Chapter 4: Strengths and weaknesses of humpback whale survey techniques in the Kimberley and recommendations for future monitoring

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1 Introduction

In this WAMIS study we have analysed data from a range of survey platforms and using a range of survey methods and included an emerging technique to count whales – very high resolution satellite imagery. Here we assess the strengths and weaknesses of each technique and attempt to assist in determining options for monitoring humpback whales in the Kimberley that provide the best approach to achieve the main management objectives while considering costs.

2 Methods

We costed each of the survey types used in the analysis here with costs based on the most recent survey of each type. Only data collection costs were included and not those for data analysis. Other strengths and weaknesses were also assessed but not on monetary terms. We assessed each of the methods in relative terms on degree of expertise required, ability to answer key management questions, the spatial coverage and any additional pros and cons. The resulting assessment is presented as a table and is designed to assist natural resource managers and decision makers to determine the best approach to achieve their specific management objectives while considering costs.

Rather than assess methods on a technique basis generically (i.e. boat survey versus aerial survey) we assessed the combination of the technique and the suggested sites and spatial coverage for such a technique to be used for humpback whales in the Kimberley. These included: 1. Aerial survey of abundance of the entire humpback whale area of use in the Kimberley, 2. Vessel survey of abundance using areas of high humpback whale density in the Kimberley, 3. Vessel survey of whale presence (direct counts) using areas of high humpback whale density in the Kimberley, 4. WorldView-3 survey of areas of high humpback whale density in the Kimberley, and 5. Land based survey at the humpback whale area a high density at Pender Bay. These are explained below.

Justification of assessed methods

Although aerial surveys can be done on variable spatial scales, here we specifically assess aerial surveys over the whole Kimberley region found to be used by humpback whales in this report (Eighty Mile Beach to Camden Sound) using a zigzag pattern similar to Figure 1b. This assessment is based on the use of systematic sampling and distance sampling methods (Buckland et al. 2011) so that absolute abundance can be calculated and trends monitored over time. Even though such surveys are high cost and need a high level of expertise, they are considered the best from the perspective of being able to address all the key management objectives. Such a survey would ideally be conducted at two weekly intervals over the humpback whale season (mid-July to mid-October). However, as cost will often be a deciding factor, smaller spatial extents might need to be considered in addition to cheaper (and safer) platforms. For example, aerial surveys may be made safer by replacing observers with digital cameras and/or with the use of long range drones (See Hodgson et al. 2013), however these options are not always more cost effective.

From the work done in this report, there are several locations predicted to be the most densely used areas within the Kimberley region and systematic sampling of these areas can reduce costs compared to surveying the entire region. These include the region in and around Pender Bay (including along the Dampier Peninsula), Camden Sound and Tasmanian Shoal region and Eighty Mile Beach. Of these, two locations have been identified as being of particular interest to ongoing management based on the large numbers of mother calf pairs and likelihood that they are breeding or nursery areas – Camden Sound and Pender Bay. Camden Sound has a whale sanctuary zone within the Lalang-garram/Camden Sound Marine Park, thus requires management; while the Pender Bay region was found to have the highest densities of whales in this study. Consequently, these two locations are recommended as priority locations for future monitoring, where resources limit broader coverage. Although these surveys could equally be done with an aerial platform, we assess them based on the use of boats and VHR satellites.

The Western Australian State Government owns assets in the form of survey vessels (Department of Fisheries, Department of Biodiversity, Conservation and Attractions) which could be used to reduce costs. We have assessed vessel surveys based on the use of systematic sampling and distance sampling methods (Buckland et al. 2011) in order to have the ability to correct for bias and calculate an abundance estimate. These methods involve measuring the range and bearing of observed whales from the vessel. Range and bearing can be determined from measures of distance down from the horizon and compass bearing obtained from marine binoculars fitted with a compass and reticules. These methods are strongly recommended where they can be implemented, but we also assess a simpler version of vessel surveys (direct counts of whales without recording range and bearing, Fig. 1). While such surveys cannot monitor trends in abundance they can be used for monitoring relative abundance and recording other things such as calf presence, whale behaviour, boat traffic, etc, all of which will inform different management questions.

Continued monitoring at Camden Sound and the Pender Bay region will also benefit from comparisons to previous work conducted there; including the recent satellite imagery in Camden Sound and a 2008 vessel survey and long-term community land-based monitoring program at Pender Bay. The latter two survey techniques were also assessed here.

3 Results

3.1 Cost and assessment of each survey method

In comparison with previous aerial and vessel surveys, the costs associated with tasking the WorldView-3 satellite appeared relatively high. The cost for both the panchromatic and 8 multispectral bands is US$56 per square kilometre. The lowest cost option for the panchromatic band, which does not include all spectrums (no infrared) for WorldView-3 was US$51 per square kilometre, giving a total cost of US$21,675 per sample day. These have been converted to Australian dollars in table 1.

In comparison, costs of an aerial survey in 2007 (the most recent sampling event) that was flown over the entire Kimberley region were much lower per square kilometre than satellite imagery (~ AUD$1.13/km^2 vs. ~ AUD$75/km^2). The costs per square kilometre to fly a distance sampling survey was inclusive of plane, pilots (2), observers (4), landing fees, accommodation and equipment. This allowed for 1444 km of linear trackline to be flown at a speed of 220 km/hr for 6.5 hour, about the longest aerial observers can be expected to be able to maintain concentration and included a one hour break on the ground in the middle of the flight. A day of flying cost AUD$18,000 (including data transcription costs) plus an initial investment of $15,000 to set the observers up with intercoms, GPS, laptop, clinometers.

Vessel surveys have cost structures that are variable and dependent mainly on the size of the vessel, whether the survey is dedicated or piggybacked (costs shared) and usually require more personnel and for longer periods of time. A typical day rate for a 24 m vessel capable of operating for 2 weeks at a time in the Kimberley with up to 10 personnel onboard may be AUD$12,000 per day including fuel and wages (including time on survey and later for data transcription) and would be capable of surveying 2200 km^2 per day (Table 1). However, if an existing State Government asset and observer team (rangers) can be utilized, these costs become negligible and the vessel surveys become an obvious choice for long term planning.

The season cost to get the management answer considered the number of surveys that would be required in a season to provide a quantitative assessment of the whale population relevant to management, aerial surveys were the most expensive (based on 10 surveys), followed by satellite surveys (based on 5 samples), and then vessel surveys (10 survey days).

The assessment of each of the methods is presented in table 2 and ranked by our recommendations if cost was not a consideration.

Table 1. Costs for each of the three survey platforms, based on the most recent aerial and vessel surveys of the Kimberley conducted by CWR. The satellite survey was based on the costs of tasking the WorldView-3 satellite here.

Item	Satellite	Aerial	Vessel
Cost/Day (AUD)	30,000	18,000	12,000
Coverage/Day (km^2)	425	14,400	2,200
Rough Cost/km^2 AUD	71	1	5
Season Cost to get management answer	$150,000	$180,000	$120,000

Table 2. Assessment of each of the survey methods in relative terms.

								Ability to answer key management questions/concerns				
Method	**Cost**	**Spatial coverage**	**Expertise for study design**	**Data analysis skill required**	**Data collection degree of difficulty**	**Pros**	**Cons**	**Monitor abundance trends**	**Model distribution & environmental associations**	**Identify areas of importance (hotspots)**	**Record behaviour and calf presence and diagnostics**	**Monitor temporal trend in numbers throughout season**
Aerial survey (abundance) e.g. zigzag survey similar to 2007 survey (Fig. 1b from Chapter 1) but extending from Eighty Mile Beach to Camden Sound every 2 weeks during the season.	High	Large	High	High	High	Can obtain absolute abundance over the whole Kimberley area used by humpback whales	A high level of expertise is required	Yes	Yes	Yes	No	Yes and will be absolute abundance
Boat survey (abundance) Using red and blue transect lines over hotspot area of Camden Sound and/or Pender Bay (fig 1) and conducted at peak season and 1-2 weeks either side (minimum)	Medium	Medium	High	High	Medium	Opportunity for other sampling (e.g. record other species, genetics, health status, mark recapture)	Limited spatial and temporal coverage	Yes but only in hotspot areas and use may not be consistent over time	No (unless expand to other areas besides hotspots)	No (see left)	Yes	No (but can monitor relative abundance if data collected regularly through whole season)

Very high resolution satellite imagery using snapshots of WV3 of peak and either side of peak season at Camden Sound and/or Pender Bay hotspots separated by 1-2 weeks.	High	Small	Medium	Low to medium	Low	Can be mobilised relatively quickly. Low effort for data collection as done remotely. Counts can be done by automated methods.	Only feasible for small spatial scales. Rough sea and cloud cover at time of image capture will obscure whales.	Potentially (but still work to be done to determine this and count only relates to the area where imagery was captured)	No (unless expand to other areas besides hotspots)	No (see left)	No	No (unless imagery collected regularly throughout entire season)
Boat survey (presence/direct counts) using priority (red) survey lines (Fig. 1) over hotspot area of Camden Sound and/or Pender Bay and conducted 1-3 times around peak season separated by 1-2 weeks.	Medium	Small	Medium	Medium	Medium	Opportunity for other sampling (e.g. record other species, genetics, health status, mark recapture)	Non-systematic survey design so cannot monitor trends in abundance	No	No (unless expand to other areas besides hotspots)	No (see left)	Yes	No (but can monitor relative abundance if data collected regularly through whole season)
Land-based survey at Pender Bay conducted over the entire humpback season	Low	Small	Medium	Medium	Medium	Ability for community involvement	Only small spatial scale, with only partial coverage of the Pender Bay hotspot.	No	No	No	Yes	Yes but relative abundance

3.2 Vessel survey recommendations

An example of transects that could be used to survey Camden Sound and Pender Bay have been included here (Figure 1). Survey transects have been designed as the main 'priority' transects (thick red zigzag transects in Figure 1). These could be done as direct counts rather than as abundance surveys, however the latter are recommended. The Camden Sound priority transects intersect the 'suitable habitat' for cow/calf groups (thin green line, Fig. 1) and the length of recent satellite imagery, while the Pender Bay priority transects cover the area with both high habitat suitability and high whale density were predicted and with the past 2008 vessel surveys by CWR. Survey transects that can be performed opportunistically (either the entire transects, or partial coverage of transects) have also been included (blue transects in Fig 1). These will allow for greater coverage and replication of transects and can be undertaken when the vessel is transiting the region.

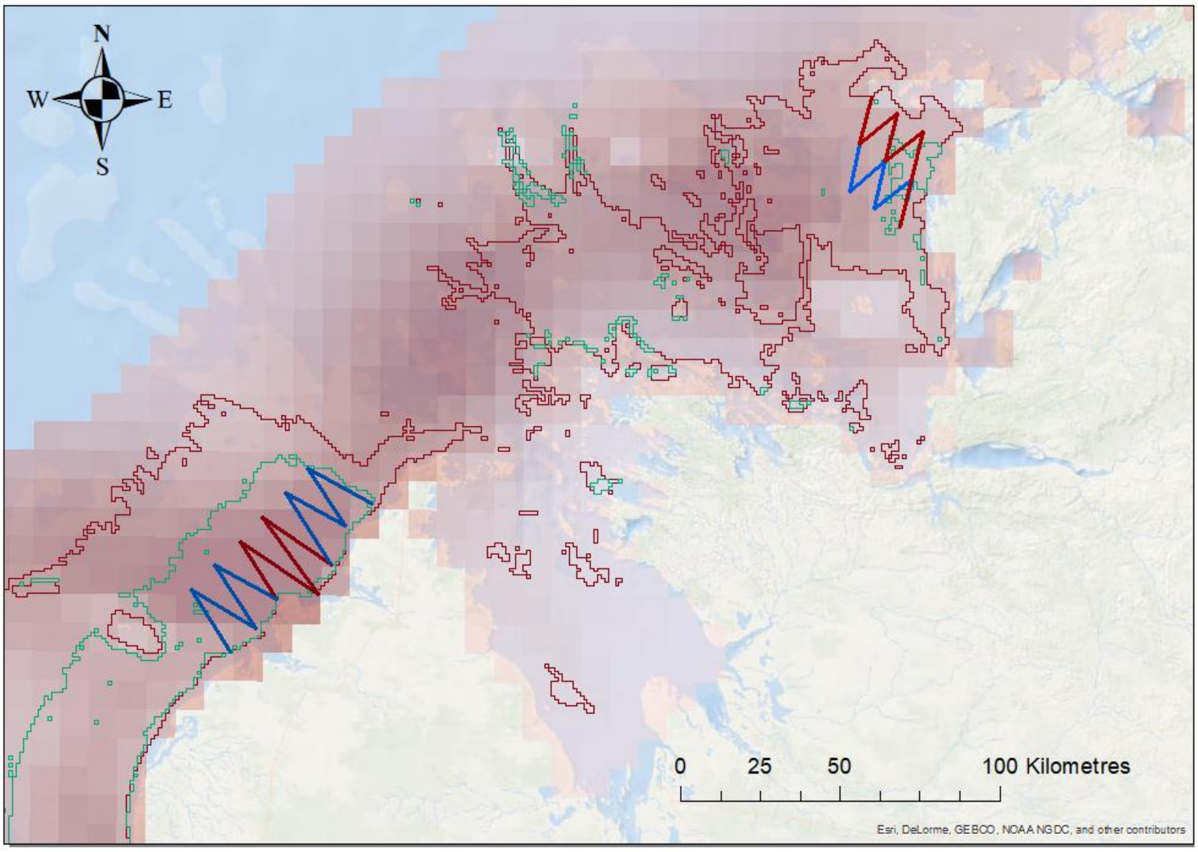

Figure 1. Suggested line transect design for humpback whales in Camden Sound and Pender Bay for state government survey vessels transiting the Kimberley region. Thick red lines show priority surveys and thick blue lines show expanded surveys to be undertaken opportunistically. Predicted whale density from the density surface model is shown in pink colours, thin red line and green line shows the predicted suitable habitat from the Maxent model for all whale groups combined and for groups with calves respectively.

A zigzag design has been suggested to reduce the time required in box-end designs to transit between transects, thus enabling an additional transect in the design that would otherwise not be possible to include. Transects in the zigzag design are 10 km apart at their widest distance. The maximum detection range of whales should be determined for each survey vessel; which is generally ~2-3 km (for far-off breaching whales) from low observation platform. The maximum detection range can be obtained by estimating the distance to the horizon from the vessel using the observer's height above the sea surface in triangulation calculations (Buckland et al. 2011). Based on the maximum detection range, the length of converging transects that have overlapping areas of observations can be determined. In these sections of the transects, observers can identify whales already observed in the previous transect to ensure that they are not double counted. The length of converging transects having some common overlapping observation areas is anticipated to be less than a fifth of the transects. If high densities make identifying whales observed from both transects prohibitive, adjustments can be made during the analytical stage by reducing the half strip-width to 1 km and clipping the transects to exclude the last few hundred meters.

Priority surveys (CS Survey 1 and PB Survey 1 in Fig 1) are recommended to be conducted as many times as possible during the whale season (mid-July to mid-October), with a minimum of one to three times (three being preferred) in mid-August. Three during the August peak season (say spaced a week or so apart) would allow for more reliable comparisons, since the timing of the peak can vary. In addition, communication with researchers, communities and managers conducting studies elsewhere along the migration path may aid in selecting the most probable peak in the Kimberley (based on trends in abundance at points along the migration). The surveys can be conducted from north to south or south to north for Pender Bay, and east to west or west to east for Camden Sound. The priority Pender Bay survey covers a total of 103 km and the Camden survey 89 km. Surveys should be attempted when wind conditions are 15 knots or less and in daylight hours only, and at vessel speeds of 8 – 10 knots. At these speeds, the priority Pender Bay survey could be covered in 6-7 hours and the Camden Sound priority survey in 3-4 hours. All other opportunistic surveys will take less than 5 hours, with the shortest 54-km opportunistic survey (CS Survey 2) estimated to take 3-4 hours. The location of waypoints at each vertex have been included here for practical implementation (Table 3).

Table 3. Waypoints for the surveys shown in Fig. 1.

Survey	Waypoint	Latitude	Longitude
PB Survey 2	1	-16° 55.50′	122° 25.26′
	2	-16° 44.28′	122° 18.66′
	3	-16° 51.36′	122° 29.64′
	4	-16° 40.38′	122° 22.56′
	5	-16° 46.38′	122° 33.18′
PB Survey 1	1	-16° 46.38′	122° 33.18′
	2	-16° 36.24′	122° 26.76′
	3	-16° 45.12′	122° 40.38′
	4	-16° 32.52′	122° 30.66′
	5	-16° 40.14′	122° 42.48′
PB Survey 3	1	-16° 40.14′	122° 42.48′
	2	-16° 27.72′	122° 34.38′
	3	-16° 33.30′	122° 44.76′
	4	-16° 23.82′	122° 38.10′
	5	-16° 30.00′	122° 49.32′
CS Survey 1	1	-15° 42.96′	124° 18.42′
	2	-15° 26.82′	124° 22.56′
	3	-15° 31.56′	124° 16.14′
	4	-15° 24.12′	124° 18.00′
	5	-15° 28.86′	124° 11.76′
	6	-15° 21.00′	124° 13.62′
CS Survey 2	1	-15° 33.00′	124° 20.46′
	2	-15° 40.26′	124° 14.28′
	3	-15° 31.56′	124° 16.14′
	4	-15° 36.54′	124° 10.32′
	5	-15° 28.86′	124° 11.76′

4 Discussion and conclusions

Future monitoring of humpback whales in the Kimberley will need to be cost effective and likely multi-purpose. Aerial surveys answered the most key management questions/concerns assessed here but cost and expertise required for conducting the surveys was high. If funding and expertise was available we recommend aerial surveys using a similar survey design as the CWR 2007 surveys (Figure 1, Chapter 1) but extending from Eighty Mile beach to Camden Sound. Annual aerial surveys are necessary to monitor trends in absolute abundance of the Kimberley humpback population, but many years of systematically sampled data are required (often decades) to effectively monitor trends. The costs of aerial surveys were cheaper per square kilometre than the other two methods but the season cost to obtain the management answer was the most expensive. Importantly, the costs do not include analysis and for aerial and vessel surveys of abundance these can be high (up to $100K). There are some other important considerations of aerial surveys and that is that key components must already be in place, such as equipment, experienced observers and pilots. Today, workloads are declining and as a consequence experienced personnel are becoming harder to find. In addition, there are a number of safety concerns for aerial surveys with loss of life of researchers and pilots around the world. But the use of cameras over observers may reduce some of the risk and the use of drones with ability to cover large distances (See Hodgson et al. 2013) may also be a low risk option. However, such long range drones will likely be as or more expensive than planes. In addition, the choice of study type and platform becomes complicated for situations where long term planning is not possible. For example, if it was known that funding was available to monitor whales in the Kimberly for five years, then planning aerial or vessel surveys may be the best options. However, if funding is intermittently available, then satellite imagery might be the best short term solution.

Satellite imagery has the advantage of being able to be analysed by one or two people and tasked at very short notice (10-14 days although success depends on commitments), so can be flexible in response to available funding. It can also be cancelled at short notice so that budgets can be deferred until the next season, something that is problematic once an aerial survey team is mobilised. A transition from aerial survey to satellite imagery is the next step in remote area management, but given the current very high costs of satellite surveys per square kilometre, they are only currently suitable for smaller areas (e.g. Camden Sound and Pender Bay). But costs will decrease over time and it may be that this becomes the best long term solution for population monitoring. It may take 5-10 years for the technology to become cheap enough to obtain imagery over the entire region used by humpback whales in the Kimberley, which is what is required to be able to have an abundance estimate for the whole region as there are so far no methods to extrapolate abundance from smaller to larger areas as is the case with systematic sampling from aerial or boat platforms.

While budgets for satellite surveys are presently difficult to identify from year to year, the WA State government is required to monitor the Marine Park and, as such, employs rangers and funds vessel patrols. These patrols can be used to undertake surveys, but in order to be able to monitor trends in abundance, a systematic sample design is required including measurements of range and bearing to each whale observed recorded (See Buckland et al. 2011). Observer training is paramount to ensure that this is done in a robust manner. If funds or expertise are not available for this to be successful then relative abundance estimates might be all that is provided from vessel surveys via direct counts along the track line. Although these direct counts are much less reliable for monitoring abundance trends, in the absence of anything else they might provide an early warning system of change in the population and can also provide other important information on calf presence and diagnostics. This is important information for distinguishing between calving and nursing/breeding areas which is important data needed for future management.

The last systematic survey of the abundance of humpback whales in the Kimberley region occurred in 2007 (CWR aerial survey). This combined with the growing vessel use of the marine environment of the Kimberley through both industrial development and tourism, highlights that this data is in urgent need of updating and to effectively monitor trends, many years of systematically sampled data are required (often decades).

5 References

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Humpback whale use of the Kimberley: understanding and monitoring spatial distribution

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