Centre for Whale Research, Inc. (WA)

A COMPARISON OF SOUTHERN HEMISPHERE BREEDING STOCK 'D' HUMPBACK WHALE POPULATION ESTIMATES FROM TWO KEY LOCATIONS ALONG THE WESTERN AUSTRALIAN COAST

Final Report

By:

**Curt Jenner¹, Micheline Jenner¹, Chandra Salgado Kent², Philippe
Bouchet³, Rebecca Dunlop⁴, Chris Burton⁵**

¹Centre for Whale Research, WA (Inc.), P.O. Box 1622 Fremantle 6959, WA.

²Centre for Marine Science and Technology (CMST), Curtin University, GPO
Box U 1987 Perth 6845, WA

³Scottish Oceans Institute, University of St. Andrews, East Sands, St. Andrews,
Fife, KY16 8LZ, UK

⁴Cetacean and Ecology Acoustics Group, School of Veterinary Sciences,
University of Queensland, St. Lucia, Qld 4072, Australia

⁵Western Whale Research, P.O. Box 1076, Dunsborough WA 6281

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Executive summary

This report aims to compare recent population estimates of southern hemisphere breeding stock D humpback whales (*Megaptera novaeangliae*) based on data collected at two key locations along the Western Australian coastline, namely North West Cape (NWC) and Shark Bay, ~400 km south of NWC. The report additionally investigates the efficacy and practicality of current survey designs, and serves as a reference point for future improvement in whale monitoring strategies (location of surveys, field protocols, etc.).

Modelling approaches to estimating the population size varied among survey years at Shark Bay, and between Shark Bay and NWC. In spite of this, no major anomalies were detected based on the trend line, except for a difference in population estimates in 2008 (33,850 for Shark Bay and 26,100 for NWC). Assuming an exponential fit ($r^2 = 0.80$), the combined population estimates resulted in an estimated 12.35% increase rate, which is 0.5% greater than the most recent estimate of the maximum plausible increase rates for western Australian humpbacks (max 11.8%; Zerbini *et al.*, 2010). We therefore assume that the southern hemisphere breeding stock D humpback whale population has been increasing at its maximum capacity during the last decade.

The largest sources of error and uncertainty of past population estimates at Shark Bay and NWC appear to be: 1) the limited samples (aerial surveys) to fit migration models, 2) the accuracy of identifying migration direction, and 3) the accuracy of $g(0)$ estimates. To address these limitations and improve future estimates, we recommend that double platform surveys with a large overlap in whales sampled be conducted (preferably land based station), and either land or aerial survey effort be increased. We recommend that either a suitable land based platform be located with a high enough elevation (~60-70 m) or an oil and gas platform in the middle of the migration path be considered to conduct second platform surveys with sufficient overlap. Oil and gas platforms are commonly 50 to 100 m in height. It must be noted that while the location and elevation (if the platform is within the desired range) would be ideal, that the noise that an oil and gas platform produces may change the behaviour of whales within a kilometre or two of the platform. This change in behaviour would likely drop off significantly beyond this range. Currently there is a plan for installation of an oil

and gas platform near NWC near to the centre of the migratory path. This region also presents relatively milder weather conditions.

Finally, the suggestions for future surveys listed above do not preclude consideration of other suitable and so far unidentified platforms, which will allow sufficient comparable land and aerial surveys for population estimates.

1 Introduction

The overall objective of this report is to compare Southern hemisphere breeding stock D humpback whale population estimates from aerial surveys conducted between 1999-2008 at two key locations: Shark Bay (Bannister and Hedley 2001, Paxton *et al.* 2005, Hedley 2009), and North West Cape (NWC; Jenner *et al.* 2002; Bouchet, 2009; Salgado Kent *et al.*, 2010), Western Australia (Figure 1). Population trends and size estimates from many years of surveys at Shark Bay have already been reported to the International Whaling Commission (IWC). Results from North West Cape surveys are presented as a prelude to this document, and have not been reported previously or been compared to population estimates at any other sites.

Figure 1: Study regions where long term data sets on humpback whale counts have been collected using aerial surveys; Shark Bay (bottom blue circle) and North West Cape (upper blue circle).

Additionally, a comparison is made between survey site characteristics, survey design, analytical methodologies, resulting parameters, and resulting estimates at North West Cape (NWC) and Shark Bay. The comparison is intended to assist in identifying sources of uncertainty, and reducing these uncertainties by improving future survey design. Ultimately this report makes recommendations for ongoing Southern hemisphere breeding stock D humpback whale population size estimates.

2 Background

North West Cape and Shark Bay are located approximately 400 km apart along the Western Australian coast. Humpback whales occur seasonally at both sites from May to November as they migrate between their feeding grounds in Antarctica to breeding grounds in the Kimberley (north-western Australia). Humpback whales observed at these two locations (but not within the gulf and bay areas) are assumed to be actively migrating. Travelling from one site to the other would only take a few days for a humpback whale swimming at average speed and following the usual migration route along the north-western Australian coastline. Because of the sheer proximity and observed consistency in the animals' migratory timing and behaviour at both sites (Bannister and Hedley 2001, Paxton *et al.* in Press, Jenner *et al.* 2001), the two locations are assumed to measure the same migratory body. Hence, it is assumed that population estimates made at the two locations on differing years should coalesce to form a logical and likely population increase, and estimates made at the two locations on the same years should be the same (or at least similar).

In an endeavour to make this exercise (a comparison of locations) as fruitful as possible, the information is presented in what may be considered a counter intuitive manner. Firstly (as per usual) the survey design and study area are described to give the reader the necessary background information required to capture the concepts presented in later discussions. Secondly, and in contrast to the normal report format, population estimates at the two locations are presented and any anomalies identified. Following from this, a comparison and examination of survey design and parameter values from the two locations are made in an attempt to explain any discrepancies in the population estimates. Finally, a discussion is presented on how survey design, parameter estimates, and ultimately population estimates could be improved in the future.

It is important to note that only absolute abundance estimates are considered in this document. Furthermore, of those estimates, only the best for any one location and survey year are reported. Multiple results have been produced for each year and site using a number of different approaches. The authors of the relevant analyses have

already compared and discussed these techniques in detail in the relevant literature (Bannister and Hedley 2001, Hedley *et al.* 2009, Salgado Kent *et al.* 2010, Paxton *et al.* in press.). To include all analyses in this report would only result in re-hashing much of the conclusions already detailed in past publications and reports.

3 Survey design and effort

Data were collected in 2000, 2001, 2006, 2007, and 2008 at North West Cape, and in 1999, 2005, and 2008 in Shark Bay (Table 1). While estimates at the various locations complement each other (since they are temporally staggered), only one overlapping year (2008) allows direct comparability between estimates (Table 1).

Table 1. Data sets used for absolute abundance of humpback whale population estimates at Shark Bay and NWC.

Reference	Location	Year	Survey type	Number of observers	Months	Number of complete surveys
Bannister and Hedley 2001	Shark Bay	1999	Aerial	2	24 Jun – 19 Aug	15
Paxton <i>et al.</i> in press	Shark Bay	2005	Aerial	2	22 Jun – 15 Aug	12
Paxton <i>et al.</i> in press	Shark Bay	2005	Land	4	9 Jul – 22 Jul	13
Hedley <i>et al.</i> 2009	Shark Bay	2008	Aerial	4	24 Jun – 19 Aug	26
Hedley <i>et al.</i> 2009	Shark Bay	2008	Land	4	8 Jul – 20 Jul	7 (+3 partial days)
Salgado Kent <i>et al.</i> 2010	NWC	2000	Aerial	2	Jun 1 – Nov 30	17
Salgado Kent <i>et al.</i> 2010	NWC	2001	Aerial	2	Jun 1 – Nov 30	15
Salgado Kent <i>et al.</i> 2010	NWC	2006	Aerial	2	Jun 13 – Oct 31	14
Salgado Kent <i>et al.</i> 2010	NWC	2007	Aerial	2	Jun 24 – Oct 31	13
Salgado Kent <i>et al.</i> 2010	NWC	2008	Aerial	4	24 Jun – 27 Aug	13
Salgado Kent <i>et al.</i> 2010	NWC	2002	Boat	3	Jun 29 – Sep 19	7

The aerial survey track lines were laid out in a systematic sampling design (box-end line transects) perpendicular to the expected migratory paths. The distance between transects for both locations was 10 km (Figure 2). The surveys were designed to fit the data requirements of Distance Sampling theory, including: placement of transects perpendicular to the bathymetric contours, and timing to include the period of migration through the study area. All attempts were made to ensure detection was at the greatest on the flight path (distance 0), as well as to avoid heaping (rounding of perpendicular distances).

Figure 2. Example survey tracks in the regions of North West Cape (2000-2008) and Shark Bay (2008; from Hedley *et al.*, 2009), Western Australia.

There were some small differences, however. NWC surveys were conducted at an altitude of 1000 feet, while Shark Bay surveys were conducted at 1000 feet in 1999, and 1500 feet in 2008. NWC surveys were flown at a speed of 120 knots, while at Shark Bay flights were completed at a speed of 120 knots in 1999, 127.5 knots in 2005, and 100 knots in 2008. The aircrafts used at NWC were a Partenavia in 2000 and 2001 and a Cessna 337 in 2006, 2007, and 2008. At Shark Bay a Partenavia was used in 1999 and 2005 and a Cessna 337 in 2008. Two observers were present on all flights (apart from 2008, see details below), each working on a different side of the aircraft.

In 2008, an attempt was made to match as closely as possible the methodologies at the two locations. The following had been planned: flying at the same speed (120 knots), including a subset of surveys flown at the same altitude (1500 ft) with the same plane (Cessna 337), and swapping observers between locations (to correct for observer bias between sites). North West Cape aerial surveys conducted in 2008 were funded by the oil and gas industry and designed to capture other smaller fauna, which made adaptation to Shark Bay methodology (particularly flight height) impractical. Shark Bay surveys were funded by ACAAMS and designed to be consistent with 1960's whaling surveys (hence a flying altitude of 1500 ft and speed of 100 knots).

The use of double blind (independent) observers for reducing observer bias was implemented at both locations in 2008, although at NWC this was only feasible for approximately every second survey. At Shark Bay double platforms (land-based, and

aerial-based) were introduced as a way of getting a better estimate of $g(0)$ and to record migration behaviours such as dive profiles and swim speeds (among others). NWC estimates were based on only one platform (airplane).

4 Comparison of population estimates and rate of increase

Modelling approaches varied greatly (Table 2). In spite of this, no major anomalies (data points that would appear to be an outliers) were detected based on the trend line, except for a difference in population estimates in 2008 (33,850 for Shark Bay and 26,100 for NWC). It is worth noting that using a crude estimate to account for perception bias at NWC, the 2008 estimate would be around 32,000 (Salgado Kent *et al.*, 2010), which is much closer to the 2008 Shark Bay estimate of approximately 34,000).

Table 2: Population estimates based on NWC and Shark Bay surveys conducted between 1999 and 2008.

Year	Date set	Method	Num of days used in model	Population Estimate	CI	Reference
1999	NM	Crude correction for g(0)	100	11,500	(9,200-14,300)	Paxton <i>et al.</i> , in press
2005	NM+	Aerial surveys with g(0) with land-based calibration	87	12,800	(7,700-44,600)	Paxton <i>et al.</i> , in press
2008	NM whales, missing distances included	NM whales, missing distances included	100	33,850	(27,340-50,260)	Hedley <i>et al.</i> , in review
2008	NM+	Aerial surveys with g(0) from focal follows	55	26,100	20,152-33,272	Salgado Kent <i>et al.</i> , 2010
2007	NM+	Aerial surveys with g(0) from focal follows	42	20,044	13,815-31,646	Salgado Kent <i>et al.</i> , 2010
2006	NM+	Aerial surveys with g(0) from focal follows	58	18,692	12,980-24,477	Salgado Kent <i>et al.</i> , 2010
2001	NM+	Aerial surveys with g(0) from focal follows	65	10,548	6,502-48,622	Salgado Kent <i>et al.</i> , 2010
2000	NM+	Aerial surveys with g(0) from focal follows	65	7,276	4,993-10,167	Salgado Kent <i>et al.</i> , 2010

Assuming an exponential fit ($r^2 = 0.80$), the combined population estimates resulted in an estimated 12.35% increase rate (Figure 3), which is 0.5% greater than the most recent estimate of the maximum plausible increase rates for western Australian humpbacks (max 11.8%; Zerbini *et al.*, 2010).

Figure 3. Trend in population size based on the best available estimates from North West Cape and Shark Bay, Western Australia.

5 Modelling approach and parameter estimates

While the population size estimates seem reasonable given the good fit of the trend model (Figure 3), the sources of uncertainty and variability are worth examining to improve future estimates.

The population estimates presented in this document relied upon a number of different statistical techniques. The field of animal abundance estimation is still growing, and new modelling approaches are continually being developed, tested and enhanced. The work conducted at Shark Bay exemplifies this progress. The analytical methods used for Shark Bay and NWC estimates at the forefront of developments in this particular

area of research. However, the tools that have been implemented depend entirely upon survey type, available data and site attributes, hence vary in their robustness. By comparing common model parameters, and examining possible sources of disparity, we attempt to tease out the causes of these disparities and recommend ways to strengthen future models.

5.1 Availability and perception bias ($g(0)$)

Population abundance estimates are most accurate when they account for availability bias (the fact that observers miss animals because they are below the water surface and are hence “unavailable” to be detected) as well as perception bias (the fact that observers miss available animals because of momentary inattention, weather conditions, etc.). In such circumstances, the probability to detect a whale on the trackline, referred to as $g(0)$, is likely inferior to 1, thereby violating a crucial assumption of Distance Sampling theory. If departures from this assumption are not identified, considerable bias may be introduced. Hence it is essential to assess the proportion of animals missed on the flight path. Estimates of $g(0)$ at Shark Bay accounted for availability and perception bias in all estimates. NWC estimates accounted for availability bias only except for in 2008, where both perception and availability biases were incorporated into the model (Table 3). Overall, estimates of $g(0)$ were greater at NWC than at Shark Bay, except in 2006 and 2007. Strictly speaking, one would expect the correction factors accounting for both availability and perception bias to be lower than those accounting for availability only.

Table 3. Estimates of $g(0)$ for NWC and Shark Bay (NM = northern migration, NM+ = northern migration plus those whales to which a northern migration direction was randomly allocated).

Year	Data set	Method	Distance at which $g(0)$ was estimated (km)	Availability and Perception bias?	$g(0)$	Reference
1999	NM	based on land-based calibration	1	A+P	0.30	Paxton <i>et al.</i> , in press
2005	NM+	based on land-based calibration	1	A+P	0.31 (0.125-0.492 CI)	Paxton <i>et al.</i> , in press
2008	NM, Missing distances excluded	based on land-based calibration		A	0.33 ± 0.26	Hedley <i>et al.</i> , in press
2008	NM+	based on boat based focal follows	0.75	A, A+P	A = 0.64 (SE = 0.03) A+P = 0.50	Salgado Kent <i>et al.</i> , 2010
2007	NM+	based on boat based focal follows	0.75	A	0.42 (SE = 0.03)	Salgado Kent <i>et al.</i> , 2010
2006	NM+	based on boat based focal follows	0.75	A	0.40 (SE = 0.03)	Salgado Kent <i>et al.</i> , 2010
2001	NM+	based on boat based focal follows	0.75	A	0.58 (SE = 0.04)	Salgado Kent <i>et al.</i> , 2010
2000	NM+	based on boat based focal follows	0.75	A	0.58 (SE = 0.04)	Salgado Kent <i>et al.</i> , 2010

In an attempt to understand the source of variation in estimates of $g(0)$, the methods used in calculations are examined here. In the first instance, we want to know whether these values are representative of the true value of detected animals. Availability at NWC, for example, was estimated using Laake *et al.*'s (1997) equation, which relied upon surface and dive interval information from boat-based focal follows conducted in 2002. Overall, the equation is considered to represent a significant improvement over formulae used in the past (Barlow *et al.*, 1988, Paxton *et al.*, in press), however, there are surely biases in groups sampled from focal follows and their associated dive and surface interval behaviours, as well as potential changes in dive behaviour due to the presence of the boat. For example, groups that are on the surface longer will be observed more easily, hence might be sampled more often; while groups that have comparatively longer dive times will be sampled less frequently and be under represented. So in general, the resulting $g(0)$ s derived from surface and dive intervals

are likely to be inflated. The level of overestimation is unknown, and perhaps should be the focus of a dedicated study.

Direct calibration from land-based observations as done in Shark Bay would thus seem to be more appealing and have a lower probability of biasing the results upwards since the time period an observer has to spot a whale migrating past the land-based station is much greater, hence the probability of an animal being available and seen, even when dive times are long and surface intervals short, is greater. It must be noted here that previous comparisons of focal follow adjustments and calibration from land-based surveys have resulted in little variation (Paxton *et al.*, in press). Furthermore, the direct calibration method in 2008 at Shark Bay was not considered to be particularly successful, primarily due to the low elevation of the platform (~25 m above sea level) and the high proportion of animals that were beyond the range of the land-based observers, and so the overlap between the aerial survey – already for only a few days – was also spatially limited. Hedley *et al.* (2009) trialed double-platform land surveys in addition to aerial-land calibrations and concluded that double-platform land-based approaches to estimate the number of pods offshore would be preferable to the aerial-land calibration, since these data would be expected to be more reliable.

Having established that the values for both locations may have some unquantified bias, we can now examine the variability in $g(0)$ estimates when the same method was used. For example, $g(0)$ estimates at NWC for all years except 2008 used Laake *et al.* (1997) equation and the same dive and surface interval data set, yet the values ranged from 0.40 to 0.64. The values used in the Laake *et al.* (1997) equation include: the expected time whales are at the surface, the expected dive length, and the time an animal is within detectable range (given the physical restrictions of the aircraft). The time that an animal is within detectable range is a function of the viewing angle forward and aft of the perpendicular line to the aircraft's centreline and the aircraft's velocity. Hence, the only variables that could change between years (since the same surface and dive data set was used and the aircraft travelled at the same velocity for all years) are the viewing angles forward and aft. These angles are a function of the aircraft's physical structure and the observers themselves. A smaller $g(0)$ would simply mean that the viewing angle was narrower. The same aircraft (Partenavia) and observers were used for almost all surveys in 2000 and 2001, and the resulting $g(0)$

were the same. In 2006, 2007 and 2008 a Cessna 337 and different observers were used. Observers' search behaviour may contribute more to the resulting $g(0)$ estimate than the aircraft types used in the surveys.

For Shark Bay surveys, $g(0)$ values estimated in 2005 were used for 1999 population estimates, however values in 2008 were derived during that same year

5.2 Pod size adjustment

If we are to presume that Shark Bay and North West Cape are equivalent in terms of whale behaviours and movements, then we could go as far as assuming that mean group sizes should also be similar at the two locations (although this will vary with observers and weather conditions). Following from this, the adjusted group size used for modelling (to correct for biases introduced from greater visibility of larger group sizes) would be expected to be approximately equivalent.

All values (mean and adjustment mean pod size) varied between ~1.2 and ~1.9 animals (Table 4). The variability observed is most likely mainly a function of survey day, since mean group size is expected to change as different cohorts of animals file past both sites and their behaviours vary over the migratory season (Dawbin, 1966). Due to high fuel costs and inappropriate weather conditions, only a limited number of 12 to 26 aerial surveys could be conducted across the northern migratory season, which spans ~40 – 100 days. A larger sample size (more frequent flights) would likely reduce the variability and increase the accuracy of population estimates.

Table 4: Adjusted mean pod size for NWC and Shark Bay analyses ($\pm$ SE, except where specified).

Year	Data set	Mean group size used in the model	Adjusted group size	Reference
1999	NM	-	1.87 (1.79-1.96 CI)	Bannister and Hedley 2001
2005	NM+ aerial	1.91 ± 0.06	-	Paxton <i>et al.</i> , in press
2008	NM, Missing distances excluded	1.21 ± 0.04	1.80 ± 0.04	Hedley <i>et al.</i> , in press Hedley <i>et al.</i> , 2010
2000	NM+	1.52 ± 0.13	1.26 ± 0.05	Salgado Kent <i>et al.</i> , 2010
2001	NM+	1.43 ± 0.05	1.54 ± 0.14	Salgado Kent <i>et al.</i> , 2010
2006	NM+	1.62 ± 0.04	1.56 ± 0.04	Salgado Kent <i>et al.</i> , 2010
2007	NM+	1.42 ± 0.02	1.77 ± 0.04	Salgado Kent <i>et al.</i> , 2010
2008	NM+	1.21 ± 0.04	1.60 ± 0.03	Salgado Kent <i>et al.</i> , 2010

5.3 Accounting for non-survey periods

Whales were only surveyed for several hours on any given day. To scale up these counts to a daily number of animals swimming through the area, mean whale migration speed was multiplied by the number of hours in a day (24), and divided by the total latitudinal length of the survey region. Hence the parameter which may have the largest influence on the non-survey period correction factor is the whale travel speed. All values estimated at NWC and Shark Bay are very similar (Table 5).

Table 5: Travelling speed of humpback whales used for correcting for non-survey periods for NWC and Shark Bay analyses.

Year	Method	Speed	Reference
2005	Based on land based focal follows at Shark Bay	5.35 km h^{-1}	Paxton <i>et al.</i> , in press
2008	Based on land based focal follows at Shark Bay	5.56 km h^{-1}	Hedley <i>et al.</i> , in press Hedley <i>et al.</i> , 2009
2000-2008	Based on 2002 boat based focal follows at NWC	5.64 km h^{-1}	Salgado Kent <i>et al.</i> 2010

5.4 Migration models

In addition to the estimation of $g(0)$, the migration model itself is expected to represent the greatest source of uncertainty. This uncertainty stems from several sources, of which the following are considered here: 1) assumption of even density distribution in a direction parallel to the track lines, 2) the small number of survey days sampled, and 3) selection of migratory season length. Rather than delving into

the type of model used to fit the migration curve (i.e. hermite polynomials, mixed models, GAMs), this discussion will focus more on how the survey design and field observations may have affected the selection and adequacy of these models.

The first issue identified above is that of assumed even distribution of animals in the direction of the track line. Population estimates done for surveys in 2005 and 2008 at Shark Bay accounted for uneven distribution by applying a spatial modelling approach. Hedley *et al.* (2009) compared the spatial modelling estimates (uncorrected for rate of passage and for $g(0)$) to those from a conventional line transect analysis in *Distance* (Thomas *et al.*, 2006) such as those done in NWC. The results showed that the estimates from the spatial model were quite comparable to those from a standard line transect analysis, with the main difference being that the variation in encounter rate was ‘smoothed’ out.

The second issue identified to be contributing significantly to the uncertainty in the migration models is the small sample size resulting from aerial surveys. This is a result of limiting weather conditions and the high cost of aerial surveys. Two possible solutions can be considered; the first is to select a location where a greater number of aerial surveys can be conducted (than in previous surveys), while the second is to find a location where suitable overlapping land and aerial based surveys can be conducted (and frequent land surveys are possible).

To implement the first solution, a location with relatively good weather conditions is required. During the northerly humpback migration season (June to September) wind characteristics are influenced by the austral winter weather cycle. High pressure cells centred over central Australia typically bring easterly winds to the region of Shark Bay and NWC, while low pressure cells centred south of the continent generate cloud and stronger westerly winds. These strong westerly winds often extend from the southwest of Australia towards the north, but tend to decrease with increasing latitudinal gradient (northwards). Hence, the further north along the western Australian coastline, the more weather conditions will allow more frequent aerial surveys to be conducted.

For the second solution to be implemented, an appropriate land based station has not yet been identified where considerable overlapping aerial and land based observations can be made. The centre of the humpback whale migratory corridor at Shark Bay and NWC is greater than 15 km away from the closest point on land. Land-based surveys effectively sample whales within 12 km (Hedley *et al.*, in press). Furthermore finding a suitable land-based station is complicated by Western Australia's generally uninhabited and low lying coastline. At Shark Bay, land-based surveys at Quobba (the location that allows the most overlap with aerial surveys) have been confounded by a high number of milling animals within the observable area (Paxton *et al.*, in press). Surveys in 2008 at the north end of Dirk Hartog Island at Shark Bay (sighting height of 25.5m above sea level) indicated that the distance to the overlap in whales sampled by land based surveys and aerial surveys was not ideal (Hedley *et al.*, 2009, Hedley *et al.*, in press). Similarly at NWC, headland height is limited (from NW Cape Lighthouse for example), and because it is several kilometres north of the bathymetry bottleneck, this location would allow a limited percentage of whales to be sampled by both aerial surveys and the land based survey.

Finally, the selection of migratory season length has a significant effect on the estimated population size. The selection of migratory season length is confounded by the limited ability for whale migration direction to be accurately recorded during aerial surveys. This is further confused by the fact that southbound whales may be more likely to be milling than northbound whales, hence, can be recorded as migrating north while in fact simply temporarily travelling north. This leads to two problems: 1) the length of the northern migration season may be assumed to be longer than it is, and 2) double counting of the same whales results in an over inflation of the estimated northerly migrating whales (since the same animal was presumably counted on its way north, and subsequently counted on its way south while temporarily travelling north). This problem perhaps could be best addressed by land or boat-based focal follows (conducted simultaneously to aerial surveys).

6 Conclusion

The largest sources of error and uncertainty of past population estimates at Shark Bay and NWC appear to be: 1) the limited samples (aerial surveys) to fit migration models, 2) the accuracy of identifying migration direction, and 3) the accuracy of $g(0)$ estimates. To address these limitations and improve future estimates, we recommend that double platform surveys with a large overlap in whales sampled be conducted (preferably land based station), and either land or aerial survey effort be increased. We recommend that either a suitable land based platform be located with a high enough elevation (~60-70 m) or an oil and gas platform in the middle of the migration path be considered to conduct second platform surveys with sufficient overlap. Oil and gas platforms are commonly 50 to 100 m in height. It must be noted that while the location and elevation of an oil and gas platform (if the platform is indeed at the desired elevation) would be ideal, the noise that an oil and gas platform produces may change the behaviour of whales within a kilometre or two of the platform. This change in behaviour would likely drop off significantly beyond this range. Hence the affect on estimated $g(0)$ of any changes in behaviour resulting from the oil and gas platform itself should be considered carefully.

Finally, the suggestions for future surveys listed above do not preclude consideration of other suitable and so far unidentified platforms, which will allow sufficient comparable land and aerial surveys for population estimates.

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