Australian Marine Mammal Centre

Final Report

(subclause 9 and Schedule Item 5 of the Funding Agreement)

- **Project No**. – 0809/6
- **Title** - Further investigation into abundance estimates of migrating humpback whales in Australia: Resolving unmodelled heterogeneity, estimating g(0) and producing new abundance estimates for both populations.
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- **Organisation** – University of Queensland

Activity Period – 23 April 2009 – 30 July 2010

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1. Activity Summary

A clear summary of approximately 500 words outlining the work undertaken and any significant findings (for publication on the Department's web site)

Heterogeneity in sighting whales is likely to arise from several factors including: (1) group characteristics such as group composition, behaviour and use of cues, distance from shore and position of surfacing, (3) sea state and associated environmental parameters; (4) angle of the sun including glare and cloud cover. This is the first time that the contribution to heterogeneity in detectability for humpback whales during land and aerial surveys has been assessed for a substantial set of variables. We found that there were a number of significant factors contributing to the detectability of passing whales; group composition, rate of passage, bearing from the land station when it was first spotted and the cue for the first sighting. The incorporation of these factors into a valid model significantly changed the final population count, from the original estimation of 6800 – 7000 whales (calculated in 2004 without including sources of heterogeneity) to approximately 7900 to 8100 whales. We found about 20% of available groups are missed by the land observers (compared to 10% calculated in 2004). Therefore, when undertaking any population survey, it is extremely important that all possible sources of heterogeneity are measured, modelled, and accounted for, within a final population model.

Aerial surveys can provide independent abundance estimates. However, estimating g0 in cetacean aerial surveys is typically problematic as current estimates of *g(0)* for humpback whale aerial surveys are substantially below 1. An inaccurate estimate of *g(0)* and lead to a severely inflated or deflated final population count. Previous

correction factors calculated for the Point Lookout land and aerial surveys have been based on simple mark-recapture data sets, but did not include any sources of heterogeneity. This study used a simple mark-capture-recapture approach to estimate g0 (by comparing sightings from a land station and from the aerial survey) and also incorporated sources of heterogeneity into the estimation of *g0*. We found that cloud cover was a major factor in affecting the sightability of groups and significantly changed the *g0*. Groups were approximately 3.7 times less likely to be observed at the highest cloud cover level compared to lower levels of cloud The previous correction factor calculated for the 2007 aerial survey raw data was 3.10 ± 0.13 (Noad et al. 2008). By incorporating sources of heterogeneity, we have increased the correction factor to 3.33 ± 0.10 which translates to a raw *g(0)*: 30 ± 3.0%. We multiplied the raw aerial *g(0)* with the correction factor from the double land platform surveys to obtain, for the first time, a robust estimate of *g(0)*: 24.0 ± 4.8% or 0.240 ± 0.048.

The combination of an elevated land-based viewing platform and a narrow migratory corridor (over 90% of humpback whales migrate within 10km off shore), has enabled us to obtain a robust estimate of *g(0)*for humpback whales, for the first time. The use of the re-calculated east Australian absolute abundance together with a comparison of the number of pods encountered during July aerial surveys yielded a population estimate of 28,007 ± 5235 whales (95% log normal CI 19,477 – 40,273). This agrees surprisingly well with Hedley et al.'s (2008) estimate of 21,750 (95% CI of 17,550 – 43,000), particularly with regards overlap of confidence intervals. This should provide additional confidence in both estimates particularly given that it uses a completely different and novel approach (albeit relying on some of the same data).

2. The Outcomes/Objectives

The degree to which the Activity has achieved the objectives

Objective 1: Using data from the 2004 and 2007 east coast land-based and aerial surveys, determine the contribution of each source of heterogeneity with regards to the detectability of passing whales.

This objective was achieved.

In this study, sources of heterogeneity are defined as factors which may affect the probability of a pod of whales being detected during a land-based and/or aerial population survey. More specifically the factors of interest to humpback whale surveys include: (1) environmental metrics, (2) time of day and season, (3) variation in observer sighting ability, (4) pod characteristics and (5) distance and bearing of the pod to the sighting platform.

a. 2004 double-land platform comparisons

Data for 17 factors that may be contributing to heterogeneity were sampled from 46 days of double land-platform whale observations (total observations = 466) between 26th May and 24th August 2004. Generalised linear modelling (GLM) was implemented in Program R to identify which factors significantly affected the probability of sighting any given pod. The response variable was binomial and based on the conditional probability (Buckland et al. 1993) where y = 0 indicated that a pod was not observed from the Norm's Seat platform given it was observed from the Whale Rock platform, and y = 1 indicated that a pod was observed from both platforms. Model selection was based on firstly, the removal of highly correlated variables and then secondly, Akaike's Information Criterion (AIC) was employed to select the most parsimonious model. Model fit to the data was assessed using cross-validation methods.

The final model identified four factors that significantly affected the detection probability of humpback whales from land. Pod composition (COMP) accounted for the greatest percentage of deviance (8.72%) in the final model and showed a positive relationship with detection probability although detection probability reached the maximum of 1 for all values of co-variates at pod compositions of 4 or greater whales. The rate of passage (RP) showed a negative relationship with detection probability indicating a decrease in detection as increasing numbers of whale pods were tracked simultaneously. The bearing direction (BEARcat) accounted for 4.07% of the deviance in the model fit with greater detection probabilities for the bearings at the extents of the field of view. That is, detection at the most northerly bearing and two most southerly bearings (E & F) were not significantly different to each other but were significantly greater than the three central eastern bearings. The sighting CUE was also found to have a significant effect on detection probability with significantly lower recapture for breaches than either blows or other types of surface activities.

b. 2007 aerial/land platform comparisons

Data for 14 factors that may be contributing to heterogeneity in whale sightings from aerial surveys were sampled from 16 days of simultaneous land and aerial platform whale observations between 3rd July and 29th July 2007. The modelling process was carried out as for the 2004 double-land platform surveys. Preliminary modelling showed that there was a significant increase of double-platform sightings on inbound transects rather than outbound transects, therefore where possible, inbound transects were included in the analyses resulting in a total of 76 observations. The final model identified two variables as having significant effect on probability of detection from aerial surveys: cloud cover and pod composition. Cloud cover had three levels and probability of sighting was significantly reduced at greater levels of cloud cover, which potentially reduces visibility through the water. Pod composition showed a positive linear relationship with detection probability.

The outcome from objective one is an updated population estimate which is based on the incorporation of the GLM analysis. The population estimate in 2004 was originally 7090± 660 whales, and has now been updated to 8070 ± 461 (95% CI 7154 – 8986), approximately 1000 more whales than originally calculated. The adjusted 2007 population is now 11,022 ± 779 whales (by applying a rate of increase of 10.95% per annum) and the predicted population estimate for 2010 is 15,053 ± 900 (95% CI 13,391 – 16,923), again applying a 10.95% per annum increase.

Objective 2: Re-examine the correction factor calculation for groups missed by the east coast land-based survey in order to improve the accuracy of the land-based abundance estimates.

This objective was achieved.

a. 2004 double-land platform comparisons

The final Generalised Linear Model (GLM) for the 2004 double-land platform surveys was used to calculate a correction factor (f_{m1}) for the number of whale pods that were available but not observed from the land platform.

f_{m1} = 1.251 ± 0.048 (standard error)

This corresponds to approximately 20% of the pods that were available, being missed by the observers on the secondary land platform. The incorporation of heterogeneity into this correction factor calculation resulted in a substantial increase on the original estimate of 10% of pods being missed from the original mark-recapture analyses on the data set (Noad et al. 2006).

b. 2007 land/aerial platform comparisons

To assess the discrepancy between the 23% of available whale pods being missed by land observers as calculated by double land platform GLM analyses and the suggested 30% of available whale pods being missed as calculated from aerial/land survey comparisons with mark-recapture methods (Noad et al. 2008), we re-examined the pod matching criteria between the 2007 land and aerial surveys. As indicated by the 2004 double land platform GLM analyses, whales were more likely to be observed from land when a pod was observed on numerous occasions over an increased time period and distance. As aerial observations tend to be short (< 1min) and most often have only one cue, there is an increased chance that these particular observations will be missed by the land observers even though the pod may have been observed on a previous or later occasion. We adjusted the matching criteria to examine land observations up to 30min before and after the aerial observation and within distances of up to 5km away. Direction of travel and rate of passage were used to assess whether aerial and land observations could be from the same pods. After adjusting the matching criteria, the percentage of pods (for a total of 51 pods) that were matched increased from 66% to 92% resulting in only four pods that were observed from aerial surveys and not from land. Of these four pods, one was observed on only one occasion and two were observed at the far northern extent of the land observation viewing platform. These factors were found to significantly reduce the probability of an available pod being observed by land in the 2004 double-land platform analyses. The fourth pod that was missed by land was an anomaly as this was clearly within sighting range and distance of the land platform. Due to the low percentage of unmatched pods (~8%) it was not possible to run GLM analyses on these data. However, as the primary aim of this assessment was to account for the discrepancy in the numbers of pods missed from land observations as calculated from double-land platform and aerial/land platform surveys, this has been successfully addressed by the re-assessment of pod matching criteria coupled with identification of significant sources of heterogeneity as found from the double-land platform analyses.

Objective 3: Improve the accuracy of *g(0)* using combined land-based and aerial platform data.

This objective was achieved.

The overall *g(0)* is calculated as the probability of whale pods being observed by aerial survey methods and the probability of whale pods being observed by land survey methods. The final GLM for the 2007 land-aerial platform surveys was used to calculate a correction factor (f_{m2}) for the number of whale pods that were available (i.e. observed from the land platform) but not observed from the aerial platform.

f_{m2} = 3.33 ± 0.10 (standard error)

The overall *g(0)* is then calculated by multiplying the probabilities of sighting available whales (inverse of the correction factor) for the 2004 and 2007 double platform surveys. The combined standard error is calculated by application of the delta method (S. Blomberg *pers. comm.*)

$$g(0) = 0.799\,(1/f_{m1}) \times 0.300\,(1/f_{m2}) = 0.240$$

Delta method to combine standard errors to obtain over all standard error (SE f_t):

$$\text{SE}\, f_t = \sqrt{\mathbf{Var}\boldsymbol{f_t}} = 0.200 = 4.80\%\ \text{SE}$$

$$\text{Var}f_t = f_{m1}^2 \times \text{var}f_{m2} + f_{m2}^2 \times \text{var}f_{m1}$$

Overall *g(0)* = 0.240 **± 0.048**

Objective 4: Provide an estimate for the west coast population by comparing east and west coast aerial surveys and extrapolating from the east coast absolute abundance estimate.

This objective was achieved.

An estimate of the west Australian humpback whale population was derived using the east Australian estimates of absolute abundance and comparing the sighting rate of pods per transect from aerial surveys in July of 2007 (east coast) and 2008 (west coast) incorporating correction factors for population growth (east coast population extrapolated from the 2004 absolute abundance estimate). All known uncertainties were taken into account.

The final west Australian population estimate for 2008 was 28,007 ± 5235 (95% log normal CI 19,477 – 40,273). Hedley *et al.* (2008) obtained a similar estimate of 21,750 (95% CI of 17,550 – 43,000). Given the large uncertainties, this method does not appear to provide any real advance on other population estimates (although its overall CI is smaller than that of Hedley *et al.*). Nevertheless it does support the results of Hedley *et al.* through the use of an entirely different methodology to obtain a similar result. The main sources of uncertainty were from calculating the average numbers of whales seen per transect in both east and west coast studies (CVs of 0.13 and 0.10 respectively). To reduce this uncertainty, it would be necessary to do more flights, and for the east coast in particular, more transects per flight, as well as standardise the window configuration of the aircraft used.

3. Appropriateness

The appropriateness of the approaches used in the development and implementation of the Activity

- The generalised linear modelling (GLM) approach we have used here to identify sources of heterogeneity in whale observations from both land and aerial platforms is an extension of a method that has been used in the literature previously (e.g. Buckland et al. 1993, Evans-Mach et al. 2002). This is a statistically sound approach (i.e. error margins and confidence in analyses can be assessed) that enables the simultaneous assessment of multiple factors and their relative contributions to heterogeneity in observations. Ultimately, this approach enables correction factors to be calculated that can be used in abundance estimates to significantly reduce effects of bias from the sources of heterogeneity.
- We have been able to undertake an ambitious analytical project as we had access to an existing rich database of double-land platform survey data as well as simultaneous land and aerial survey data that had been collected as part of an ongoing population abundance assessment of the Eastern Australian humpback whale group (Noad et al. 2006, 2008). The east coast of Australia is an ideal platform from which to undertake this project as the majority of whales pass the coast off North Stradbroke Island within 10km which enables all of these pods to be observed simultaneously from land-based surveys as well as from aerial surveys. This is in contrast to many other locations including the Western Australian coastline where pods pass the coastline at much greater distances from shore (details) which makes it difficult to accurately monitor pods from land and therefore obtain complementary and ground-truthing data for aerial surveys.
- The comparsion between result from the east and west coast aerial surveys relies on a number of assumptions. The first is that the transects cross the same proportion (essentially all) of the migratory stream so that they are comparable between the west and east coasts. This assumption is probably reasonably robust and is well supported, especially for the east coast (Noad *et al*., 2008). The second is that the proportion of the total population passing in July is the same for the two populations. To maximise likely comparability, it would be better to have both aerial surveys performed in the same year. The third assumption is that observer performance is similar in the two surveys. One of this report’s authors, RD, worked as an observer on both surveys and so at least one of the observers was standardised, at least part of the time. The fourth main assumption was that the average pod size for the two populations was the same. We used pods per transect as the basic measure rather than whales per transect as this would have required accurate assessment of pod size which is difficult from the air. This is a difficult assumption to test as, although we have good data from the east coast land-based survey, far fewer data are available from the west coast land-based surveys and this may be biased by the fact that only part of the population can be reliably seen from the land stations used.

4. Effectiveness

The degree to which the Activity has effectively met its stated objectives
This project has effectively met its stated objectives. This is the first time that double-land platform survey and land-aerial surveys have been combined to obtain a robust estimate of g(0) for an aerial line transect for humpback whales. Although there are several refinements that can be undertaken to increase the precision in the correction factors for the 2007 surveys, this project has successfully shown that the g(0) for undertaking aerial surveys is lower than previous g(0) estimates and therefore, abundance estimates made using these g(0) values are likely to be underestimates of true abundance. • The 2004 double-land platform analysis was data rich and the cross-validation analysis showed good support to the final model. The results of this analysis illustrates the importance of being able to track pods accurately whilst in the study area during the migration so as to increase the probability of observing available pods from land. • The 2007 land-aerial platform analysis was sound though more limited in the amount of data available, resulting in less cross-validation model support than for the 2004 surveys. However, the results clearly show that the probability of sighting available pods from the aerial surveys is much lower than has been previously proposed for aerial surveys. The overall *g(0)* calculated indicates that at best, around 25% of the available pods are being sighted from aircraft during surveys. This has significant implications for the use of distance sampling methods when using aerial surveys to calculate population abundances for humpback whales • Given that absolute abundance estimates of the east coast population will continue to be produced with increasing accuracy, and that aerial surveys are likely to continue as a major part of west coast population estimates, with a little more coordination this method may prove to be cost effective for future population estimates, complimenting the computationally more challenging methods employed by Hedley *et al.*(2008).