys (typically about three to about two months respectively), hence allowing for more movement of minke whales into and out of the Areas while these were under survey.

Clearly, there is scope to attempt to improve the regression method used to provide g(0)-adjusted abundance estimates in this paper by investigating the inclusion of other co-variates, such as those related to sighting conditions such as Beaufort sea state. The regression approach may introduce bias, as the form of the detection function for the OK approach differs from that assumed for this analysis in equation (19); the size of this bias could be investigated by applying the methods of this paper to the data IDCR-SOWER data and comparing the results to those obtained using the OK method of Okamura and Kitakado (2012). Furthermore, in JARPA II the SVs use Closing mode and Passing mode where the latter now includes an Independent Observer (Matsuoka *et al*., 2012). The sighting survey was canceled due to by anti-whaling NGOs but it could be conducted in future surveys. The availability of data on duplicate sightings will allow the application of methods such as OK and SPLINTR to estimate g(0) directly, which will hopefully reduce variance compared to the g(0)-adjusted estimates of this paper and hence improve estimates of trends in abundance for the minke whales based on JARPA and JARPA II information in combination..

Application of JARPA and JARPA II abundance trend

One of the features of JARPA and JARPA II is that, unlike for the IDCR-SOWER programme, surveys have been repeated in the same area and in the same months every second year over a long period.

Therefore, the JARPA and JARPA II surveys facilitate both estimation of trends and the extent of inter-year variability in local abundance. These abundance series as well as those from IDCR/SOWER can be used to estimate abundance trends using population dynamics models which incorporate catch-at-age data and so integrate information from a number of different sources (Punt *et al*., 2013; Mori *et al*., 2006). Through their use in such population models, the abundance estimates and trends derived from JARPA and JARPA II which are reported in this paper provide information to complement that available to estimate sustainable catch levels for minke whales in Areas IIIE, IV, V and VIW.

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Table 1. Smearing parameters for each survey mode in JARPA II period used in abundance estimation. Units for angles are degrees which for radial distance the values given are proportions.

	SVC		SVP	
Year	Angle	Distance	Angle	Distance
2005/06	11.003	0.199	6.038	0.177
2006/07	7.000	0.220	4.975	0.171
2007/08	4.848	0.136	6.099	0.202
2008/09	5.780	0.157	3.782	0.144

Table 2. List of the factors which the sensitivity of abundance estimates and/or trends is examined. Specifications are given for both the base case and the sensitivities, with more details provided in Hakamada *et al*. (in press).

Sensitivity factors	Specifications for the base case	Specifications for sensitivities
'Shoulder' of detection function	Estimation by stratum, except that when sample size is less than 15, strata are pooled.	For SSVs, ESHW averaged over the vessels concerned was used. For SVs the detection function estimation takes account of covariates.
Trackline following ice edge contours	Complete tracklines used.	(1)Exclude trackline segments along the ice edge (Option B). (2)Use only the transects parallel to lines of longitude (Option C).
Abundance in gaps between northern and southern strata	Assume same density as in stratum to the north.	(1)Assume the density is 0. (2)Assume the same density as in the stratum to the south.
Interpolation of density in the unsurveyed area within a stratum	Estimated density assumed to apply to complete stratum for JARPA. Interpolation using GLM was used for JARPA II.	Extrapolate based on average ratio of density in the unsurveyed to surveyed area as estimated in other years with complete coverage for JARPA.
"Skipping"	Assumed not to introduce bias.	Exclude the abundance estimates for years when "skipping" occurred when.estimating trends.
g(0)	Assumed to equal 1	Adjust for g(0) estimates provided by the regression model detailed in the text.

Table 3. List of strata which survey coverage was considered incomplete during 2005/06-2008/09.

Year	Strata	Survey mode	Longitudinal sector
Area IIIE			
2005/06	IIIEN	SVC,SVP	35°E-55°E
2005/06	IIIES	SVC,SVP	35°E-55°E
Area IV			
2007/08	Prydz Bay	SVC,SVP	Whole strata
Area V			
2005/06	V-NW	SVC,SVP	159°E-165°E
2005/06	V-SW	SVC,SVP	159°E-165°E
2006/07	V-NW	SVC,SVP	130°E-159°E
2006/07	V-SW	SVC,SVP	130°E-159°E
2007/08	V-NW	SVC,SVP	161°E-165°E
2007/08	V-SW	SVC	161°E-165°E
2008/09	V-NW	SVC,SVP	161°E-165°E

Table 4. Status of survey in each year for blocks to apply equation (20). Definition of the blocks are provided in main text. S: surveyed U: Not surveyed.

Area IIIE

Year	IIIEN1	IIIEN2	IIIES1	IIIES2
2005/06	U	S	U	S
2007/08	S	S	S	S

Area IVW

Year	PB	SW	NW
2005/06	S	S	S
2007/08	U	S	S

Area VW

Year	5WN1	5WN2	5WS1	5WS2
2005/06	S	U	S	U
2006/07	U	S	U	S
2007/08	S	U	S	S*
2008/09	S	U	S	U

*: The block was surveyed by only in passing mode.

Table 5. Values of the parameters of the regression model of equation (21) relating OK estimates of g(0) to school size distribution statistics and other covariates for IDCR-SOWER survey blocks in Areas III, IV, V and VI. The residuals standard derivation for the model fit is 0.08.

	Estimate	SE
a	0.622	0.051
b	0.042	0.018
c	-0.064	0.020
NS	-0.066	0.077
AreaIV	-0.019	0.055
AreaV	-0.039	0.050
AreaVI	-0.032	0.061
*NS*AreaIV*	-0.028	0.107
*NS*AreaIV*	0.067	0.089
*NS*AreaVI*	0.104	0.104

Table 6a. The abundance estimates from SSV survey mode for minke whales in Area IIIE (south of 60°S) in the JARPA period. *A*=size of research area; *n*=number of schools sighted on primary effort (truncated at a perpendicular distance of 1.5 n.miles after smearing); *L*=primary searching distance; *esw*=the effective search half width (hazard rate model estimate); *E(s)*=mean school size; *D*= estimated density (individuals/100 n.miles2); *P*=estimated abundance.

Year	Stratum	*A*	Period	*n*	*L*	*n/L**100	CV	*esw*	CV	*E(s)*	CV	*D*	*P*	CV
		(n.miles^2)			(n.miles)			(n.miles)				(ind.)	(ind.)	
1995/96	IIIE	253,343	12/8-22	69.2	2431.2	0.028	0.190	0.444	0.189	1.298	0.054	0.042	**10,546**	**0.222**
1997/98	IIIE	250,985	12/16-31	76.7	3238.1	0.024	0.320	0.761	0.239	1.649	0.072	0.026	**6,435**	**0.352**
1999/00	IIIE	357,358	12/15-26	95.4	1256.0	0.076	0.485	0.765	0.155	1.679	0.070	0.083	**29,794**	**0.495**
2001/02	IIIE	355,282	12/9-25	123.3	2202.8	0.056	0.552	0.696	0.162	2.770	0.136	0.111	**39,560**	**0.566**
2003/04	IIIE	324,032	11/30-12/23	146.4	3377.7	0.043	0.352	0.835	0.148	2.083	0.034	5.407	**17,522**	**0.364**

Table 6b. The abundance estimates from SSV survey mode for minke whales in Area VIW (south of 60°S) in the JARPA period. The notation is as for Table 6a.

Year	Stratum	*A*	Period	*n*	*L*	*n/L**100	CV	*esw*	CV	*E(s)*	CV	*D*	*P*	CV
		(n.miles^2)			(n.miles)			(n.miles)				(ind.)	(ind.)	
1996/97	VIW	205,180	12/15-1/4	76.8	2625.5	0.029	0.193	0.744	0.162	1.785	0.078	0.035	**7,201**	**0.220**
1998/99	VIW	316,727	3/16-31	69.6	572.5	0.122	0.314	0.788	0.149	1.235	0.051	0.095	**30,194**	**0.327**
2000/01	VIW	290,908	12/11-31	112.8	2897.5	0.039	0.210	0.654	0.161	1.422	0.058	0.042	**12,317**	**0.232**
2002/03	VIW	329,256	12/2-1/1	118.2	4398.3	0.027	0.203	0.510	0.139	1.209	0.038	0.032	**10,486**	**0.219**
2004/05	VIW	292,218	12/7-25	117.9	2826.5	0.042	0.285	0.561	0.154	1.361	0.049	0.051	**14,805**	**0.300**

Table 6c. The abundance estimates from SVC survey mode for minke whales in Area IIIE (south of 60°S) in the JARPA and JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A*	Period	*n*	*L*	*n/L**100	CV	*esw*	CV	*E(s)*	CV	*D*	*P*	CV
		(n.miles^2)			(n.miles)			(n.miles)				(ind.)	(ind.)	
1995/96	IIIE	253,343	12/8-22	5.0	733.9	0.681	0.486	0.178	0.561	1.000	0.000	0.019	**4,843**	**0.742**
1997/98	IIIE	250,985	12/16-30	6.0	697.0	0.861	0.440	0.372	0.984	1.000	0.000	0.012	**2,902**	**1.078**
1999/00	IIIE	356,046	12/5-13,21-26	4.0	188.1	2.127	1.296	0.428	0.422	1.667	0.400	0.041	**14,749**	**1.420**
2001/02	IIIE	354,965	12/9-24	20.0	257.9	7.755	0.548	0.384	0.265	3.889	0.249	0.392	**139,277**	**0.658**
2003/04	IIIE	324,032	11/30-12/24	31.1	373.2	8.346	0.5987	0.35491	0.5725	1.8071	0.1112	0.212	**68,853**	**0.836**
2005/06	IIIEN	128,829	1/7-19	10.8	149.8	7.212	0.558	0.664	0.360	1.729	0.143	0.094	12,098	0.679
	IIIES	30,323	1/7-19	10.0	238.7	4.190	0.497	0.664	0.360	1.729	0.143	0.055	1,654	0.630
	Total	159,152		20.8	388.4								**13,752**	**0.628**
2007/08	IIIEN	228,382	12/15-1/7	6.0	322.2	1.862	0.521	0.447	0.226	1.800	0.122	0.037	8,562	0.581
	IIIES	50,431	12/15-1/7	22.0	241.7	9.101	0.515	0.447	0.226	1.800	0.122	0.183	9,241	0.575
	Total	278,813		28.0	564.0								**17,804**	**0.447**

Table 6d. The abundance estimates from SVC survey mode for minke whales in Area IV (south of 60°S) in the JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A*	Period	*n*	*L*	*n/L**100	CV	*esw*	CV	*E(s)*	CV	*D*	*P*	CV
		(n.miles^2)			(n.miles)			(n.miles)				(ind.)	(ind.)	
2005/06	NW	228,919	1/3-6,2/1-15	8.5	297.5	2.856	0.417	0.609	0.281	1.733	0.143	0.041	9,298	0.523
	NE	213,660	2/17-24,3/5-12	6.0	462.7	1.297	0.424	0.609	0.281	1.733	0.143	0.018	3,940	0.528
	SW	47,117	1/3-6,2/1-15	31.9	227.8	13.987	0.841	0.407	0.440	3.961	0.285	0.680	32,040	0.991
	SE	37,228	2/17-24,3/5-12	2.8	189.6	1.478	0.677	0.407	0.440	3.961	0.285	0.072	2,674	0.855
	PB	31,689	1/20-1/31	22.6	95.1	23.775	0.368	0.483	0.573	2.318	0.171	0.571	18,083	0.702
	Total	558,613		71.8	1,272.6								**66,035**	**0.537**
2007/08	NW	213,311	1/7-13,2/25-3/2	6.0	281.7	2.130	0.456	0.447	0.226	1.800	0.122	0.043	9,148	0.523
	NE	216,236	3/2-20	1.0	503.6	0.199	0.856	0.447	0.226	1.800	0.122	0.004	865	0.894
	SW	39,787	1/7-13,2/25-3/2	7.0	193.4	3.619	0.640	0.447	0.226	1.800	0.122	0.073	2,899	0.689
	SE	36,277	3/2-20	6.0	261.8	2.292	0.484	0.447	0.226	1.800	0.122	0.046	1,674	0.548
	Total	505,611		20.0	1,240.6								**14,585**	**0.412**

Table 6e. The abundance estimates from SVC survey mode for minke whales in Area V (south of 60°S) in the JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A* (n.miles²)	Period	*n*	*L* (n.miles)	*n/L* *100	CV	*esw* (n.miles)	CV	*E(s)*	CV	*D* (ind.)	*P* (ind.)	CV
2005/06	NW	238,068	12/9-22,3/11-20	8.0	202.45	3.952	1.018	0.766	0.171	3.387	0.235	0.087	20,794	1.059
	SW	49,999	12/9-22,3/11-20	22.5	156.49	14.363	1.000	0.766	0.171	3.3871	0.235	0.317	15,873	1.041
2006/07	NW	38,740	2/12-15	1.0	22.9	4.368	0.312	0.844	0.161	2.722	0.190	0.070	2,730	0.399
	NE	340,889	1/2-10	21.8	560.3	3.886	0.315	0.844	0.161	2.722	0.190	0.063	21,373	0.402
	SW	9,260	2/12-15	5.0	12.4	40.463	0.447	0.689	0.276	1.421	0.071	0.418	3,866	0.530
	SE	139,575	1/13-31	69.8	607.9	11.479	0.271	0.689	0.276	1.421	0.071	0.118	16,531	0.393
	Total	528,463		97.5	1203.4								**44,500**	**0.265**
2007/08	NW	275,376	1/26-2/18	10.0	280.9	3.561	0.923	0.865	0.311	3.564	0.171	0.073	20,208	0.988
	SW	43,609	1/26-2/18	39.3	149.9	26.201	0.543	0.865	0.311	3.564	0.171	0.540	23,549	0.649
2008/09	NW	224,275	12/10-1/1	2.0	391.3	0.511	0.666	0.591	0.196	2.173	0.075	0.009	2,108	0.698
	NE	324,889	2/2-8,2/28-3/10	5.0	358.7	1.394	0.558	0.591	0.196	2.173	0.075	0.026	8,329	0.596
	SW	64,901	12/10-1/1	8.0	145.9	5.484	0.849	0.591	0.196	2.173	0.075	0.101	6,546	0.875
	SE	277,209	2/4-27	133.3	686.5	19.420	0.161	0.591	0.196	2.173	0.075	0.357	99,003	0.264
	Total	891,274		148.3	1582.3								**115,986**	**0.259**

Table 6f. The abundance estimates from SVC survey mode for minke whales in Area VIW (south of 60°S) in the JARPA and JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A* (n.miles²)	Period	*n*	*L* (n.miles)	*n/L* *100	CV	*esw* (n.miles)	CV	*E(s)*	CV	*D* (ind.)	*P* (ind.)	CV
1996/97	VIW	206,490	12/14-1/1	29.6	1015.7	2.913	0.236	0.410	0.442	2.044	0.193	0.073	**14,994**	**0.537**
2000/01	VIW	290,908	12/11-29	30.0	660.6	4.547	0.280	0.835	0.189	2.071	0.143	0.056	**16,403**	**0.367**
2002/03	VIW	309,998	12/3-30	8.0	354.7	2.255	0.523	0.466	0.286	1.500	0.333	0.036	**11,260**	**0.683**
2004/05	VIW	292,218	12/7-12/24	7.0	243.0	2.881	0.378	0.388	0.297	1.286	0.143	0.048	**13,948**	**0.502**
2006/07	VIWN	220,818	12/16-30	5.0	194.4	2.572	0.351	0.844	0.161	2.722	0.190	0.041	9,164	0.430
	VIWS	31,008	12/16-30	9.0	189.6	4.748	1.368	0.844	0.161	2.722	0.190	0.077	2,376	1.390
	Total	251,826		14.0	384.0								**11,539**	**0.468**
2008/09	VIWN	275,376	1/10-31	2.0	263.5	0.759	1.309	0.432	0.389	1.277	0.092	0.011	1,870	1.369
	VIWS	43,609	1/1-2/2	34.8	235.1	14.794	0.309	0.432	0.389	1.277	0.092	0.219	16,677	0.505
	Total	318,985		36.8	498.5								**18,547**	**0.504**

Table 6g. The abundance estimates from SVP survey mode for minke whales in Area IIIE (south of 60°S) in the JARPA and JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A* (n.miles²)	Period	*n*	*L* (n.miles)	*n/L* *100	CV	*esw* (n.miles)	CV	*E(s)*	CV	*D* (ind.)	*P* (ind.)	CV
1997/98	IIIE	250,985	12/16-30	2.0	309.1	0.647	0.908	1.500	0.000	1.000	0.000	0.002	**541**	**0.908**
1999/00	IIIE	356,046	12/5-13,21-26	5.0	527.8	0.947	0.610	0.361	1.415	1.667	0.400	0.022	**7,782**	**1.592**
2001/02	IIIE	354,965	12/9-24	19.1	426.2	4.487	0.465	0.680	0.385	3.889	0.249	0.128	**45,569**	**0.653**
2003/04	IIIE	324,032	11/30-12/24	154.5	1490.4	10.363	0.4024	0.756	0.1815	1.8071	0.1112	12.384	**40,128**	**0.455**
2005/06	IIIEN	128,829	1/7-19	65.6	524.4	12.507	0.163	0.702	0.158	1.729	0.143	0.154	19,834	0.268
	IIIES	30,323	1/7-19	46.3	436.3	10.616	0.239	0.513	0.364	1.729	0.143	0.179	5,424	0.458
	Total	159,152		111.9	960.8								**25,258**	**0.247**
2007/08	IIIEN	228,382	12/15-1/7	5.0	609.2	0.821	0.448	0.379	0.447	1.800	0.122	0.019	4,448	0.645
	IIIES	50,431	12/15-1/7	29.6	884.4	3.344	0.271	0.379	0.447	1.800	0.122	0.079	4,002	0.537
	Total	278,813		34.6	1493.6								**8,450**	**0.535**

Table 6h. The abundance estimates from SVP survey mode for minke whales in Area IV (south of 60^{o}S) in the JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A* (n.miles^2)	Period	*n*	*L* (n.miles)	*n* /*L* *100	CV	*esw* (n.miles)	CV	*E* (*s*)	CV	*D* (ind.)	*P* (ind.)	CV
2005/06	NW	228,919	1/3-6,2/1-15	32.5	833.9	3.901	0.298	0.660	0.077	2.388	0.096	0.071	16,149	0.322
	NE	213,660	2/17-24,3/5-12	6.6	987.6	0.669	0.359	0.660	0.077	2.388	0.096	0.012	2,587	0.379
	SW	47,117	1/3-6,2/1-15	143.7	631.7	22.751	0.339	0.660	0.077	2.388	0.096	0.411	19,387	0.360
	SE	37,228	2/17-24,3/5-12	41.2	675.9	6.091	0.481	0.660	0.077	2.388	0.096	0.110	4,101	0.496
	PB	31,689	1/20-1/31	15.4	285.9	5.376	0.380	0.660	0.077	2.388	0.096	0.097	3,081	0.400
	Total	558,613		239.4	3,415.0								**45,305**	**0.225**
2007/08	NW	213,311	1/7-13,2/25-3/2	17.0	677.2	2.510	0.279	0.553	0.117	2.204	0.100	0.050	10,668	0.319
	NE	216,236	3/2-20	1.0	828.8	0.121	0.838	0.553	0.117	2.204	0.100	0.002	520	0.852
	SW	39,787	1/7-13,2/25-3/2	19.0	654.1	2.900	0.498	0.553	0.117	2.204	0.100	0.058	2,298	0.521
	SE	36,277	3/2-20	6.5	558.0	1.169	0.619	0.553	0.117	2.204	0.100	0.023	845	0.638
	Total	505,611		43.5	2,718.1								**14,330**	**0.275**

Table 6i. The abundance estimates from SVP survey mode for minke whales in Area V (south of 60^{o}S) in the JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A* (n.miles^2)	Period	*n*	*L* (n.miles)	*n* /*L* *100	CV	*esw* (n.miles)	CV	*E* (*s*)	CV	*D* (ind.)	*P* (ind.)	CV
2005/06	NW	238,068	12/9-22,3/11-20	73.6	411.32	17.888	0.524	0.662	0.169	3.387	0.235	0.457	108,895	0.598
	SW	49,999	12/9-22,3/11-20	69.7	496.156	14.042	0.516	0.88225	0.1514	3.3871	0.235	0.270	13,477	0.587
2006/07	NW	38,740	2/12-15	11.0	74.4	14.794	0.255	0.780	0.363	2.722	0.190	0.258	10,001	0.482
	NE	340,889	1/2-10	15.0	1547.5	0.969	0.241	0.780	0.363	2.722	0.190	0.017	5,766	0.475
	SW	9,260	2/12-15	13.8	123.9	11.132	0.490	0.812	0.102	1.421	0.071	0.097	903	0.505
	SE	139,575	1/13-31	263.5	1665.0	15.825	0.153	0.812	0.102	1.421	0.071	0.139	19,343	0.197
	Total	528,463		303.3	3410.7								**36,013**	**0.370**
2007/08	NW	275,376	1/26-2/18	28.1	867.3	3.239	0.318	0.499	0.507	3.564	0.171	0.116	31,848	0.622
	SW	43,609	1/26-2/18	80.0	715.0	11.185	0.299	0.573	0.136	3.564	0.171	0.348	15,165	0.370
2008/09	NW	224,275	12/10-1/1	1.0	753.4	0.133	0.952	0.286	0.483	2.173	0.075	0.005	1,132	1.071
	NE	324,889	2/2-8,2/28-3/10	14.0	1010.9	1.385	0.500	0.286	0.483	2.173	0.075	0.053	17,114	0.699
	SW	64,901	12/10-1/1	16.6	492.3	3.381	0.383	0.569	0.625	2.173	0.075	0.065	4,190	0.737
	SE	277,209	2/4-27	581.5	2071.3	28.074	0.196	1.138	0.077	2.173	0.075	0.268	74,271	0.223
	Total	891,274		613.1	4327.8								**96,707**	**0.221**

Table 6j. The abundance estimates from SVP survey mode for minke whales in Area VIW (south of 60^{o}S) in the JARPA and JARPA II period. The notation is as for Table 6a.

Year	Stratum	*A* (n.miles^2)	Period	*n*	*L* (n.miles)	*n* /*L* *100	CV	*esw* (n.miles)	CV	*E* (*s*)	CV	*D* (ind.)	*P* (ind.)	CV
1996/97	VIW	206,490	12/14-1/1	29.6	1015.7	2.913	0.236	0.410	0.442	2.044	0.193	0.073	**14,994**	**0.537**
2000/01	VIW	290,908	12/11-29	30.0	660.6	4.547	0.280	0.835	0.189	2.071	0.143	0.056	**16,403**	**0.367**
2002/03	VIW	309,998	12/3-30	8.0	354.7	2.255	0.523	0.466	0.286	1.500	0.333	0.036	**11,260**	**0.683**
2004/05	VIW	292,218	12/7-12/24	7.0	243.0	2.881	0.378	0.388	0.297	1.286	0.143	0.048	**13,948**	**0.502**
2006/07	VIWN	220,818	12/16-30	7.8	561.95	1.384	0.973	0.439	0.296	2.722	0.190	0.043	9,469	1.034
	VIWS	31,008	12/16-30	19.0	531.68	3.574	0.634	0.439	0.296	2.722	0.190	0.111	3,435	0.725
	Total	251,826		26.8	1093.6								**12,904**	**0.813**
2008/09	VIWN	275,376	1/10-31	1.0	458.09	0.218	0.763	0.490	0.140	1.277	0.092	0.003	474	0.781
	VIWS	43,609	1/1-2/2	183.0	755.04	24.237	0.211	0.490	0.140	1.277	0.092	0.316	24,109	0.269
	Total	318,985		184.0	1213.1								**24,584**	**0.266**

Table 7. Interpolated abundance estimate using model (20) for strata which survey coverage considered incomplete listed in Table 3.

Year	Strata	P_{SVC}	$CV(P_{SVC})$	P_{SVP}	$CV(P_{SVP})$
Area IIIE					
2005/06	IIIEN	20,444	0.597	29,408	0.402
2005/06	IIIES	3,817	0.657	7,912	0.457
Area IV					
2007/08	Prydz Bay	3,310	1.282	3,310	1.282
Area V					
2005/06	V-NW	21,005	0.999	105,110	0.590
2005/06	V-SW	15,267	0.945	13,807	0.530
2006/07	V-NW	21,528	0.608	34,290	0.507
2006/07	V-SW	8,894	0.450	7,400	0.578
2007/08	V-NW	21,177	0.855	31,709	0.557
2007/08	V-SW	21,273	0.603	-	-
2008/09	V-NW	4,708	0.703	4,686	1.005

Table 8. AICc, estimated instantaneous annual rates of increase (α) and estimated additional variance (σ) the various log-linear models applied to estimate α for Areas IIIE+ IV and Area V+VIW where the minke whale abundance estimates input to those models are for the base case (i.e. the estimates shown in Tables 6a-6j and 7). Values shown in bold below are for the model selected on the basis on minimum AICc.

a) Areas IIIE + IV

model	AIC_c	ΔAIC_c	α	SE(α)	α95%*LL*	α95%*UL*	σ	SE(σ)
i)	**135.274**	**0.00**	**0.011**	**0.017**	**-0.023**	**0.045**	**0.755**	**0.069**
ii)	139.435	4.16	0.016	0.019	-0.022	0.054	0.754	0.069
iii) with T1	142.479	7.21	0.023	0.020	-0.016	0.061	0.740	0.068
iii) with T2	140.406	5.13	0.023	0.020	-0.016	0.062	0.744	0.068
iii) with T3	136.768	1.49	0.026	0.019	-0.011	0.064	0.702	0.065
iii) with T4	141.357	6.08	0.018	0.020	-0.021	0.057	0.756	0.069
iv) with T1	145.970	10.70	0.040	0.021	-0.002	0.082	0.628	0.063
iv) with T2	139.499	4.23	0.044	0.021	0.003	0.086	0.677	0.065
iv) with T3	135.967	0.69	0.037	0.019	0.000	0.075	0.636	0.062
iv) with T4	141.638	6.36	0.026	0.020	-0.014	0.065	0.718	0.067

b) Areas V + VIW

Model	AICc	ΔAIC_c	α	SE(α)	α95%*LL*	α95%*UL*	σ	SE(σ)
i)	**68.802**	**0.00**	**0.006**	**0.014**	**-0.022**	**0.033**	**0.575**	**0.059**
ii)	69.971	1.17	-0.008	0.016	-0.039	0.023	0.560	0.059
iii) with T1	72.279	3.48	-0.012	0.015	-0.042	0.018	0.531	0.058
iii) with T2	71.154	2.35	-0.010	0.015	-0.040	0.020	0.540	0.059
iii) with T3	71.006	2.20	-0.011	0.015	-0.040	0.018	0.499	0.056
iii) with T4	69.432	0.63	-0.014	0.015	-0.044	0.016	0.525	0.058
iv) with T1	81.359	12.56	-0.010	0.016	-0.042	0.022	0.454	0.058
iv) with T2	77.596	8.79	-0.005	0.015	-0.035	0.025	0.485	0.058
iv) with T3	70.436	1.63	-0.010	0.015	-0.040	0.019	0.407	0.055
iv) with T4	69.041	0.24	-0.021	0.016	-0.053	0.010	0.474	0.057

Table 9. Estimated coefficients of the log-linear models selected on the basis of AICc to provide estimates of the rate of increase in minke whale abundance, α.

a)Areas IIIE+IV

Parameter	Estimate	SE
factor(S)SW	8.318	0.252
factor(S)SE	8.143	0.252
factor(S)NW	8.772	0.262
factor(S)NE	8.575	0.265
factor(S)PB	8.447	0.265
factor(S)IIIE	9.609	0.314
α	0.011	0.017
σ	0.755	0.069

b)Areas V+VIW

Parameter	Estimate	SE
factor(S)SW	9.336	0.220
factor(S)SE	10.373	0.222
factor(S)NW	9.858	0.222
factor(S)NE	9.917	0.225
factor(S)VIW	9.591	0.257
α	0.006	0.014
σ	0.575	0.059

Table 10. Abundance estimates for Areas IIIE, IV, VW, VE and VIW based upon data for each survey mode separately.

Area IV

Year	P_{SSV}	$CV(P_{SSV})$	P_{SVC}	$CV(P_{SVC})$	P_{SVP}	$CV(P_{SVP})$
1989/90	29,993	0.527	-	-	-	-
1991/92	32,418	0.720	-	-	-	-
1993/94	27,989	0.539	26,546	0.909	-	-
1995/96	28,919	0.579	51,264	0.703	-	-
1997/98	17,272	0.763	15,936	0.776	-	-
1999/00	42,852	0.495	74,312	0.739	42,858	0.555
2001/02	46,355	0.660	24,471	0.579	58,176	0.744
2003/04	59,918	1.031	25,910	0.969	48,984	1.050
2005/06	-	-	66,035	0.815	62,608	0.617
2007/08	-	-	17,896	0.740	13,766	0.759

Area VW

Year	P_{SSV}	$CV(P_{SSV})$	P_{SVC}	$CV(P_{SVC})$	P_{SVP}	$CV(P_{SVP})$
1990/91	35,108	0.575	-	-	-	-
1992/93	22,404	0.625	-	-	-	-
1994/95	11,764	0.604	22,386	0.727	-	-
1996/97	14,434	0.574	26,708	0.800	-	-
1998/99	55,577	0.746	110,993	1.315	-	-
2000/01	14,626	1.053	48,616	1.632	54,285	1.016
2002/03	53,682	0.562	72,139	0.869	131,686	0.545
2004/05	27,696	0.629	20,679	0.708	31,437	0.644
2005/06	-	-	36,272	0.944	118,917	0.875
2006/07	-	-	30,422	0.765	41,690	0.754
2007/08	-	-	42,450	0.753	46,588	0.722
2008/09	-	-	11,586	0.708	9,547	0.761

Area VE

Year	P_{SSV}	$CV(P_{SSV})$	P_{SVC}	$CV(P_{SVC})$	P_{SVP}	$CV(P_{SVP})$
1990/91	65,638	0.597	-	-	-	-
1992/93	43,743	0.631	-	-	-	-
1994/95	73,495	0.676	130,091	0.659	-	-
1996/97	74,981	0.701	91,891	0.681	-	-
1998/99	62,440	0.602	21,673	0.816	-	-
2000/01	87,228	0.492	284,474	1.765	131,735	0.980
2002/03	97,677	0.720	39,963	0.605	73,666	0.611
2004/05	40,729	0.519	59,222	0.668	53,492	0.622
2006/07	-	-	37,904	0.553	25,109	0.536
2008/09	-	-	107,332	0.640	91,385	0.542

Area IIIE

Year	P_{SSV}	$CV(P_{SSV})$	P_{SVC}	$CV(P_{SVC})$	P_{SVP}	$CV(P_{SVP})$
1995/96	10,546	1.086	4,843	1.285	-	-
1997/98	6,435	0.967	2,902	1.659	-	-
1999/00	29,794	1.016	14,749	1.328	7,782	1.472
2001/02	39,560	1.059	139,277	1.129	45,569	1.465
2003/04	17,522	0.979	68,853	1.554	40,128	1.342
2005/06	-	-	24,261	1.090	37,320	1.156
2007/08	-	-	17,804	0.907	8,450	1.209

Area VIW

Year	P_{SSV}	$CV(P_{SSV})$	P_{SVC}	$CV(P_{SVC})$	P_{SVP}	$CV(P_{SVP})$
1996/97	7,201	0.697	14,994	0.953	-	-
1998/99	30,194	0.707	16,403	0.785	-	-
2000/01	12,317	0.682	11,260	1.185	29,494	0.837
2002/03	10,486	0.742	13,948	0.845	8,792	0.899
2004/05	14,805	0.735	11,539	0.826	17,926	0.651
2006/07	-	-	18,547	0.751	12,904	1.072
2008/09	-	-	34,941	0.812	24,584	0.617

Table 11a. Weights (W) (see text) and the weighted average over survey modes to provide a minke whale abundance estimate (P_{WA}) for each year with taking model error into account.

Area IV

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	$CV(P_{WA})$
1989/90	1.00	-	-	29,993	0.527
1991/92	1.00	-	-	32,418	0.720
1993/94	0.73	0.27	-	27,598	0.473
1995/96	0.82	0.18	-	32,970	0.458
1997/98	0.47	0.53	-	16,562	0.542
1999/00	0.53	0.07	0.41	44,945	0.338
2001/02	0.16	0.76	0.08	30,807	0.402
2003/04	0.11	0.74	0.15	32,970	0.682
2005/06	-	0.35	0.65	63,794	0.509
2007/08	-	0.32	0.68	15,088	0.645

Area VW

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	$CV(P_{WA})$
1990/91	1.00	-	-	35,108	0.575
1992/93	1.00	-	-	22,404	0.625
1994/95	0.87	0.13	-	13,132	0.482
1996/97	0.83	0.17	-	16,535	0.480
1998/99	0.97	0.03	-	57,478	0.668
2000/01	0.80	0.05	0.15	22,115	1.105
2002/03	0.59	0.24	0.17	71,210	0.382
2004/05	0.32	0.48	0.20	25,108	0.390
2005/06	-	0.87	0.13	47,035	0.769
2006/07	-	0.71	0.29	33,655	0.638
2007/08	-	0.45	0.55	44,736	0.549
2008/09	-	0.24	0.76	10,031	0.569

Area VE

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	$CV(P_{WA})$
1990/91	1.00	-	-	65,638	0.597
1992/93	1.00	-	-	43,743	0.631
1994/95	0.74	0.26	-	88,311	0.489
1996/97	0.58	0.42	-	82,065	0.498
1998/99	0.39	0.61	-	37,466	0.558
2000/01	0.93	0.01	0.06	91,197	0.445
2002/03	0.06	0.64	0.31	53,603	0.398
2004/05	0.58	0.15	0.27	46,941	0.353
2006/07	-	0.29	0.71	28,818	0.400
2008/09	-	0.47	0.53	98,820	0.422

Area IIIE

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	$CV(P_{WA})$
1995/96	0.36	0.64	-	6,897	0.914
1997/98	0.45	0.55	-	4,478	0.911
1999/00	0.13	0.06	0.80	11,205	0.862
2001/02	0.87	0.09	0.04	48,540	0.711
2003/04	0.86	0.01	0.13	21,133	0.782
2005/06	-	0.65	0.35	28,822	0.807
2007/08	-	0.19	0.81	10,237	0.778

Area VIW

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	$CV(P_{WA})$
1996/97	0.84	0.16	-	8,434	0.601
1998/99	0.23	0.77	-	19,592	0.537
2000/01	0.58	0.36	0.06	12,891	0.507
2002/03	0.47	0.09	0.45	10,030	0.480
2004/05	0.30	0.47	0.23	14,009	0.430
2006/07	-	0.49	0.51	15,655	0.625
2008/09	-	0.31	0.69	27,790	0.507

Table 11b. Weights (W) (see text) and the weighted average over survey modes to provide a minke whale abundance estimate (P_{WA}) for each year without taking model error into account.

Area IV

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	CV(P_{WA})
1989/90	1.00	-	-	29,993	0.228
1991/92	1.00	-	-	32,418	0.396
1993/94	0.85	0.15	-	27,780	0.147
1995/96	0.88	0.12	-	31,601	0.198
1997/98	0.49	0.51	-	16,590	0.277
1999/00	0.59	0.03	0.38	43,673	0.125
2001/02	0.17	0.77	0.06	30,269	0.218
2003/04	0.22	0.72	0.05	34,701	0.373
2005/06	-	0.11	0.89	62,979	0.334
2007/08	-	0.24	0.76	14,739	0.570

Area VW

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	CV(P_{WA})
1990/91	1.00	-	-	35,108	0.220
1992/93	1.00	-	-	22,404	0.350
1994/95	0.90	0.10	-	12,805	0.275
1996/97	0.91	0.09	-	15,540	0.293
1998/99	0.98	0.02	-	56,927	0.538
2000/01	0.87	0.01	0.11	19,603	1.031
2002/03	0.71	0.16	0.13	66,544	0.234
2004/05	0.44	0.21	0.35	27,554	0.243
2005/06	-	0.89	0.11	45,541	0.701
2006/07	-	1.00	0.00	30,422	0.534
2007/08	-	0.35	0.65	45,157	0.408
2008/09	-	0.484	0.516	10,534	0.638

Area VE

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	CV(P_{WA})
1990/91	1.00	-	-	65,638	0.353
1992/93	1.00	-	-	43,743	0.376
1994/95	0.52	0.48	-	100,771	0.254
1996/97	0.58	0.42	-	82,155	0.300
1998/99	0.52	0.48	-	43,037	0.286
2000/01	0.98	0.00	0.02	88,274	0.255
2002/03	0.09	0.47	0.43	59,961	0.244
2004/05	0.68	0.06	0.26	45,177	0.229
2006/07	-	0.10	0.90	26,418	0.188
2008/09	-	0.39	0.61	97,563	0.193

Area IIIE

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	CV(P_{WA})
1995/96	0.84	0.16	-	9,614	0.220
1997/98	0.75	0.25	-	5,566	0.367
1999/00	0.20	0.03	0.77	12,404	0.615
2001/02	0.92	0.05	0.03	44,801	0.582
2003/04	0.95	0.01	0.05	18,927	0.355
2005/06	-	0.62	0.38	29,261	0.379
2007/08	-	0.10	0.90	9,406	0.291

Area VIW

Year	W_{SSV}	W_{SVC}	W_{SVP}	P_{WA}	CV(P_{WA})
1996/97	0.96	0.04	-	7,530	0.258
1998/99	0.27	0.73	-	20,166	0.280
2000/01	0.87	0.11	0.02	12,571	0.257
2002/03	0.73	0.10	0.17	10,543	0.218
2004/05	0.40	0.29	0.31	14,843	0.228
2006/07	-	0.76	0.24	17,206	0.556
2008/09	-	0.17	0.83	26,364	0.226

Table 12. Variance–covariance matrices for the logarithm of minke whale abundance estimates when weighted over survey modes for Areas IIIE, IV, VW, VE and VIW.

Area IIIE

	1995/96	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08
1995/96	0.501						
1997/98	-0.018	0.604					
1999/00	-0.018	0.045	0.220				
2001/02	-0.017	0.066	0.470	0.604			
2003/04	-0.023	0.064	0.020	0.077	0.556		
2005/06	0.005	-0.018	-0.015	0.028	0.003	0.409	
2007/08	-0.029	0.008	0.004	-0.006	0.025	0.038	0.477

Area IV

	1989/90	1991/92	1993/94	1995/96	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08
1989/90	0.245									
1991/92	-0.017	0.418								
1993/94	-0.002	-0.008	0.202							
1995/96	-0.003	0.004	0.013	0.190						
1997/98	0.008	-0.009	0.008	0.005	0.258					
1999/00	0.003	0.002	-0.001	-0.008	-0.006	0.108				
2001/02	0.004	0.014	0.009	-0.001	-0.006	-0.002	0.149			
2003/04	-0.013	-0.016	-0.018	-0.004	-0.001	0.002	0.013	0.382		
2005/06	-0.031	0.005	0.017	0.009	-0.011	0.020	0.030	-0.011	0.231	
2007/08	0.005	0.047	0.003	0.026	-0.002	-0.006	0.015	0.000	-0.048	0.348

Area VW

	1990/91	1992/93	1994/95	1996/97	1998/99	2000/01	2002/03	2004/05	2005/06	2006/07	2007/08	2008/09
1990/91	0.286											
1992/93	0.017	0.330										
1994/95	-0.035	-0.043	0.219									
1996/97	0.044	0.007	0.024	0.197								
1998/99	0.019	0.014	-0.027	0.042	0.393							
2000/01	-0.076	-0.079	0.053	-0.095	-0.007	0.798						
2002/03	0.039	-0.024	-0.016	0.017	0.040	0.010	0.119					
2004/05	-0.022	-0.036	0.038	-0.007	0.007	-0.036	-0.010	0.145				
2005/06	0.039	-0.041	0.111	-0.054	0.062	0.247	0.035	0.020	0.392			
2006/07	0.068	0.048	0.008	-0.034	0.031	-0.046	-0.035	-0.002	-0.050	0.274		
2007/08	-0.015	-0.053	0.020	0.018	-0.027	-0.046	-0.009	0.016	0.033	-0.071	0.238	
2008/09	0.004	0.105	0.003	0.029	0.004	-0.022	-0.031	0.002	-0.073	-0.012	0.070	0.258

Area VE

	1990/91	1992/93	1994/95	1996/97	1998/99	2000/01	2002/03	2004/05	2006/07	2008/09
1990/91	0.305									
1992/93	-0.007	0.335								
1994/95	-0.026	0.009	0.212							
1996/97	-0.037	-0.001	-0.035	0.221						
1998/99	0.007	-0.032	0.067	-0.030	0.170					
2000/01	-0.032	0.019	-0.010	0.017	0.003	0.184				
2002/03	-0.033	0.006	-0.029	-0.001	0.007	-0.015	0.137			
2004/05	-0.002	0.057	0.025	0.011	0.060	-0.014	-0.001	0.117		
2006/07	0.009	-0.012	0.007	-0.035	0.021	-0.037	0.037	0.008	0.144	
2008/09	-0.038	-0.026	-0.021	0.023	0.032	-0.007	-0.007	-0.015	0.024	0.153

Area VIW

	1996/97	1998/99	2000/01	2002/03	2004/05	2006/07	2008/09
1996/97	0.280						
1998/99	-0.004	0.884					
2000/01	0.016	0.001	0.130				
2002/03	0.023	-0.002	0.051	0.254			
2004/05	-0.024	-0.046	0.011	0.015	0.229		
2006/07	0.012	-0.040	0.120	0.005	-0.022	0.207	
2008/09	0.074	0.015	0.054	-0.027	0.020	-0.050	0.170

Table 13. The values of g(0) predicted by the regression model of equation (21) and mean school size E(s) for the various JARPA and JARPA II strata. Instances where these fall below or above the lowest (0.405) or highest (0.794) OK values used in developing the regression relationship are shown in italics. When calculating g(0) adjusted abundance estimates for the JARPA and JARPA II using the value below, those values in italics have been replaced by the appropriate bounding OK value. Note also, as specified in the text, that values of E(s) below that are greater than 8 were set equal to 8 when applying the regression model to calculate g(0).

Area IV SSV			Area IV SVC			Area V SSV			Area V SVC		
Strata	g(0)	$E(s)$	Strata	g(0)	$E(s)$	Strata	g(0)	$E(s)$	Strata	g(0)	$E(s)$
8990NW	0.527	1.321	9192SW	0.556	3.543	9091NW	0.500	2.277	9293NW	0.600	1.565
8990NE	0.486	2.250	9192SE	0.563	2.769	9091NE	0.590	2.167	9293NE	0.669	8.059
8990SW	0.606	1.988	9192PB	0.593	5.805	9091SW	0.573	2.706	9293SW	0.518	4.479
8990SE	0.577	2.700	9394NW	0.520	1.280	9091SE	0.530	2.429	9293SE	0.478	3.535
8990PB	0.611	1.767	9394NE	0.501	1.650	9293NW	0.605	1.500	9495NW	0.483	3.627
9192NW	0.485	1.729	9394SW	0.461	2.700	9293NE	0.594	1.543	9495NE	0.579	1.958
9192NE	0.405	2.208	9394SE	0.530	3.328	9293SW	0.481	3.613	9495SW	0.520	3.875
9192SW	0.613	2.271	9394PB	0.626	1.545	9293SE	0.585	2.342	9495SE	0.507	4.239
9192SE	0.616	1.842	9596NW	0.508	2.353	9495NW	0.563	2.414	9697NW	0.496	3.929
9192PB	0.581	2.507	9596NE	0.471	2.222	9495NE	0.581	1.631	9697NE	0.578	1.933
9394NW	0.525	1.375	9596SW	0.595	2.800	9495SW	0.549	2.780	9697SW	0.629	7.100
9394NE	0.490	1.767	9596SE	0.502	3.322	9495SE	0.575	2.256	9697SE	0.592	6.223
9394SW	0.538	2.266	9596PB	0.583	1.960	9697NW	0.592	1.683	9899NW	0.584	3.500
9394SE	0.564	2.843	9798NW	0.505	2.824	9697NE	0.592	1.903	9899NE	0.558	2.150
9394PB	0.635	2.049	9798NE	0.520	1.800	9697SW	0.540	3.079	9899SW	0.497	4.143
9596NW	0.502	2.344	9798SW	0.621	1.806	9697SE	0.459	3.101	9899SE	0.706	4.143
9596NE	0.471	1.882	9798SE	0.613	1.806	9899NW	0.595	1.865	0001NW	0.627	6.118
9596SW	0.594	2.268	9798PB	0.614	1.806	9899NE	0.567	2.744	0001NE	0.618	6.118
9596SE	0.532	2.535	9900NW	0.552	1.381	9899SW	0.522	4.575	0001SW	0.557	1.727
9596PB	0.620	1.465	9900NE	0.516	1.381	9899SE	0.586	2.235	0001SE	0.591	2.250
9798NW	0.405	2.632	9900SW	0.607	2.600	0001NW	0.572	1.872	0203NW	0.589	2.231
9798NE	0.452	1.708	9900SE	0.608	6.140	0001NE	0.541	1.984	0203NE	0.603	1.636
9798SW	0.543	2.011	9900PB	0.556	4.917	0001SW	0.456	3.038	0203SW	0.576	2.000
9798SE	0.592	1.742	0102NW	0.512	1.627	0001SE	0.470	3.365	0203SE	0.579	1.931
9798PB	0.551	3.065	0102NE	0.552	1.627	0203NW	0.568	2.189	0405NW	0.627	1.526
9900NW	0.524	1.208	0102SW	0.624	1.627	0203NE	0.575	1.931	0405NE	0.592	1.526
9900NE	0.526	1.314	0102SE	0.628	1.627	0203SW	0.463	3.196	0405SW	0.595	2.357
9900SW	0.511	3.865	0102PB	0.623	1.627	0203SE	0.504	2.691	0405SE	0.551	2.219
9900SE	0.687	8.737	0304NW	0.543	3.710	0405NW	0.574	2.200	0506NW	0.480	3.559
9900PB	0.492	2.821	0304NE	0.552	3.710	0405NE	0.583	1.543	0506SW	0.479	3.559
0102NW	0.518	1.368	0304SW	0.538	3.710	0405SW	0.667	8.391	0607NW	0.515	2.846
0102NE	0.405	2.027	0304SE	0.605	3.710	0405SE	0.429	2.393	0607SW	0.577	1.857
0102SW	0.595	1.741	0304PB	0.636	3.710				0607NE	0.515	2.846
0102SE	0.559	2.036	0506NW	0.687	10.500				0607SE	0.577	1.857
0102PB	0.518	3.077	0506NE	0.687	10.500				0708NW	0.505	3.558
0304NW	0.525	1.373	0506SW	0.520	2.000				0708SW	0.503	3.558
0304NE	0.476	1.574	0506SE	0.520	2.000				0809NW	0.466	3.236
0304SW	0.526	2.717	0506PB	0.575	2.423				0809SW	0.465	3.236
0304SE	0.589	1.856	0708NW	0.587	1.975				0809NE	0.466	3.236
0304PB	0.626	1.966	0708NE	0.587	1.975				0809SE	0.465	3.236
			0708SW	0.493	1.975						
			0708SE	0.493	1.975						
			0708PB	0.587	1.975						

Table 13 (Cont).

Area IIIE SSV			Area IIIE SVC			Area VIW SSV			Area VIW SVC		
Strata	g(0)	$E(s)$	Strata	g(0)	$E(s)$	Strata	g(0)	$E(s)$	Strata	g(0)	$E(s)$
9596IIIE	0.634	1.459	9596IIIE	0.665	1.000	9697VIW	0.534	2.322	9697VIW	0.564	2.111
9798IIIE	0.621	1.673	9798IIIE	0.665	1.000	9899VIW	0.602	1.371	0001VIW	0.595	1.400
9900IIIE	0.560	2.074	9900IIIE	0.635	3.000	0001VIW	0.489	3.660	0203VIW	0.590	1.500
0102IIIE	0.487	2.858	0102IIIE	0.531	3.889	0203VIW	0.610	1.200	0405VIW	0.613	1.286
0304IIIE	0.576	2.594	0304IIIE	0.636	2.241	0405VIW	0.581	1.634	0607VIW	0.520	2.846
			0506IIIE	0.582	2.667				0809VIW	0.595	1.556
			0708IIIE	0.606	1.975						

Table 14. Minke whale abundance estimates when weighted over survey modes for the various sensitivity tests. Percentage changes are relative to the base case. For the base case the CV of each estimate is shown in parentheses.

Area IV

Year	1989/90	1991/92	1993/94	1995/96	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08	Average of change
Base case	**29,993**	**32,418**	**27,598**	**32,970**	**16,562**	**44,945**	**30,807**	**32,970**	**63,794**	**15,088**	-
	(0.527)	**(0.720)**	**(0.473)**	**(0.458)**	**(0.542)**	**(0.338)**	**(0.402)**	**(0.682)**	**(0.509)**	**(0.645)**	
Trackline option B	26,135	28,589	20,941	25,624	15,789	43,122	46,577	24,795	20,748	17,518	-
	-12.9%	-11.8%	-24.1%	-22.3%	-4.7%	-4.1%	51.2%	-24.8%	-67.5%	16.1%	-10.5%
Trackline option C	28,946	30,430	28,985	28,860	19,326	45,115	54,066	53,075	25,810	20,969	-
	-3.5%	-6.1%	5.0%	-12.5%	16.7%	0.4%	75.5%	61.0%	-59.5%	39.0%	11.6%
Alternative detection functions	31,136	34,949	29,606	28,722	28,320	71,563	50,111	42,844	28,987	25,052	-
	3.8%	7.8%	7.3%	-12.9%	71.0%	59.2%	62.7%	29.9%	-54.6%	66.0%	24.0%
Gap density = 0	29,053	31,062	26,082	26,404	16,249	53,858	48,350	28,322	25,508	19,786	-
	-3.1%	-4.2%	-5.5%	-19.9%	-1.9%	19.8%	56.9%	-14.1%	-60.0%	31.1%	-0.1%
Gap density = stratum to the south	24,165	24,539	24,723	32,741	17,831	55,449	42,348	29,696	30,394	21,573	-
	-19.4%	-24.3%	-10.4%	-0.7%	7.7%	23.4%	37.5%	-9.9%	-52.4%	43.0%	-0.6%
Extrapolation for incomplete coverage	29,085	31,603	24,869	31,441	16,339	53,235	49,912	30,558	26,373	20,521	-
	-3.0%	-2.5%	-9.9%	-4.6%	-1.4%	18.4%	62.0%	-7.3%	-58.7%	36.0%	2.9%
Skipping correction	-	-	24,735	29,692	16,288	56,982	50,810	30,333	27,832	21,316	-
(Ignoring the first two surveys)	-	-	-10.4%	-9.9%	-1.7%	26.8%	64.9%	-8.0%	-56.4%	41.3%	5.8%
g(0) adjustment	50,736	55,878	44,127	55,024	30,585	95,725	91,987	53,260	48,570	41,094	
	69.2%	72.4%	59.9%	66.9%	84.7%	113.0%	198.6%	61.5%	-23.9%	172.4%	87.5%

Area V

Year	1990/91	1992/93	1994/95	1996/97	1998/99	2000/01	2002/03	2004/05	2006/07	2008/09	Average of change
Base case	**100,745**	**78,919**	**104,013**	**99,680**	**118,779**	**106,991**	**151,072**	**74,030**	**67,661**	**109,173**	-
	(0.445)	**(0.371)**	**(0.458)**	**(0.461)**	**(0.515)**	**(0.523)**	**(0.326)**	**(0.336)**	**(0.308)**	**(0.523)**	
Trackline option B	122,928	81,716	108,256	160,110	135,547	108,120	124,819	81,913	73,605	94,958	-
	22.0%	3.5%	4.1%	60.6%	14.1%	1.1%	-17.4%	10.6%	8.8%	-13.0%	9.4%
Trackline option C	146,733	86,866	124,378	162,693	145,831	117,597	135,090	77,014	73,602	98,742	-
	45.6%	10.1%	19.6%	63.2%	22.8%	9.9%	-10.6%	4.0%	8.8%	-9.6%	16.4%
Alternative detection functions	116,939	83,776	162,192	163,258	103,951	124,455	140,249	83,024	94,667	106,329	-
	16.1%	6.2%	55.9%	63.8%	-12.5%	16.3%	-7.2%	12.1%	39.9%	-2.6%	18.8%
Extrapolation for incomplete coverage	126,701	78,546	114,884	142,237	124,170	103,468	118,477	94,021	65,730	95,561	-
	25.8%	-0.5%	10.5%	42.7%	4.5%	-3.3%	-21.6%	27.0%	-2.9%	-12.5%	7.0%
Skipping correction	-	-	131,234	91,093	107,463	110,894	107,607	66,138	54,470	93,220	-
	-	-	26.2%	-8.6%	-9.5%	3.6%	-28.8%	-10.7%	-19.5%	-14.6%	-7.7%
g(0) adjustment	224,784	151,466	221,444	299,433	255,613	207,068	237,176	132,431	139,878	200,831	
	123.1%	91.9%	112.9%	200.4%	115.2%	93.5%	57.0%	78.9%	106.7%	84.0%	109.1%

Table 15. Estimated annual rate of increase in minke whale abundance (α), together with their standard errors and 95% confidence intervals, as provided by the log-linear model selected by AICc for the base case and sensitivities for Areas IIIE+IV and V+VIW. σ is the standard derivation of the 'model error' distribution associated with the logarithms of the abundance estimates. Base_P: Base case (based on abundance), Base_D: Base case but using density instead of abundance, TB: Trackline option B, TC: Trackline option C, DF: Alternative detection function, G0: Density in Gap =0, GB: Density in Gap is as in stratum to the south, IC: Interpolation in incomplete coverage area, SK: Omit years when skipping occurred.

a) Areas IIIE + IV

Sensitivity	α	SE(α)	α95%*LL*	α95%*UL*	σ	SE(σ)	Selected model
Base_P	0.011	0.017	-0.023	0.045	0.755	0.069	i)
Base_D	0.010	0.016	-0.022	0.042	0.688	0.064	i)
TB	0.014	0.020	-0.025	0.053	0.745	0.068	iii) with T3
TC	0.028	0.019	-0.010	0.065	0.699	0.065	iii) with T3
DF	0.031	0.019	-0.006	0.069	0.700	0.065	iii) with T3
G0	0.001	0.022	-0.042	0.045	0.556	0.075	iii) with T3
GB	0.034	0.019	-0.005	0.072	0.659	0.063	iv) with T3
IC	0.026	0.019	-0.011	0.063	0.690	0.065	iii) with T3
SK	0.037	0.024	-0.010	0.085	0.725	0.070	iii) with T3
g(0) adjusted	0.025	0.019	-0.013	0.063	0.717	0.066	iii) with T3

b) Areas V+VIW

Sensitivity	α	SE(α)	α95%*LL*	α95%*UL*	σ	SE(σ)	Selected model
Base_P	0.006	0.014	-0.022	0.033	0.575	0.059	i)
Base_D	0.004	0.013	-0.021	0.034	0.509	0.055	i)
TB	-0.006	0.015	-0.038	0.025	0.430	0.055	iv) with T3
TC	-0.017	0.015	-0.047	0.013	0.409	0.055	iv) with T3
DF	-0.005	0.016	-0.038	0.028	0.458	0.054	iv) with T3
IC	-0.009	0.015	-0.040	0.023	0.415	0.054	iv) with T3
SK	-0.013	0.020	-0.055	0.028	0.498	0.061	iv) with T4
g(0) adjusted	-0.006	0.016	-0.039	0.026	0.430	0.057	iv) with T3

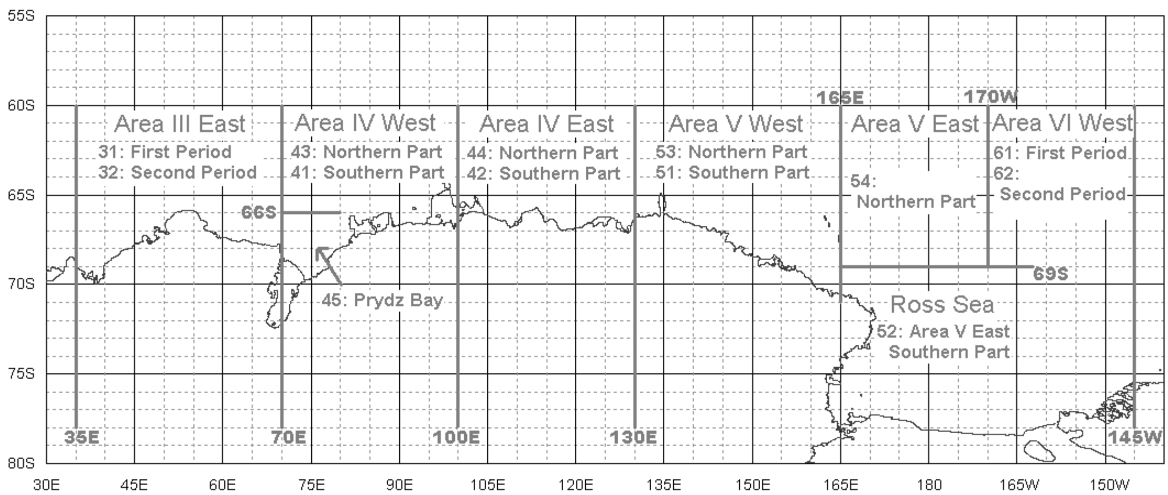


Figure 1. Stratification of the JARPA and JARPA II research area. Area IIIE and VIW were stratified into northern and southern strata in the JARPA II period.

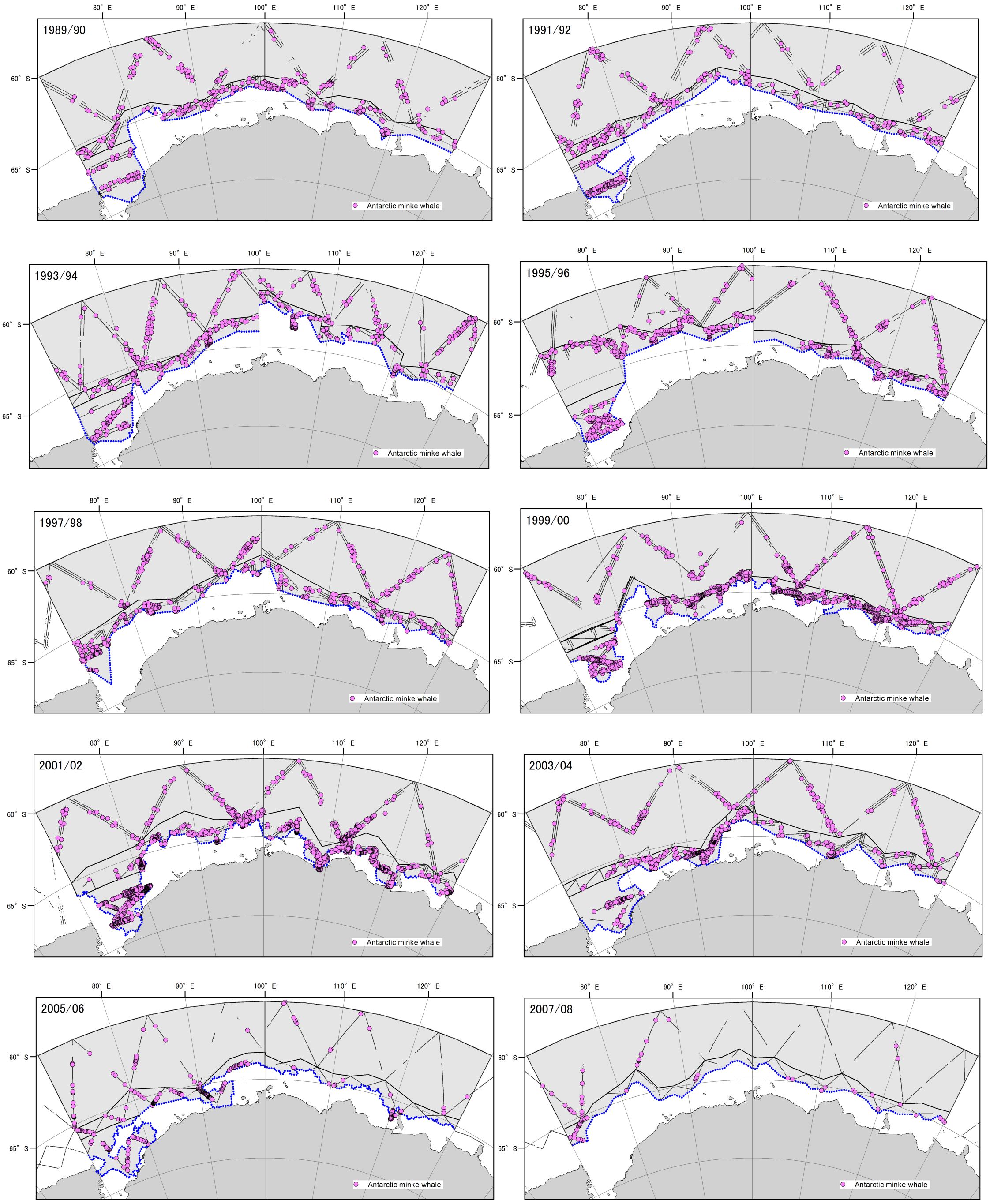


Figure 2a. Primary searching effort (thin lines) and associated primary sightings of minke whales (pink circle) in Area IV (70°E-130°E) together with the ice edge (dotted blue line) from 1989/90 to 2007/08 JARPA and JARPA II surveys.

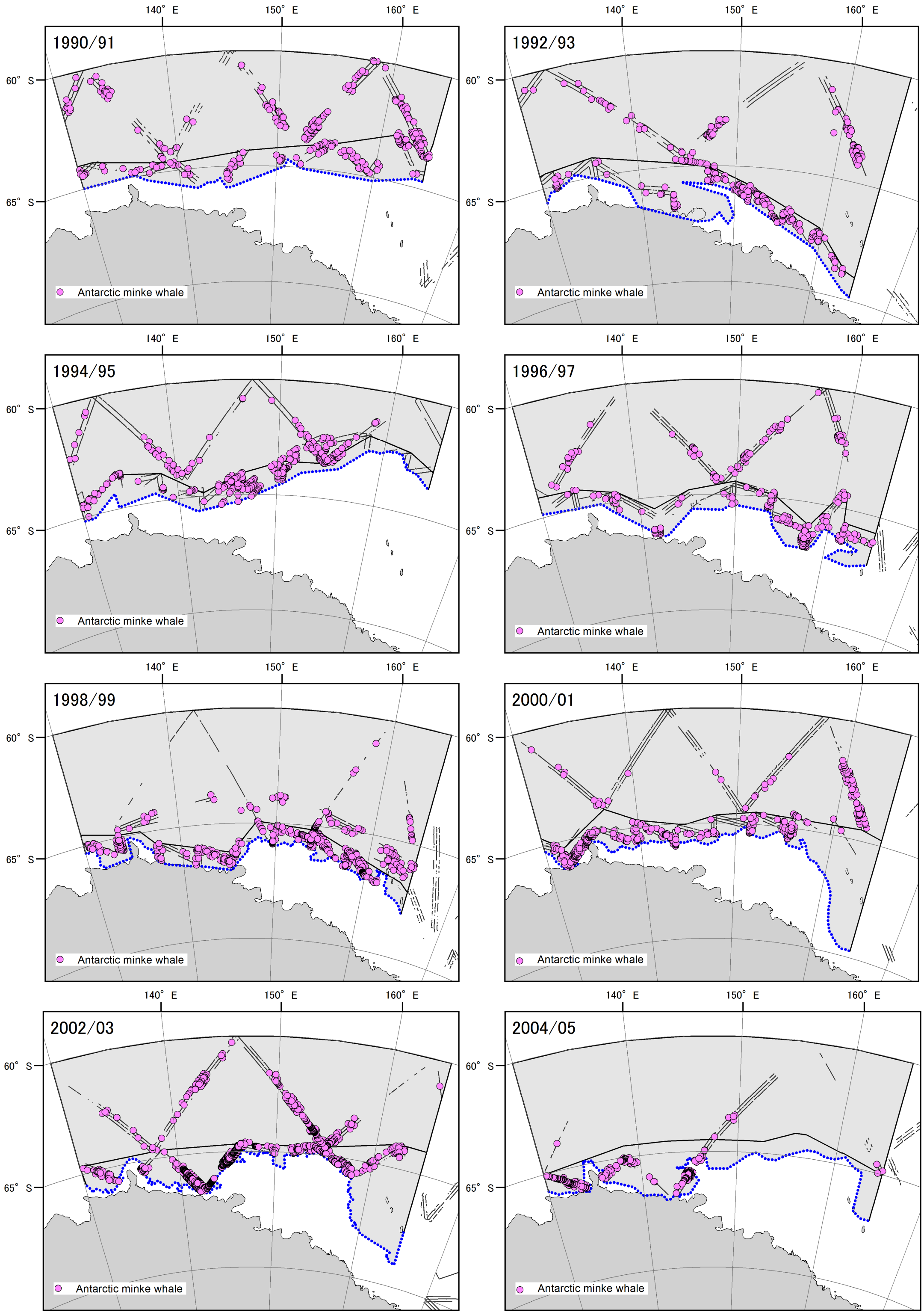


Figure 2b. Primary searching effort (thin lines) and associated primary sightings of minke whales (pink circle) in Area VW (130°E-165°E)together with the ice edge (dotted blue line) from 1990/91 to 2008/09 JARPA and JARPA II surveys.

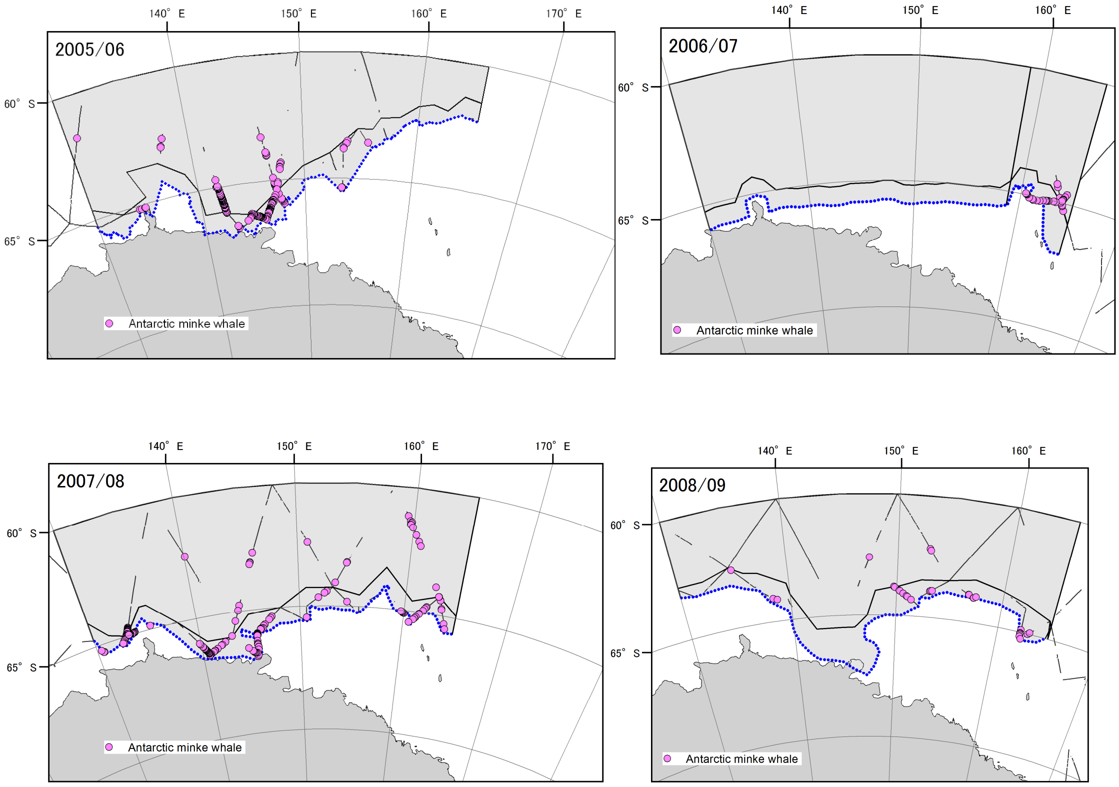


Figure 2b (Cont.).

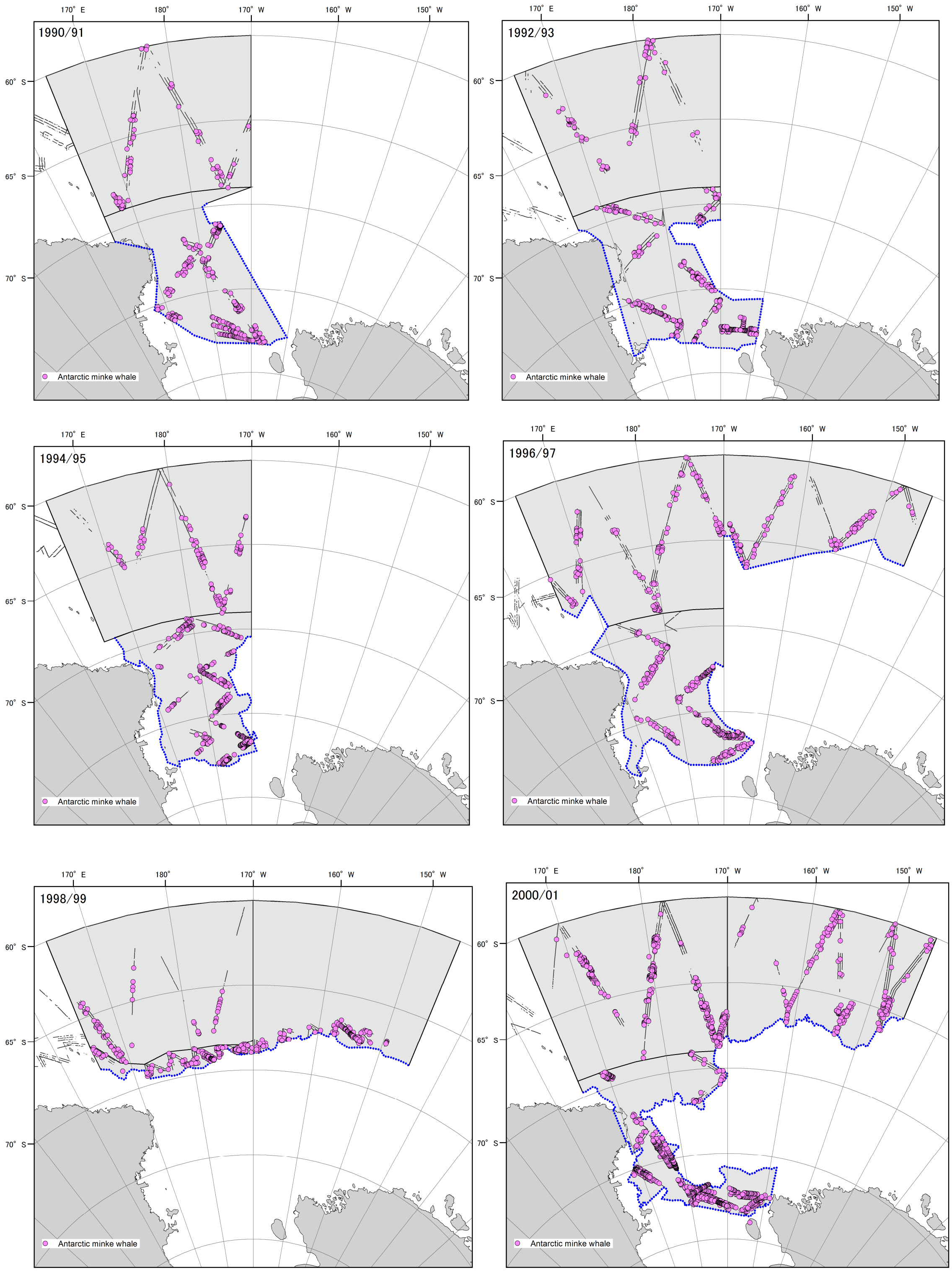


Figure 2c. Primary searching effort (thin lines) and associated primary sightings of minke whales (pink circle) in Areas VE and VIW (165^{o}E-145^{o}W)together with the ice edge (dotted blue line) from 1990/91 to 2008/09 JARPA and JARPA II surveys.

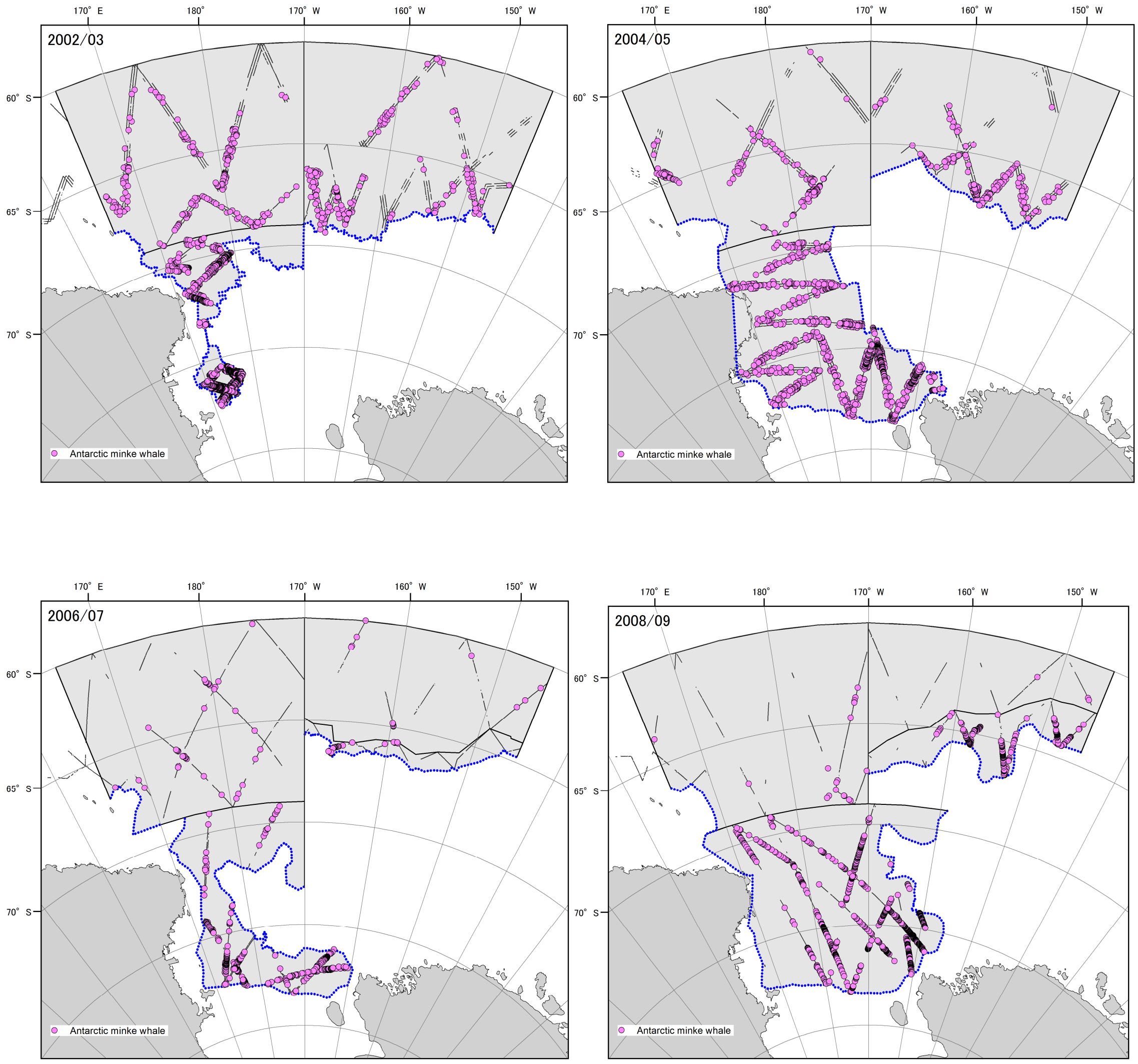


Figure 2c (Cont.).

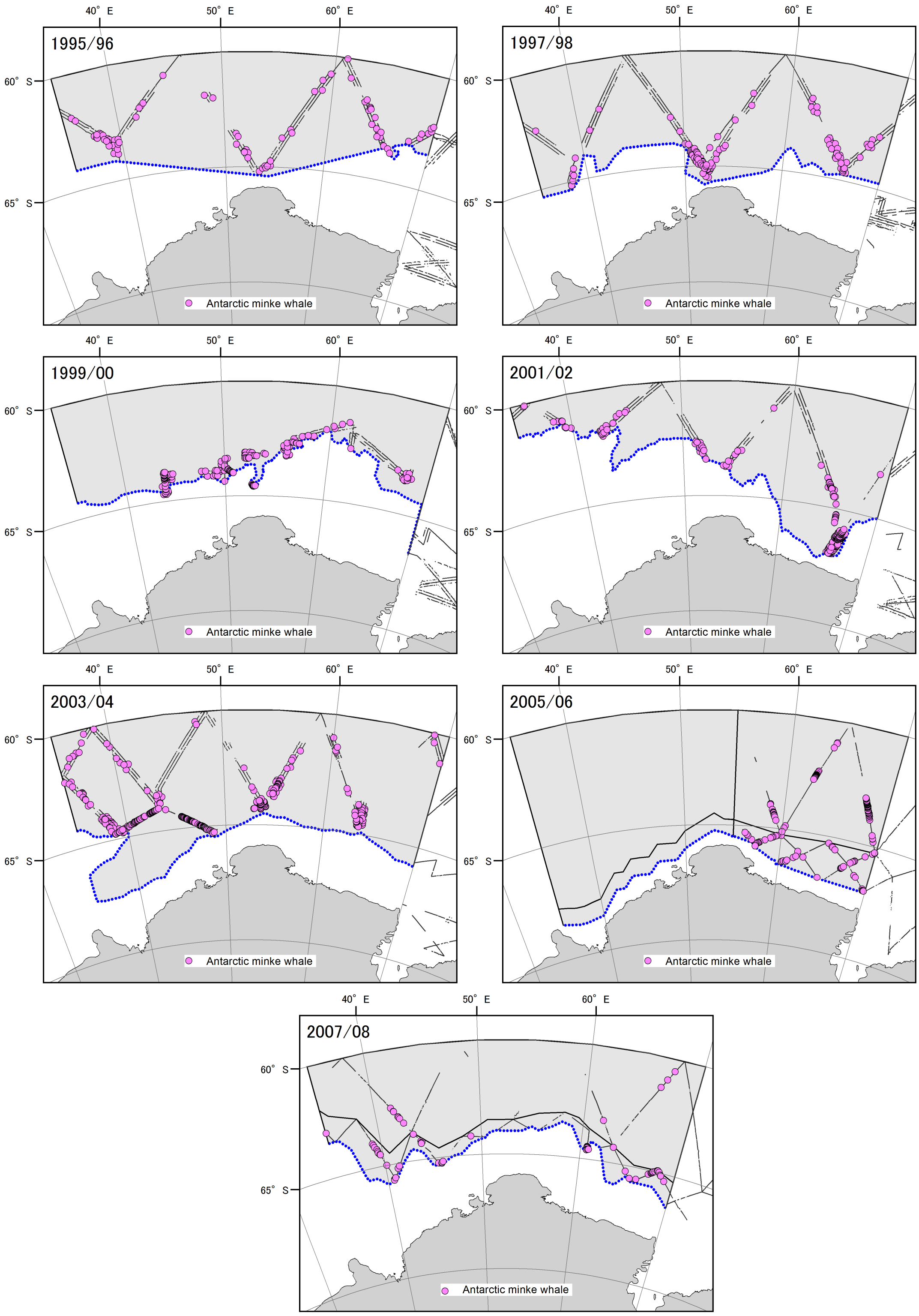


Figure 2d. Primary searching effort (thin lines) and associated primary sightings of minke whales (pink circle) in Area IIIE (35°E-70°E) together with the ice edge (dotted blue line) from 1995/96 to 2007/08 JARPA and JARPA II surveys.

a) Areas IIIE, IV and part of V combined (35°E-175°E).

1989/90

IV-NW 5	IV-NE 2
IV-SW 3	IV-SE 1
IV-PB 4	

1991/92

IV-NW 5	IV-NE 1
IV-SW 3	IV-SE 2
IV-PB 4	

1993/94

IV-NW 5	IV-NE 2
IV-SW 3	IV-SE 1
IV-PB 4	

1995/96

III-E 1	IV-NW 3	IV-NE 5
	IV-SW 2	IV-SE 6
	IV-PB 4	

1997/98

III-E 1	IV-NW 2	IV-NE 4
	IV-SW 5	IV-SE 3
	IV-PB 6	

1999/00

III-E 1	IV-NW 2	IV-NE 3
	IV-SW 5	IV-SE 4
	IV-PB 6	

2001/02

III-E 1	IV-NW 2	IV-NE 3
	IV-SW 5	IV-SE 4
	IV-PB 6	

2003/04

III-E 1	IV-NW 2	IV-NE 3
	IV-SW 5	IV-SE 4
	IV-PB 6	

2005/06

III-NE 3	IV-NW 4	IV-NE 6	V-NW 2	V-NE 1
III-SE 3	IV-SW 4	IV-SE 6	V-SW 2	V-SE 1
	IV-PB 5			

2007/08

III-NE 1	IV-NW 2	IV-NE 3	V-NW 4	V-NE unsurveyed
III-SE 1	IV-SW 2	IV-SE 3	V-SW 4	V-SE unsurveyed
	IV-PB unsurveyed			

b) Areas V and VIW combined (130°E-145°W)

1990/91

V-NW 2	V-NE 4
V-SW 1	V-SE 3

1992/93

V-NW 3	V-NE 1
V-SW 2	V-SE 4

1994/95

V-NW 2	V-NE 3
V-SW 1	V-SE 4

1996/97

V-NW 4	V-NE 2	VI-W 1
V-SW 3	V-SE 5	

1998/99

V-NW 2	V-NE 1	VI-W 5
V-SW 3	V-SE 4	

2000/01

V-NW 4	V-NE 2	VI-W 1
V-SW 5	V-SE 3	

2002/03

V-NW 4	V-NE 2	VI-W 1
V-SW 5	V-SE 3	

2004/05

V-NW 4	V-NE 2	VI-W 1
V-SW 5	V-SE 3	

2006/07

V-NW 4	V-NE 2	VI-NW 1
V-SW 4	V-SE 3	VI-SW 1

2008/09

V-NW 1	V-NE 4	VI-NW 2
V-SW 1	V-SE 3	VI-SW 2

Figure 3. Survey order by strata for the JARPA and JARPA II cruises from 1989/90 to 2008/09. Key: III=Area III, IV=Area IV, V=Area V, VI=Area VI, E=East, W=West, NW=North-West, NE=North-East, SW=South-West, SE=South-East, PB= Prydz Bay. Common number in a season indicates that two strata were surveyed in a same period. V-NE, V-SE and IV-PB strata could not be surveyed at all in 2007/08 season.

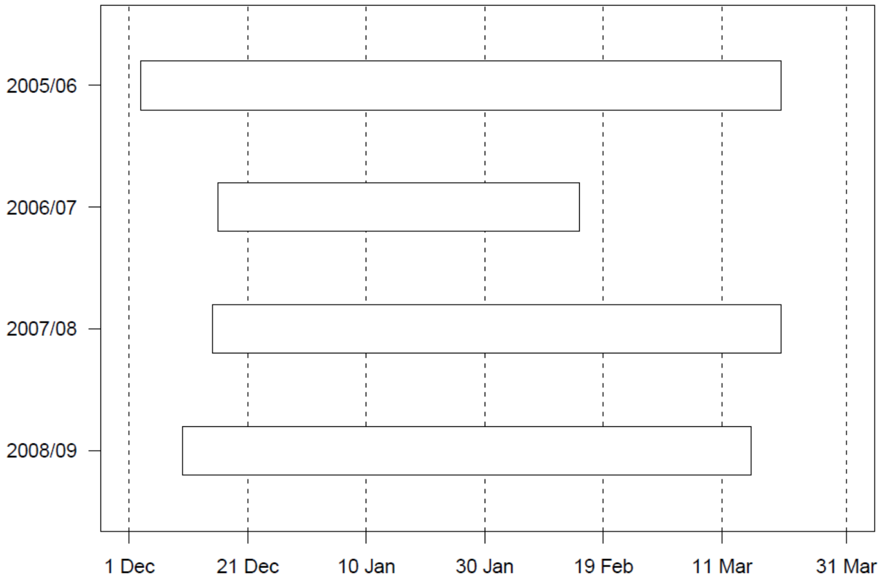


Figure 4. Start and end dates of JARPA II surveys (2005/06-2008/2009) in the survey area.

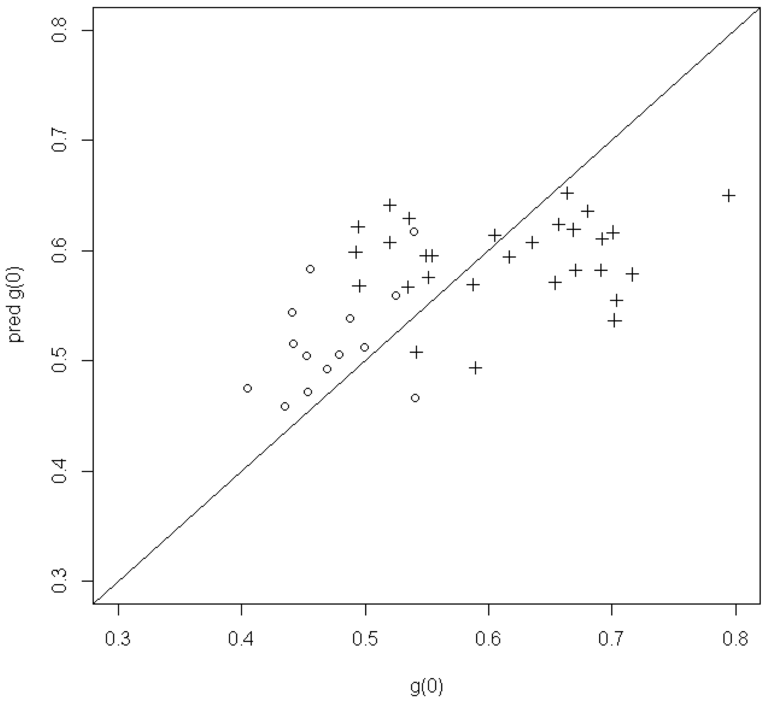
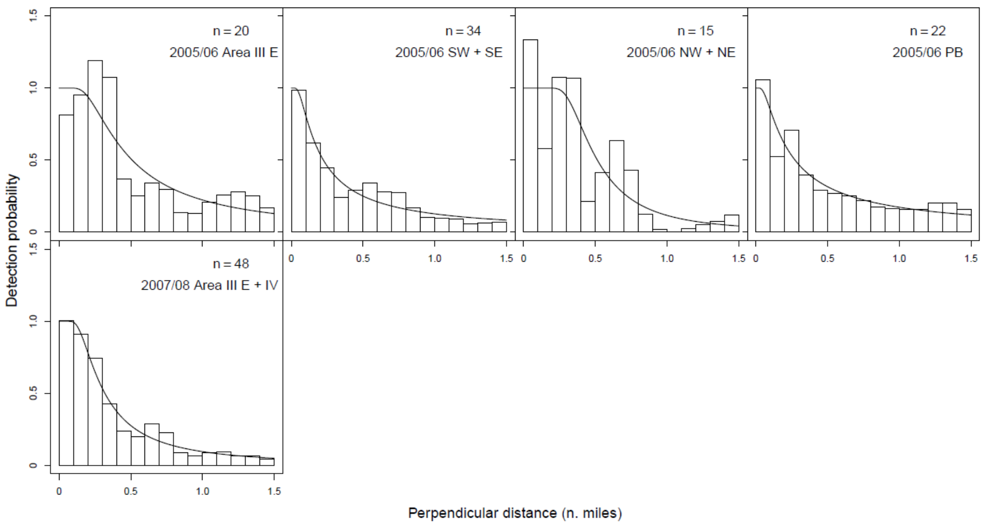


Figure 5. The values predicted by the regression relationship of equation (21) for g(0) by block for the IDCR-SOWER surveys in Areas III, IV, V and VI are shown plotted against the estimates obtained by circumpolar cruise (CPII) are shown by (o) and those from CPIII by (+). A 45^{o} line is added to show where points would reflect exact agreement.

Areas IIIE and IV



Areas V and VIW

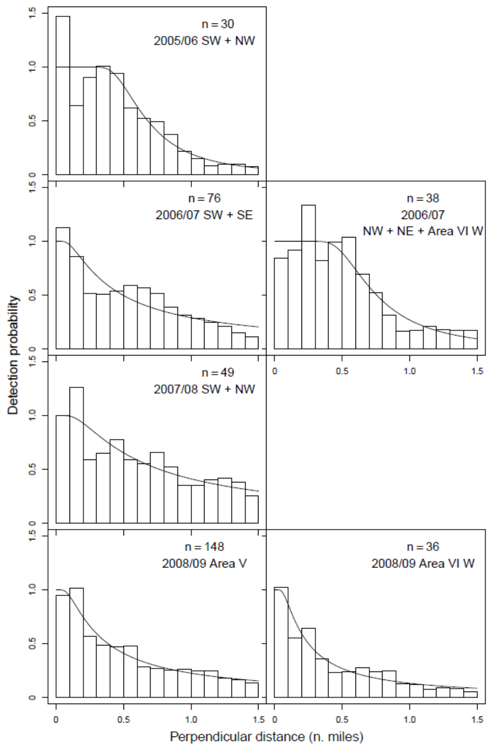
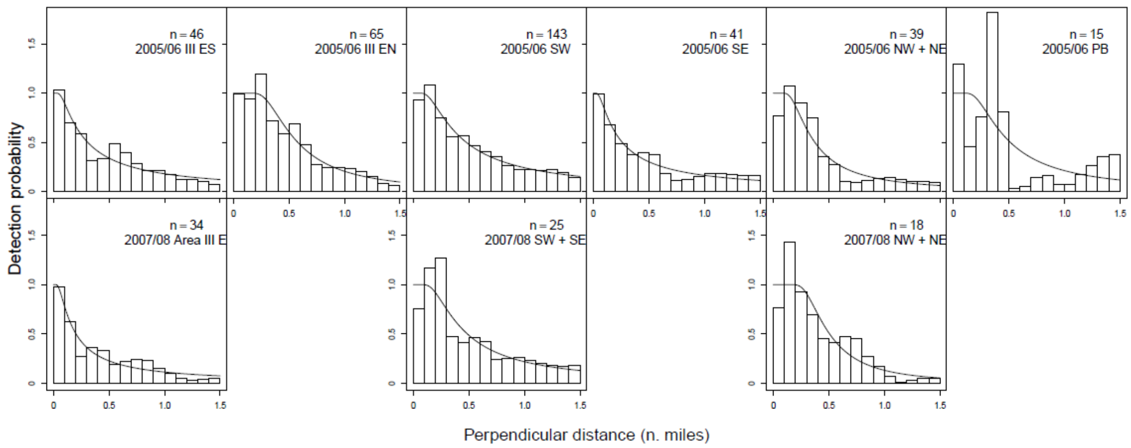


Figure 6a. Histograms of the smeared perpendicular distance (in n.miles) distributions of minke school sightings with fitted detection functions for each stratum in Areas IIIE, IV, V and VIW for SVC data. *n* is the number of the sightings used in estimation of the detection function.

Areas IIIE and IV



Areas V and VIW

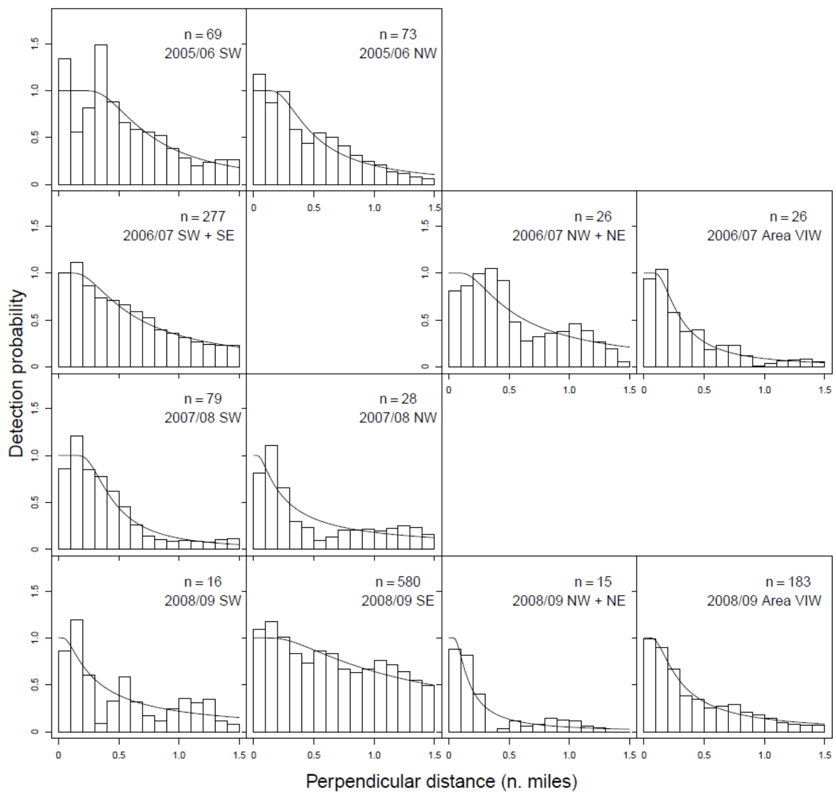
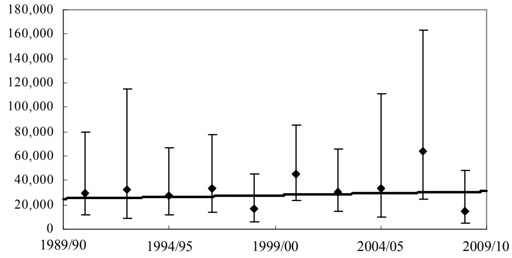


Figure 6b. Histograms of the smeared perpendicular distance (in n.miles) distributions of minke school sightings with fitted detection functions for each stratum in Areas IIIE, IV, V and VIW for SVP data. *n* is the number of the sightings used in estimation of the detection function.

Area IV



Area V

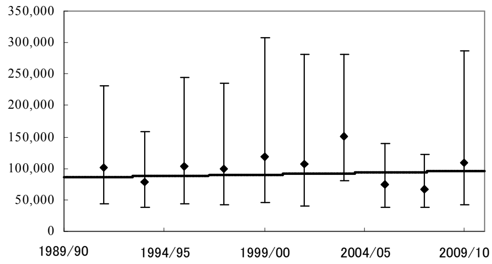
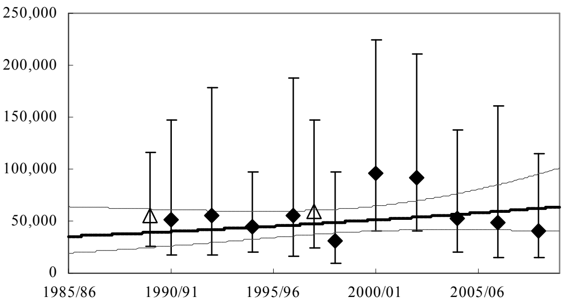


Figure 7. The base case estimates of annual abundance from Table 14 together with their 95% CIs are compared to exponential trend estimated by the AICc-selected model i) of equation (7) for Areas IV (left panel) and V (right panel).

Area IV



Area V

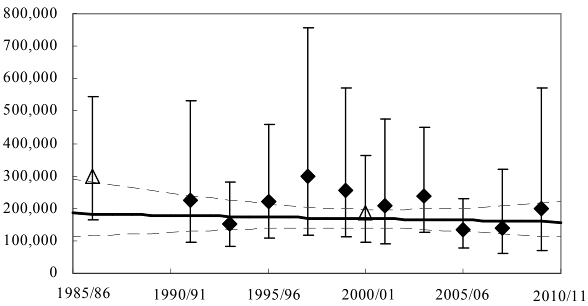


Figure 8. Plots as for Figure 7, but with the abundance estimates and associated exponential model for the base case replaced by the corresponding g(0)-adjusted results. The IDCR-SOWER estimates for a common northern boundary for CPII and CPIII as agreed by the 2012 IWC SC meeting are shown by the open triangles (IWC, 2013); their confidence intervals include allowance for additional variance, as do those for the JARPA and JARPA II surveys. The dashed curves indicate the 95% CIs for the exponential model.