Analysis of simulated Antarctic minke surveys using the "standard" method and the "direct duplicate" method

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ABSTRACT
Four new scenarios (sc33–sc36) of simulated survey data are analysed using the "standard" distance sampling method and the direct duplicate method of Palka (1995). The new scenarios were "blind" in that true simulated densities and the factors included were not revealed. Estimated densities were 0.029, 0.021, 0.082, and 0.063 whales per km^2 for the four scenarios using the "standard" method, and 0.029, 0.020, 0.081, and 0.062 whales per km^2 for the direct duplicate method. Some negative bias in estimates is expected from the standard method due to whales on the trackline being missed by the surveys. If true, the direct duplicate method then failed to correct for this bias for these scenarios, as resulting estimates were very similar to those obtained from the "standard" method.

INTRODUCTION

Circumpolar abundance estimates for Antarctic minke whales (*Balaenoptera bonaerensis*) have been obtained from the IWC's IDCR/SOWER programmes using standard line transect methodology (Branch and Butterworth 2001, Branch 2005c). These estimates were appreciably lower in the third circumpolar set of surveys (CPIII, 1991/92–2003/04) than in the second circumpolar set (CPII, 1985/86–1990/91). There are many possible reasons for this difference (Branch 2006), one of which is that the bias associated with the estimation methods may have changed over time. In particular, the "standard" method assumes that all whales on the trackline are spotted, conventionally termed the $g(0)=1$ assumption, where $g(y)$ is the probability that a school is detected at perpendicular distance y from the vessel trackline. Three alternative analysis methods have been developed to provide estimates of the abundance from the surveys, in the hope that these will provide better estimates of abundance without making this assumption: the Big Beautiful Model (Bravington 2004), the hazard probability model (Okamura and Kitakado 2004, Okamura *et al.* 2005), and the integrated model method (Cooke 2001).

To test the robustness of these models, two previous sets ("2004" and "2005") of simulated survey data have been produced for analysis (Palka and Smith 2004, 2005). These data sets were analysed using the three alternative analysis methods, the "standard" method, and in addition a variant of the "standard" method called the direct duplicate method (Palka 1995). Results were presented at previous IWC meetings (Bravington 2004, Palka 2004, Branch 2005a, 2005b, Okamura and Kitakado 2005). Four new scenarios with associated simulated data, for which the true parameters were completely unknown, are analysed here using the "standard" method and the direct duplicate method.

METHODS

Input data

Four sets of new simulation data (sc33, sc34, sc35, and sc36) were provided by D. Palka, pers. comm. Simulated data differ somewhat from the IDCR/SOWER surveys (Branch 2005b). Simulation methods are described elsewhere and are similar to those used for the "2004" and "2005" sets of data (Palka and Smith 2005). As before, each scenario contains 100 simulated surveys (iterations). The key difference from last year's analysis is that the factors underlying each scenario and the true simulated values for density were not revealed, making the tests for these scenarios truly blind. This ensured that the analytical methods could not be adjusted to obtain better density estimates by, for example, adding covariates known to be important in the simulated data.

Analysis: "standard" method

The analytical methods for the "standard" method are described in detail in Branch (2005b). The methods used to analyse the actual IDCR/SOWER data differ slightly from those used to analyse the simulated data (Branch 2005b), primarily in that no closing mode data are available to estimate mean school size so that IO data are used; furthermore the sightings are not "smeared" and the statistical package *R* is used to automate the process of calling Distance software instead of the software package DESS. The standard line transect formula used for estimating the density of whales (D_w) and schools (D_s) is:

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$$D_s = \frac{n}{2\mu L}, \quad D_w = D_s E[s]$$

where:

n = number of schools sighted within truncation distance of 1.5 n.miles

L = total survey length

μ = estimated strip half width, or esw, using a hazard rate model

$E[s]$ = estimated mean school size, using a regression method except in exceptional circumstances

Analysis: direct duplicate method

Methods for applying the direct duplicate method (Palka 1995) to these simulated data were described previously by Branch (2005a). Estimates of density are obtained using the same formula as for the "standard" method, except that separate estimates are obtained for sightings made in three different ways: those made from the barrel (topman) position, from the independent observer (IO) platform, and those sighted by both the barrel and the IO platform (i.e. duplicate sightings). Sightings from the bridge are excluded from the analysis. The Petersen two-sample mark-recapture equation is then assumed to hold in that whales can either be sighted ("marked") by the barrel or the IO platform, while duplicate sightings are treated as recaptures. The density of whales (D_w) is given by:

$$D_w = \frac{D_{w,IO} D_{w,topman}}{D_{w,duplicates}}$$

where:

$D_{w,IO}$ = density calculated from all sightings seen from the IO platform

$D_{w,topman}$ = density calculated from all sightings seen from the topman platform

$D_{w,duplicates}$ = density calculated from all sightings seen from both the IO platform and the topman platform

RESULTS

"Standard" method

Estimated school size was similar (2.31–2.36) over the four scenarios but estimated effective strip half width is lower for sc34 (1146 m) and sc36 (1143 m) than for sc33 (1722 m) and sc35 (1731 m). The estimated densities of whales for the four scenarios are 0.029, 0.021, 0.082, and 0.063 per km^2 (Table 1, Figure 1). Mean CVs for the density estimates were 0.07–0.10.

Direct duplicate method

Estimated school size is slightly higher from the IO platform sightings (2.45–2.56) and topman sightings (2.39–2.49) than the estimates from all platforms obtained for the "standard" method; duplicate sightings have even higher estimated school sizes of 2.51–2.74 (Table 2). For all scenarios, strip half-widths from individual platforms are narrower than obtained from all platforms, and narrower still for duplicate sightings. The estimated density of whales is 0.98–0.99 of that obtained using the "standard" method (Table 2, Figure 2).

DISCUSSION

The "standard" method and direct duplicate method provide near-identical estimates of density for the four new simulations. In previous analyses, the direct duplicate method nearly always estimated density to be higher than the "standard" method (Branch 2005b, 2005a), but this difference was most pronounced for simulated surveys alternating between closing mode and IO mode. For scenarios consisting only of IO mode, similar to those provided for this assessment, the difference between estimates from the "standard" method and direct duplicate method were minimal. It is to be expected that some whales on the simulated trackline were missed, and thus that the "standard" estimates are negatively biased. It was expected that the direct duplicate method would be less affected by this bias, as appeared to be the case for previous simulations (Branch 2005a), but for the present simulations the direct duplicate method did not provide higher estimates of density than the "standard" method, suggesting that it did not adequately account for this bias. In most cases the CVs for the direct duplicate method's estimates of density are somewhat higher, as might be expected since this approach implicitly attempts estimation of more parameters from the data.

ACKNOWLEDGEMENTS

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REFERENCES

Branch, T. A. 2005a. Applying the direct duplicate method to simulated IDCR/SOWER survey data. IWC Paper **SC/57/IA15**:10pp.

Branch, T. A. 2005b. Estimated density of Antarctic minke whales obtained from simulated IDCR/SOWER survey data using the "standard method". IWC Paper **SC/57/IA14**:16pp.

Branch, T. A. 2005c. Preliminary abundance estimates for Antarctic minke whales from three completed sets of IDCR/SOWER circumpolar surveys, 1978/79 to 2003/04. IWC Paper **SC/57/IA16**:26 pp.

Branch, T. A. 2006. Possible reasons for the appreciable decrease in abundance estimates for Antarctic minke whales from the IDCR/SOWER surveys between the second and third circumpolar sets of cruises. IWC Paper **SC/58/IA4**:8pp.

Branch, T. A., and D. S. Butterworth. 2001. Southern Hemisphere minke whales: standardised abundance estimates from the 1978/79 to 1997/98 IDCR/SOWER surveys. Journal of Cetacean Research and Management **3**:143-174.

Bravington, M. 2004. A new spatial abundance estimator, applied to simulated survey data. IWC Paper **SC/56/IA3**:12 pp.

Cooke, J. G. 2001. A modification of the radial distance method for dual-platform line transect analysis, to improve robustness. IWC Paper **SC/53/IA31**:7 pp.

Okamura, H., and T. Kitakado. 2004. Advance in an abundance estimation model of Antarctic minke whales. IWC Paper **SC/56/IA9**:12 pp.

Okamura, H., and T. Kitakado. 2005. Performance of an Antarctic minke whale's abundance estimator when applied to simulated data. IWC Paper **SC/57/IA4**:6pp.

Okamura, H., T. Kitakado, and M. Mori. 2005. An improved method for line transect sampling in Antarctic minke whale surveys. Journal of Cetacean Research and Management **7**:97-106.

Palka, D. 1995. Abundance estimate of the Gulf of Maine harbor porpoise. Reports of the International Whaling Commission (Special Issue) **16**:27-50.

Palka, D. 2004. Results of three methods when applied to simulated data. IWC Paper. 2 pp.

Palka, D. L., and D. W. Smith. 2004. Simulating the IDCR/SOWER surveys - 2004. IWC Paper **SC/56/IA6**:16 pp.

Palka, D. L., and D. W. Smith. 2005. Description of 2005 simulations of the IWC/SOWER Southern Hemisphere minke whale abundance surveys. IWC Paper **SC/57/IA2**:8pp.

Table 1. Summary statistics (mean and CV) for the "standard" method. Results are given for effective strip half-width in m, esw, estimated mean school size, E[s], density of schools in no per km^2, D_s, and density of whales in no per km^2, D_w.

Scenario	esw	CV	$E[s]$	CV	D_s	CV	$\boldsymbol{D_w}$	**CV**
sc33	1722	0.075	2.36	0.056	0.0123	0.085	**0.0290**	**0.098**
sc34	1146	0.075	2.31	0.049	0.0089	0.082	**0.0206**	**0.093**
sc35	1731	0.079	2.35	0.049	0.0349	0.090	**0.0820**	**0.102**
sc36	1143	0.071	2.36	0.040	0.0268	0.076	**0.0630**	**0.071**

Table 2. Summary statistics (mean and CV) for the direct duplicate (DD) method. Component estimates are given based on the sightings from the IO platform, topman platform and for duplicate sightings made from both the IO and topman platforms. Components are effective strip half-width in m, esw, estimated mean school size, E[s], density of schools in no per km^2, D_s, and density of whales in no per km^2, D_w.

Scenario	esw (IO)	CV	esw (top)	CV	esw (dup)	CV
sc33	1454	0.086	1655	0.082	1340	0.101
sc34	1013	0.086	1162	0.088	984	0.099
sc35	1428	0.084	1657	0.085	1287	0.097
sc36	988	0.088	1160	0.083	943	0.101

Scenario	$E[s]$ (IO)	CV	$E[s]$ (top)	CV	$E[s]$ (dup)	CV
sc33	2.45	0.060	2.41	0.064	2.51	0.075
sc34	2.48	0.055	2.43	0.052	2.64	0.070
sc35	2.46	0.062	2.39	0.056	2.53	0.074
sc36	2.56	0.051	2.49	0.046	2.74	0.057

Scenario	D_s (IO)	CV	D_s (top)	CV	D_s (dup)	CV
sc33	0.0105	0.097	0.0113	0.091	0.0096	0.116
sc34	0.0069	0.097	0.0076	0.098	0.0059	0.109
sc35	0.0287	0.101	0.0316	0.095	0.0260	0.121
sc36	0.0202	0.096	0.0223	0.091	0.0170	0.112

Scenario	D_w (IO)	D_w (top)	D_w (dup)	$\boldsymbol{D_w}$ **(DD)**	**CV**
sc33	0.0256	0.0272	0.0242	**0.0288**	**0.114**
sc34	0.0171	0.0184	0.0155	**0.0203**	**0.097**
sc35	0.0706	0.0753	0.0658	**0.0810**	**0.100**
sc36	0.0516	0.0555	0.0464	**0.0617**	**0.080**

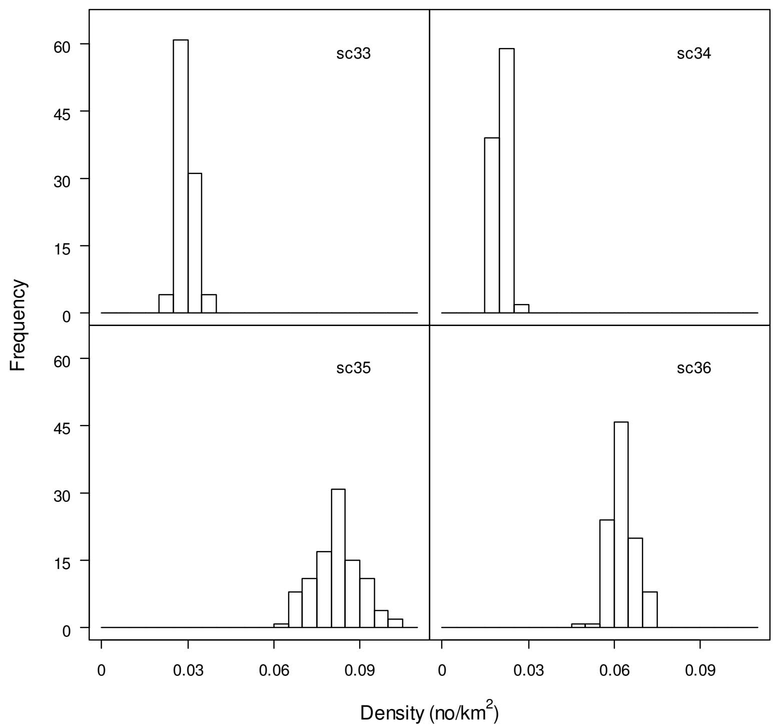

Figure 1. Histograms of density estimates (whales per km²) obtained using the “standard” method.

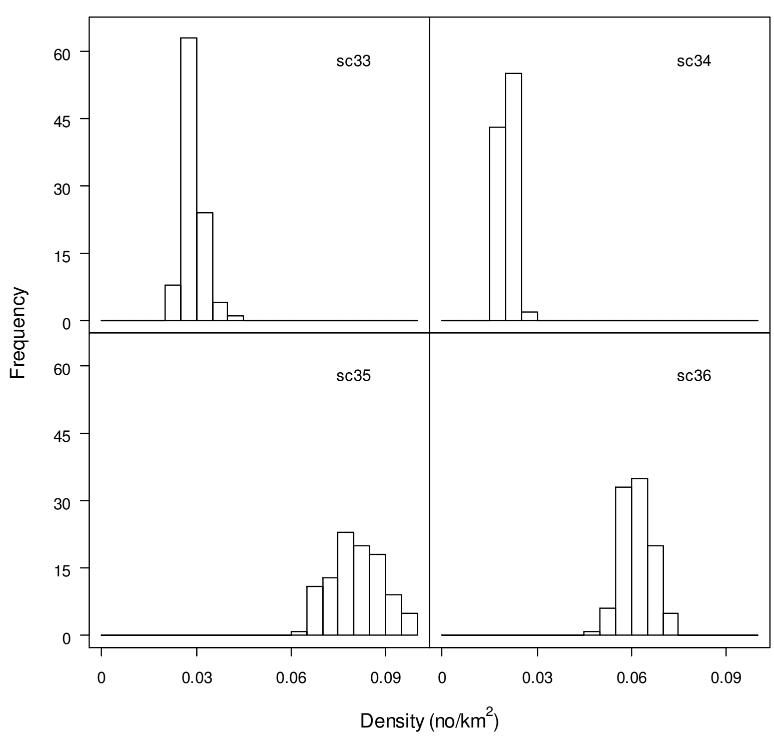

Figure 2. Histograms of density estimates (whales per km²) obtained using the direct duplicate method.