Amrun Project
2018 Inshore Dolphin Survey Report

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Executive Summary

Rio Tinto Alcan Weipa (RTW)'s Amrun Project involves the construction and operation of a bauxite mine and associated processing facilities, barge and ferry terminals, and a Port and shipping activities near Weipa, Queensland. As part of the approvals and planning process for the Amrun Project, an *Inshore Dolphin Offset Strategy* (hereafter referred to as the "Strategy") was designed primarily to obtain knowledge about the distribution, abundance and habitat utilised by populations of Australian snubfin dolphins (*Orcaella heinsohni*) and Australian humpback dolphins (*Sousa sahulensis*) in the region from Weipa to Aurukun. As outlined in the Strategy, the survey design requires dolphin surveys to be undertaken prior to construction, during construction and after construction of the Amrun Port and river facilities.

Following a pre-construction baseline survey conducted by GHD in 2014, Blue Planet Marine (BPM) was contracted by RTW to conduct annual surveys during the construction phase of the Project (2016-2018). The 2018 inshore dolphin survey was the third and final construction-phase survey and the fourth overall survey completed to date. This report provides details about the 2018 survey, as well as analyses of the combined 2014, 2016, 2017 and 2018 data.

Three vessels undertook simultaneous, predetermined line-transect surveys from 13-26 October 2018 to collect sighting, photo-identification and habitat data on inshore dolphins encountered at three sites from Pine River to Aurukun. A total of 350 hours and 13 minutes were spent on the water for the 2018 survey, with all vessels at all sites totalling 4,028 kilometres travelled. Of this time, 133 hours and 46 minutes were spent 'on effort' (i.e. observing for dolphins while on transect) (1,618 km).

Including both on and off effort sightings, the research team sighted a total of 90 dolphin groups consisting of 498 individuals, including seven mixed species groups. As per previous surveys in 2014, 2016 and 2017, humpback dolphins were encountered in the highest number of groups and totalled the most individual sightings (humpback dolphins: 58 groups, 279 individuals; inshore bottlenose: 28/172, snubfin: 5/36, unidentified dolphin 4/7, spinner: 1/3 and orca 1/1). A total of 27 humpback dolphin calves, 28 inshore bottlenose calves plus one neonate, and 2 snubfin dolphin calves were sighted during the 2018 survey. The observer team also sighted 334 individuals of other (i.e. non-dolphin) marine megafauna species during the 2018 survey, the most numerous of which were marine turtles (n=147) and sea snakes (n=128).

At least one useable identification photograph was obtained from 72 (80%) of the 90 dolphin groups encountered in 2018. Images of marked animals of sufficient photo quality to be used in capture recapture (CR) analyses included 103 humpback dolphins (77 of which were photographed in one secondary sample (SS), 16 in two SS, 6 in three SS and 4 photographed in four SS); 72 bottlenose dolphins (71 photographed in one SS and 1 photographed in two SS); 16 snubfin dolphins (15 photographed in one SS and one photographed in two SS); and 1 orca. Four spinner dolphins were also photographed but all were unmarked.

Over the four years of survey to date, dolphin species sighted include humpback dolphins (242 groups / 937 individuals), inshore bottlenose dolphins (84/569), offshore bottlenose dolphins (3/31), snubfin dolphins (19/79), and spinner dolphins (5/41). Humpback dolphins were encountered at the highest rate in all four surveys, with Linear Encounter Rates (LERs) of this species highest in 2014 (0.12 dolphins sighted per km travelled on effort) and lowest in 2016 (0.04). LERs for bottlenose dolphins were highest in 2018 (0.07 dolphins per km) and lowest in 2016 (0.01). Snubfin dolphins were encountered at low rates in all four surveys (2014, 2016 and 2017 = 0.01, 2018 = 0.02 dolphins per km).

With humpback, snubfin and bottlenose dolphins having been sighted in every year of the survey from 2014-2018, each of these species was found in the same general areas in each year of the survey, including in proximity to the river and port facilities. However, one exception was the lack of humpback dolphins sighted in the Hey River in 2016. Although small sample sizes and limited survey

effort prevent strong conclusions from being drawn about the causes of this observation, there are several possible explanations:

- animals moving in and out of the study area, for example due to prey availability, seasonal differences or environmental factors;
- differences in sampling methods and local experience. For example, research permit conditions for the 2016 survey allowed the vessel to spend no more than 30 minutes within 50 m of encountered groups, whereas the limit was 60 minutes for the 2014, 2017 and 2018 surveys. The 2016 survey team was also less experienced in local conditions compared with other years;
- potential displacement of animals as a result of construction and vessel activities associated with the Amrun Project river facilities, as well as activities related to an adjacent mining lease at Hey Point (Green Coast Resources). Although dredging and piling activities for the Amrun Project Hey River and Humbug Terminals had been completed at least two months prior to the 2016 survey, displacement and follow on effects cannot be ruled out. With increased vessel traffic associated with both the Amrun Project and with Green Coast Resources having started shipping bauxite from their Hey Point barge loading facility in the month leading up to the 2016 survey, it is possible that the combined activities at this location resulted in a shift in dolphin distribution.

However, increased sightings of humpback dolphins in the Hey River in 2017 and 2018 suggest that any decline in dolphins at this location may have been a temporary shift in distribution rather than a permanent one. Despite this observation, fewer dolphins were sighted in the Hey River in 2017 and 2018 than in 2014, and this should be monitored in future. Post-construction surveys will provide further evidence regarding this issue.

Following the discovery of false positive and false negative errors in the photoidentification data from 2014 for both humpback and bottlenose dolphins, a reanalysis was conducted to correct any misidentification errors before collating capture histories for statistical modelling. Capture history data were combined for the 2014, 2016, 2017 and 2018 surveys in order to carry out capture-recapture population modelling. Sample sizes were sufficient to obtain abundance estimates for humpback dolphins (n=264 individuals identified with sufficient quality to be used in capture-recapture modelling) and bottlenose dolphins (n=178), but insufficient for snubfin dolphins (n=26).

Estimated abundance of humpback dolphins present in the study area (1,014 km^2) during each of the primary samples was 211 (95% Confidence Interval (CI): 168-266) in 2014, 230 (95% CI 146-361) in 2016, 227 (95% CI 164-315) in 2017 and 183 (95% CI 151-221) in 2018. Therefore, typically, it is likely that more than 180 humpback dolphins use the combined sampling areas at Site 1 (Weipa), Site 2 (Boyd Point) and Site 3 (Aurukun) during a two-week period between October and December. These abundance estimates represent some of the highest recorded anywhere in Australia for this species to date. Future surveys in the region are required to provide more information about the broader population in western Cape York.

A model was able to be fitted to the capture history data for bottlenose dolphins, however the uncertainty introduced into the estimates by very small numbers of individuals captured more than once in the same year was expressed in wide confidence intervals. The estimates of total population size show a steady increase from 119 (95% CI 81-175) in 2014, 152 (95% CI 86-270) in 2016, 276 (95% CI 181-422) in 2017 and 435 (95% CI 271-700) individual bottlenose dolphins estimated to have used the study area during a two-week period in October 2018. Consequently, while it is not clear how much confidence should be placed on the model estimates, it seems clear that the local population is certainly not decreasing and may be increasing rapidly. The rate of increase in the between-year estimates is far greater than could result from *in situ* births and indicates a very high rate of immigration.

Having successfully completed surveys to meet the Strategy objectives in 2014, 2016, 2017 and 2018, the combined datasets and analyses provide an important contribution to knowledge on inshore dolphins locally and in the broader Western Cape York region. These data allow for more informed management and planning decisions to be made as the Project enters the operational phase. Additionally, local Traditional Owners (TOs) have been involved in all four surveys, as well as in training days for the project, gaining skills and experience in marine fauna observation and in monitoring dolphin populations.

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1. Introduction

Rio Tinto Alcan Weipa (RTW) has been mining bauxite north of the Embley River near Weipa, Queensland, on the western side of the Cape York Peninsula since 1963. In order to develop bauxite reserves south of the Embley River, the Amrun Project involves the construction and operation of a bauxite mine and associated processing facilities, barge and ferry terminals, and a Port and shipping activities (Figure 1). Originally known as the "South of Embley" Project, the name was changed to "Amrun" in consultation with the Wik Waya people, the traditional custodians of the land where the port and processing facilities are located, to coincide with their name for the area near Boyd Point.

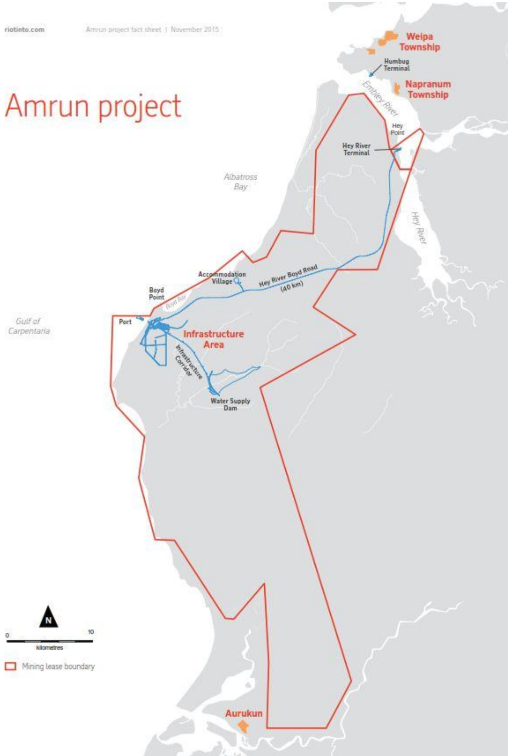

Figure 1. Overview of the Amrun Project. Source: Rio Tinto Weipa.

As part of the Commonwealth EPBC Approval (EPBC 2010/5642), Rio Tinto was required to develop and implement an *Inshore Dolphin Offset Strategy* (RTA 2014, hereafter referred to as "the Strategy") for the Project. In relation to this study, the Strategy was designed primarily to:

- obtain knowledge about the distribution and abundance of local and regional populations of Australian snubfin (*Orcaella heinsohni*) and Australian humpback dolphins (*Sousa sahulensis*) in the Western Cape York area;
- identify habitat utilised by these species;
- contribute to the independent research on Australian snubfin and Australian humpback dolphins; and
- provide information on Traditional Owner employment opportunities associated with the implementation of the Strategy.

As outlined in the Strategy, the survey design required inshore dolphin surveys to be undertaken in the area from Weipa (latitude 12.60^{o}S) to Aurukun (13.35^{o}S) prior to construction, during construction and after construction of the Amrun Project Port and river facilities. The findings from these surveys will be used to inform management decisions for the project on an ongoing basis, as well as to contribute to independent research on the dolphin species encountered. Although humpback and snubfin dolphins are the primary focus of the surveys, information is also collected on other cetacean species encountered, such as bottlenose (*Tursiops* spp.) and spinner dolphins (*Stenella longirostris*), as well as other marine megafauna sighted opportunistically (e.g. turtles, sea snakes, sharks, rays).

Following a pre-construction baseline survey conducted by GHD in 2014, Blue Planet Marine (BPM) was contracted by RTW to conduct annual surveys during the construction phase of the Amrun Port and river facilities (2016-2018). Construction and shipping activities for the Amrun Project were completed according to the following timeline:

- April 2016 – completion of river dredging using a small backhoe
- May 2016 – completion of Port dredging using a Cutter Suction Dredge (CSD)
- June 2016 – August 2016 completion of piling for Humbug and Hey river Terminals
- June 2017 - December 2017 - completion of piling activities for Port works
- December 2017 – May 2018 completion of overwater works for Port activities
- May 2016 – December 2018 - ongoing ferry and Roll-on Roll-off (RORO) trips between Humbug and Hey River Terminals
- December 2018 – first shipment from the new Amrun port.

It should be noted that an adjacent mining lease operated by Green Coast Resources had also carried out vessel activities in the Hey River during 2016 – 2018, with the first bauxite shipment from GRC's Hey Point barge loading facility occurring in October 2016.

The 2018 dolphin survey constituted the last of the construction phase surveys for the Amrun Project. This report provides details about the 2018 survey and analyses of the combined 2014-2018 data, as well as recommendations for future surveys in the post-construction phase of the Strategy.

2. Methodology

2.1 Permits and Animal Ethics approvals

The 2016-2018 dolphin surveys were conducted under Scientific Permit WISP17664416 issued by the Queensland Department of Environment and Heriatge Protection in accordance with section 12(f) of the *Nature Conservation (Administration) Regulation 2006* and Cetacean Permit 2016 – 0006 issued by the Australian Government Department of the Environment and Energy under the provisions of section 238 of the *Environment Protection and Biodiversity Conservation Act 1999*. The conditions of the State and Commonwealth research permits were similar, except that the state permit allowed the survey vessel to follow a group or an individual marine mammal for a period of up to 60 minutes at a time, while the Commonwealth permit allowed follows of no more than 30 minutes at a time for the 2016 survey. In order to avoid confusion and maintain consistency, the more conservative restriction of 30 minutes was implemented throughout the 2016 survey. A Commonwealth permit variation was obtained prior to the 2017 survey to bring it into line with the state permit and allow the survey vessel to follow a group or an individual marine mammal for a period of up to 60 minutes at a time. The 60 minute time limit was then implemented for the 2017 and 2018 surveys.

Animal ethics approval (CA 2016/09/1000) for the 2016-2018 surveys was granted by the Animal Ethics Committee of the Queensland Department of Agriculture and Fisheries.

2.2 Vessel survey methods

The methods used for the 2018 survey followed those of the 2014, 2016 and 2017 surveys, described in detail in the *Inshore Dolphin Offset Strategy* (RTA Weipa 2014) and the *2014 Inshore Dolphin*

Baseline Survey report (GHD 2015), as well as subsequent survey reports (BPM 2018, 2019). Three vessels undertook simultaneous, predetermined line-transect surveys to collect sighting, photo-identification and habitat data on inshore dolphins encountered at three sites ranging from Pine River in the north to Aurukun in the south (Figure 2). The total area of site 1 is 410 km^2, site 2 is 287 km^2 and site 3 is 317 km^2 for a total study area of 1,014 km^2. The transect lines used for the 2018 survey were the same as those used for the 2014-2017 surveys, with some minor adjustments made in 2017 to avoid areas with very shallow water that were unable to be navigated, even at high tide. Data were also collected on dolphins sighted while transiting between the sites. For the 2018 survey, BPM's 7m RHIB, *Koopa*, was used to survey site 1, while the 17m live-aboard vessel, *Phantom IV*, was used in conjunction with the 6.4m RHIB, *Coda*, to complete the surveys at Sites 2 and 3, and to assist with site 1 as needed (Figure 3).

These surveys were designed using Robust Design capture-recapture methods, such that each primary sample (i.e. each year's total survey) consisted of several smaller secondary samples. Each primary sample from 2014-2018 included four secondary samples, with each secondary sample consisting of *either* an "A" *or* a "B" transect at each site, plus river transects ("R" transects) for sites 1 and 3 (Table 1 and Figures 4-6). There were no river transects at site 2.

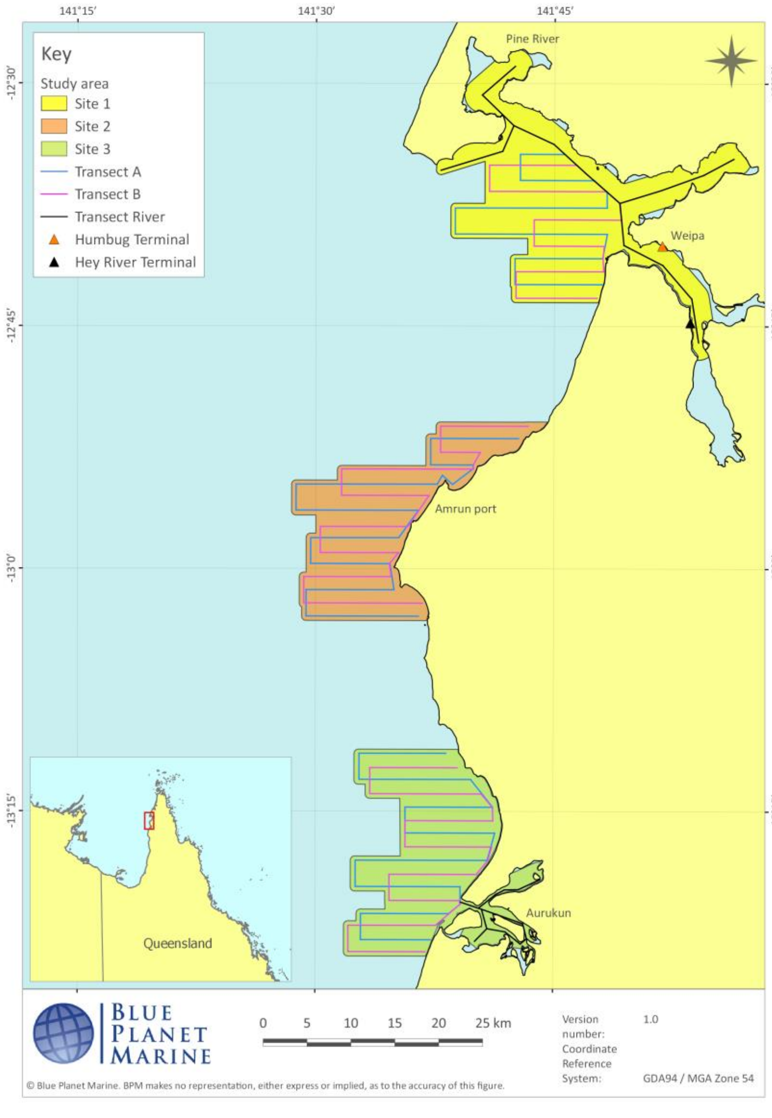

Figure 2. Overview of transects for the Inshore Dolphin Survey undertaken in October 2018.

Figure 3. BPM Research vessels *Koopa* (top left), *Coda* (top right) and *Phantom IV* (bottom) used for the 2018 survey.

Table 1. Transects completed per secondary sample during the 2014-2018 surveys.

Secondary sample	Site 1 transects	Site 1 total km	Site 2 transects	Site 2 total km	Site 3 transects	Site 3 total km	Total
Sample 1	A1 to A13, R1-R15	154.1	A14 to A32	111.6	A33 to A49, R16-R28	137.3	403.1
Sample 2	B1 to B14, R1-R15	146.9	B15 to B32	103.3	B33 to B51, R16-R28	129.1	379.3
Sample 3	A1 to A13, R1-R15	154.1	A14 to A32	111.6	A33 to A49, R16-R28	137.3	403.1
Sample 4	B1 to B14, R1-R15	146.9	B15 to B32	103.3	B33 to B51, R16-R28	129.1	379.3
Total km	602.0		429.9		533.0		1564.9

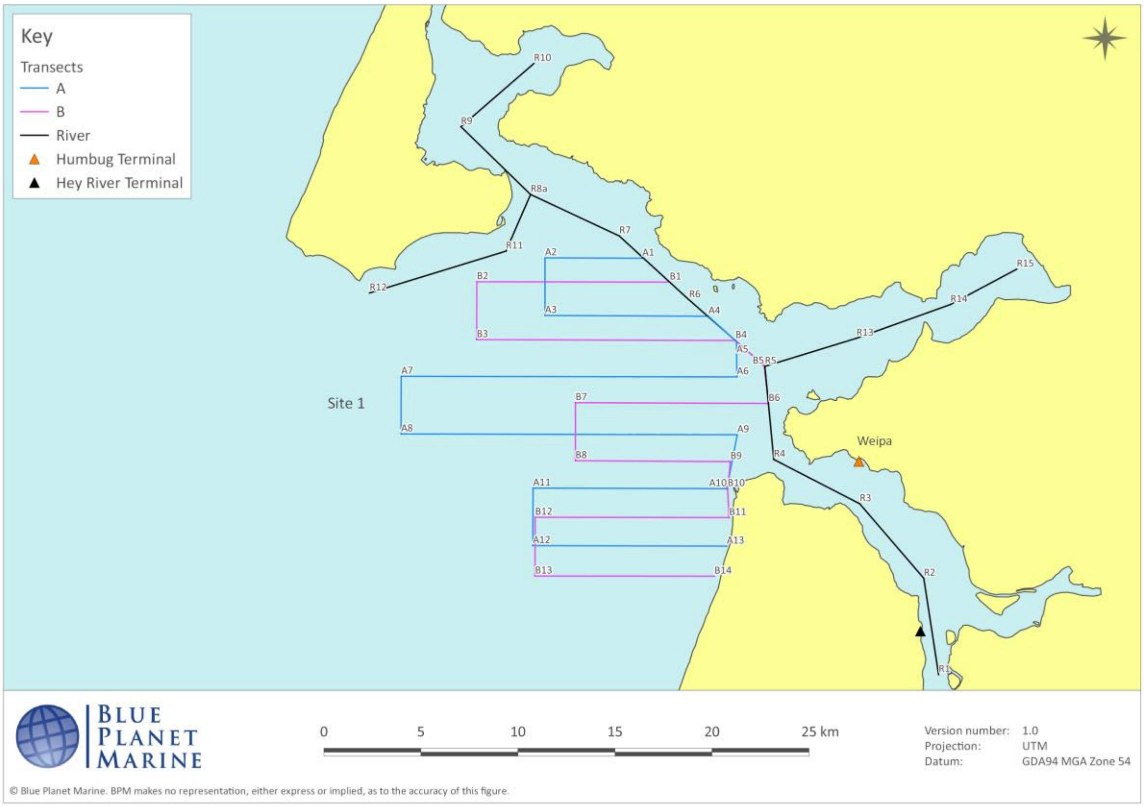

Figure 4. Site 1 transects.

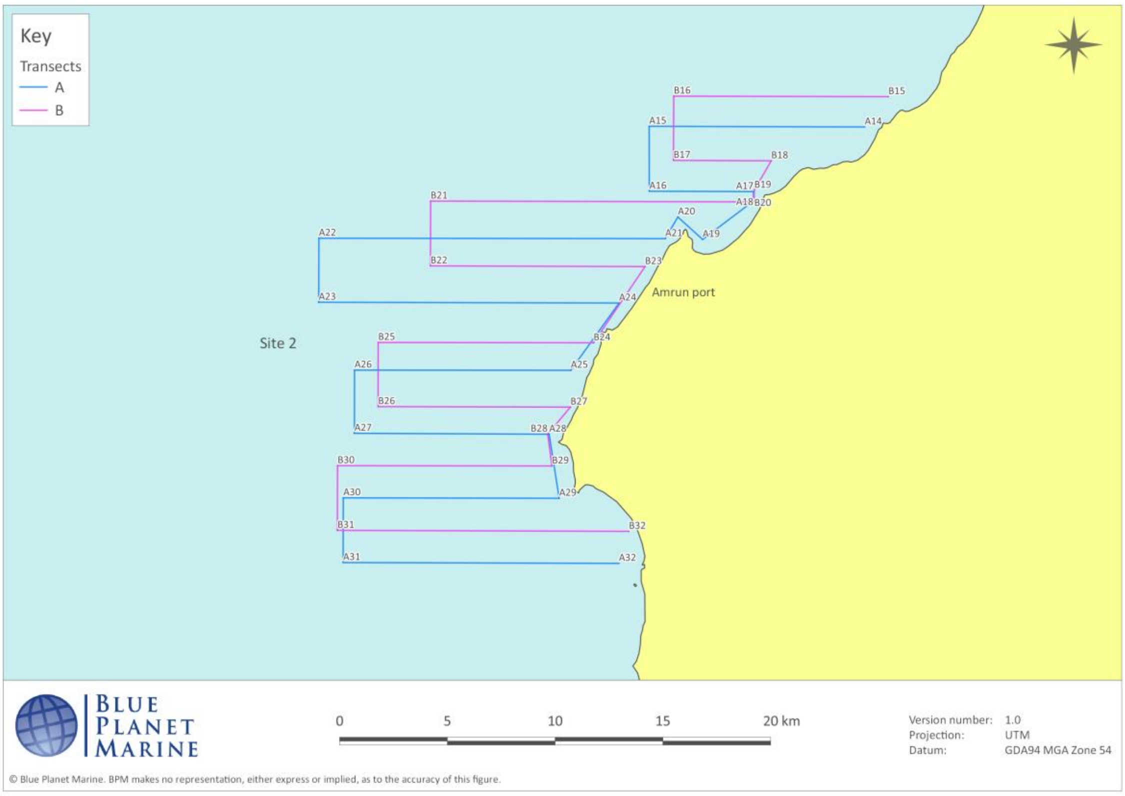

Figure 5. Site 2 transects.

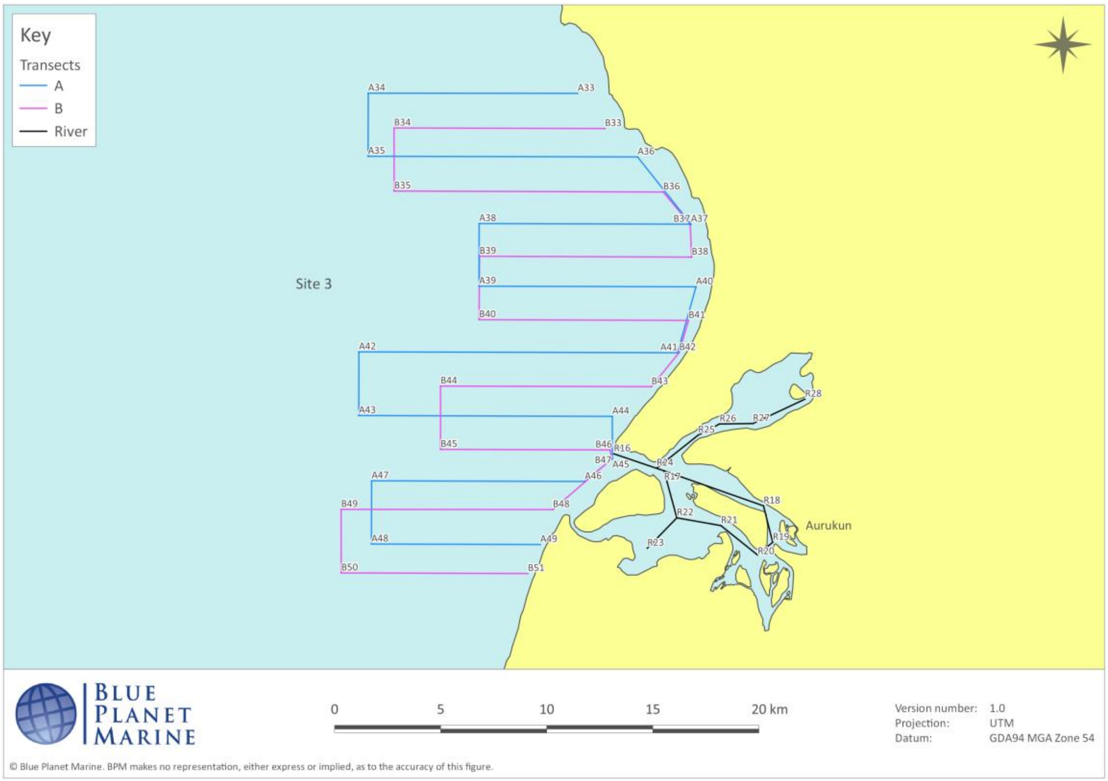

Figure 6. Site 3 transects.

All vessels followed the same protocols regardless of which site they were surveying. As each vessel travelled along the predetermined transect lines, at least two observers and the vessel master observed for dolphins and other marine megafauna. This was defined as being 'on effort' (i.e. observing for dolphins while on transect). When dolphins were sighted, observers recorded the date, time, location and Beaufort sea state and went 'off effort' to approach the dolphin group and determine their species, group size, composition and behaviour. Detailed protocols regarding determination of group size, composition and behavioural categories followed GHD (2014). Photo-identification data were also collected to identify individual dolphins for capture-recapture analysis.

Environmental parameters were recorded using ProDSS water quality meters at least once an hour while on effort and at the location of each dolphin sighting throughout the survey. Parameters recorded included depth, temperature, conductivity, turbidity and pH. Tidal cycle and tidal state were also recorded.

Once all required data had been collected for a dolphin sighting, or the maximum permitted contact time with a group under the scientific research permit had been reached, the vessel returned as closely as possible to the location at which it had left the transect and resumed travelling on effort. Data were also collected on dolphins encountered while off effort (for example, while travelling between transects, to and from the boat ramp, or back to the transect line after finishing data collection with another group), following the same protocols as for on effort sightings. In addition to dolphin sightings, data (including time, location, species, group composition and depth) were collected on other marine megafauna sighted opportunistically throughout the survey, including dugongs, turtles, sharks, rays, seasnakes and crocodiles.

GPS tracks were recorded throughout the survey at a maximum of one minute intervals, with vessel speeds ranging from 10-15 km/h while on effort. Surveys were generally abandoned in Beaufort sea states of >3, with a small number of transect segments completed in Beaufort 4. No transects were commenced in Beaufort 4 conditions. If conditions increased to Beaufort 4 during a transect, this transect was completed in some instances and later rerun if time and weather allowed before starting the next secondary sample.

Survey training days, which included testing of equipment and data collection systems, were completed on 10 - 12 October 2018 followed by the survey itself which was completed over 14 days from 13 - 26 October 2018. A team of 16 researchers undertook the survey in 2018 (Figure 7), including Traditional Owners Trini Kerindun (Land and Sea Management Program (LSMP)) Miles Kerindun (LSMP), and Percy Callope (Land and Rehabilitation team (L&R)), as well as Darren Lee (L&R), members of RTW's Health, Safety and Environment (HSE) team Linda Wells, Jess Hommelhoff, Emma Haddon and Sherie Hinschen and BPM's Dave Paton, Anthony Muyt, Liz Hawkins, Corey Lardner, Mitch Burrows, Andrew Nichols, Chris Witty and Dan Burns.

Figure 7. Members of the 2018 dolphin survey team. Top row L to R: Percy Callope, Anthony Muyt, Liz Hawkins, Jess Hommelhoff, Miles Kerindun, Trini Kerindun. Bottom image L to R: Dan Burns, Andrew Nichols, Percy Callope.

2.3 Data analysis methods

2.3.1 Photo-identification data and abundance estimates

Photographic data analysis followed standard photo-identification methods (e.g. Urian *et al.* 1999, Beasley *et al.* 2013, Brown *et al.* 2014), and protocols outlined in GHD (2015) and Brooks *et al.* (2014). All photographs of dolphins collected during the 2018 survey were analysed using Adobe Lightroom software to extract the best identification photograph(s) of each dolphin in each group, including the left and right dorsal fin of the individual (when available).

Not all individuals have sufficiently distinctive marks to support unambiguous identification. Only distinctively marked individuals may be considered to be captured in photographs. Capture-recapture models can therefore only yield estimates of the number of distinctively marked members in a population. This estimate can then be adjusted for the 'unmarked' proportion to yield an estimate of total population size, as described below.

For each species, the number of good quality photographs (P_t) and, of those, the number that depicted a distinctively marked individual (P_m) was recorded for each group encounter. A binary logistic model was fitted to the distinctiveness data on the set of good quality photographs (1 = distinctively marked, 0 = not distinctively marked) to estimate the marked proportion (M_p) of the population. The model was fitted as a binomial model of the number of distinctively marked dolphins in each group from of the total number of dolphins in the group.

The total abundance (N_{total}) of each population for any sampling period may be estimated by dividing the estimated abundance of marked dolphins ($\hat{N}_{marked}$) by the estimated marked proportion ($\hat{M}_p$):

$$\hat{N}_{total} = \hat{N}_{marked} \Big/ \hat{M}_p, \text{ with } \hat{\mathrm{S}}\mathrm{E}(\hat{N}_{total}) = \hat{N}_{total} \sqrt{Var(\hat{N}_{marked}) \Big/ \left(\hat{N}_{marked}\right)^2 + Var(\hat{M}_p) \Big/ \left(\hat{M}_p\right)^2}$$

Log-normal confidence intervals for abundance estimates may be calculated following Burnham *et al.* (1987):

$$\hat{N}_{lower} = \hat{N} \big/ C \text{ and } \hat{N}_{upper} = \hat{N} \cdot C, \text{ where } C = \exp\left(z_{\alpha/2} \sqrt{\log_e \left[1 + \left(\hat{S}E(\hat{N}) \big/ \hat{N} \right)^2 \right]} \right)$$

All identification photographs were graded for image quality and distinctiveness in order to minimise bias and avoid violation of model assumptions for capture-recapture analyses. Due to the low number of sightings, both "on effort" and "off effort" sightings were combined and included in capture-recapture (CR) analyses. Only good quality images of individuals assessed as being sufficiently distinctive as to be identifiable from the lowest quality image in the analysis were included. Capture history data were analysed using CAPTURE within the program MARK (White and Burnham 1999).

Prior to collating all years of photoidentification data for the project, a number of errors were detected in the 2014 photo-identification and capture history data. These errors included both false positive errors (i.e. images of two different dolphins being judged as of the same individual) and false negative errors (i.e. two images of the same dolphin being judged as of two different individuals). Examples of these are presented in Appendix I (Figure 39 - Figure 42) and included two false positives each of humpback and bottlenose dolphins, plus seven false negatives of humpback dolphins and five false negatives of bottlenose dolphins. The importance of avoiding misidentification errors in capture-recapture analyses to estimate population parameters has been demonstrated previously (Yoshizaki *et al.* 2009, Link *et al.* 2010; Morrison *et al.* 2011). To ensure accuracy for subsequent multi-year comparisons, the 2014 data were corrected prior to collation of capture histories. Once this had been completed, matching of all individual images collected to date yielded capture history data on the three survey sites (Weipa, Boyd Point and Aurukun) for the four years 2014, 2016, 2017 and 2018 for humpback and bottlenose dolphins. Matches were checked by two experienced researchers during the final collation stage to minimise the potential for matching errors.

A Robust Design model (CRD; Kendall *et al.*1995, Kendall and Nichols 1995, Kendall *et al.* 1997) was fitted to the data from the four secondary samples in each of the four primary (annual) samples. The model provided estimates of abundance in each primary sample, capture probabilities in each secondary sample, apparent survival (alive and in the area) between primary samples, and temporary emigration between primary samples.

In the CRD model, temporary emigration (probability of absence from the sampling area for the duration of a primary sample) was modelled in terms of two parameters, γ'' and γ'. γ'' estimated the probability of presence in the previous sample and absence in the present sample, and γ' estimated the probability of absence in both the previous and present samples.

As no survey was conducted in 2015, this introduced a missing year in the otherwise annual series. A dummy year was included in the data for 2015 to construct a regular annual series in order to put the estimates of apparent survival and temporary emigration on a consistent annual basis. Estimates were obtained by fixing the probability of capture at zero for each of the four secondary samples for the dummy year and the apparent survival and temporary emigration parameters for the dummy year were fixed equal to some other year. No estimates in the results for 2015 are reported or interpreted.

Goodness of fit was tested using the program U-Care (Choquet at al. 2005) on data collapsed to primary samples. Overdispersion was estimated as the model chi-square divided by its degrees of freedom. Where detected, significant overdispersion was included the model to yield correct standard errors for the estimates.

The abundance estimates from the model apply only to the proportion of the population which is distinctively marked. An estimate of the total population size was then made by dividing by an estimate of the proportion of distinctively marked individuals in the population.

2.3.2 Encounter rates

Linear Encounter Rates (LER) for the 2018 survey were calculated by dividing the total number of dolphins sighted on effort by the total kilometres travelled on effort. This differs from the method used in the 2014 pre-construction report (GHD 2015), in which encounter rates were calculated using both on and off effort sightings divided by the total distance travelled on effort. In the belief that on-effort-only encounter rates provide a more accurate statistic than the method used for the 2014 report[1], we have recalculated the 2014 encounter rates using only on effort sightings divided by on effort distances to facilitate comparison between surveys, as well as other studies.

Survey Area Encounter Rates (SAER) were calculated as the total number of dolphins sighted on effort divided by the total area surveyed on effort, assuming a 500m strip width (i.e. 250 m either side of the transect line, estimated to be the average distance to which dolphins could be reliably observed under a variety of sea conditions (Brown *et al.* 2014)). As per the method used for LERs, we have recalculated the 2014 encounter rates using only on effort sightings to facilitate comparison between surveys. In order to compare pre-construction SAERs with construction-phase SAERs, an additional analysis was conducted by combining effort and sightings data for the three construction-phase surveys (2016, 2017 and 2018).

Using a 3 x 3 km grid overlain on the study area and assuming a 500 m strip width, on-transect survey effort (km^2 per grid cell) was calculated for the 2018 survey (Appendix I - Figure 43), as well as for the pre-construction survey and construction phase surveys combined. Dolphins sighted per grid cell were then used to calculate SAERs across the study area for the 2018 survey and to compare SAERs between project phases. All mapping was conducted using QGIS software (QGIS Development Team (2018)) with a coordinate reference system of GDA94 / MGA Zone 54.

2.3.3 Environmental parameters associated with sightings

The 2018 survey commenced on 13 October as tides were moving from spring to neap following the new moon on 9 October. The first quarter moon occurred on 17 October and full moon on 25 October. For the purposes of analysis, tides from 13-20 October were considered neap tides, with spring tides

[1] If on AND off effort sightings are included in encounter rate calculations then they should be divided by on AND off effort kilometres. Considering off effort travel typically occurred at higher speeds and without consistent observer effort, BPM believes restricting calculations to on-effort-only data provides a more accurate statistic.

for the remainder of the survey (21-26 October). Tidal states were considered 'high' or 'low' if a sighting was within 15 minutes of the stated relevant tide time according to the Bureau of Meteorology tide tables for Weipa (Humbug Point), otherwise they were considered 'rising' or 'falling'.

3. Results

3.1 2018 Survey

3.1.1 Survey conditions present

A total of 350 hours and 13 minutes were spent on the water for the 2018 survey, with all vessels at all sites totalling 4,028 kilometres travelled. Of this time, 133 hours and 46 minutes were spent 'on effort' (i.e. observing for dolphins while on transect) (1,618 km). Beaufort sea state conditions while on effort ranged from 0 to 4 throughout the survey (Table 2).

Table 2. Beaufort sea state conditions during on effort components of the 2018 survey.

Beaufort sea state	Distance travelled (km)	Pecentage of total distance travelled (%)
0	12.4	0.8
1	391.6	24.2
2	763.9	47.2
3	425.9	26.3
4	23.6	1.5
Total	1617.5	100.0

3.1.2 Sightings

3.1.2.1 Dolphins

During the 2018 survey, including both on and off effort sightings, the research team sighted a total of 90 dolphin groups consisting of 498 individuals, including seven mixed species groups (Table 3, Figure 8). Dolphin sightings at Site 1, 2 and 3 are shown separately in Appendix I (Figure 44, Figure 45, and Figure 46). For the purposes of this report, all references to bottlenose dolphins (*Tursiops* spp.) refer to the inshore ecotype unless explicitly stated otherwise (i.e. offshore bottlenose is explicitly stated when relevant).

Table 3. On and off effort dolphin sightings during the 2018 survey.

Species	Groups (ON)	Individuals (ON)	Minimum group size (ON)	Maximum group size (ON)
Humpback	52 (30)	256 (136)	1 (1)	30 (30)
Inshore bottlenose	23 (15)	135 (88)	1 (1)	25 (25)
Snubfin	4 (1)	34 (20)	3 (20)	20 (20)
Orca	1 (1)	1 (1)	1 (1)	1 (1)
Unidentified dolphin	3 (2)	6 (3)	1 (1)	3 (2)
Mixed (Humpback/Inshore bottlenose)	4 (2)	40 (22)	4 (4)	18 (18)
Mixed (Humpback/Snubfin)	1 (0)	5 (0)	5 (0)	5 (0)
Mixed (Humpback/Unidentified dolphin)	1 (1)	5 (5)	5 (5)	5 (5)
Mixed (Inshore bottlenose/Spinner)	1 (1)	16 (16)	16 (16)	16 (16)
Total	90 (53)	498 (291)	1 (1)	30 (30)

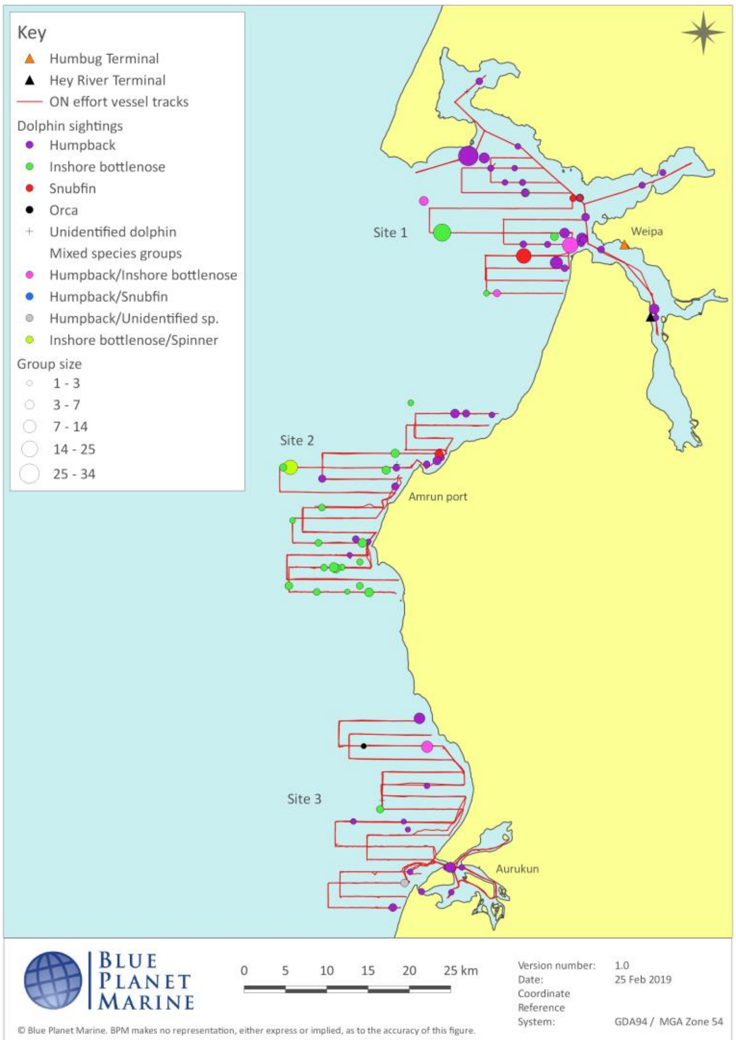

Figure 8. Overview of all on and off effort dolphin groups sighted for the 2018 Inshore Dolphin Survey.

3.1.2.2 Non-dolphins

During the 2018 survey, the observer team also sighted 334 individuals of other (i.e. non-dolphin) marine megafauna species (Site 1 - Figure 9, Site 2 - Figure 10, Site 3 - Figure 11). Of the non-dolphin species sighted, the most common were marine turtles (n=147, 44%), sea snakes (n=128, 38%), sharks (n=31, 9%) and rays (n=24, 7%).

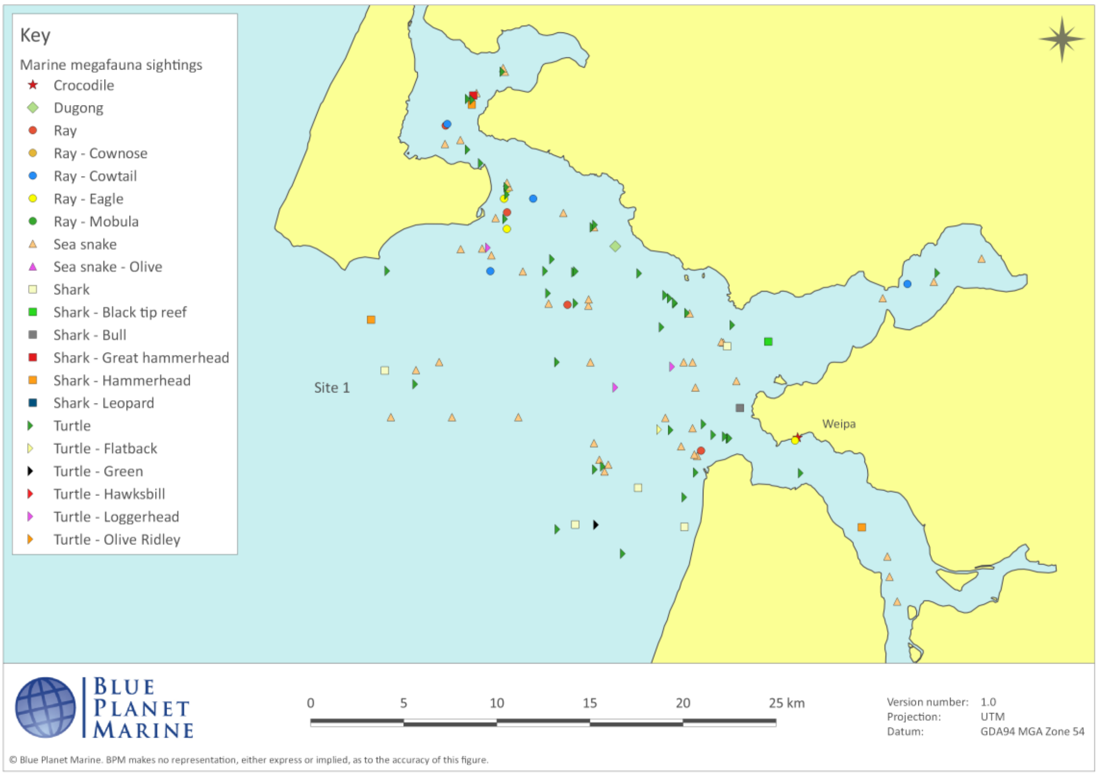

Figure 9. Locations of all other marine megafauna observed both on and off effort at Site 1 during the 2018 dolphin survey.

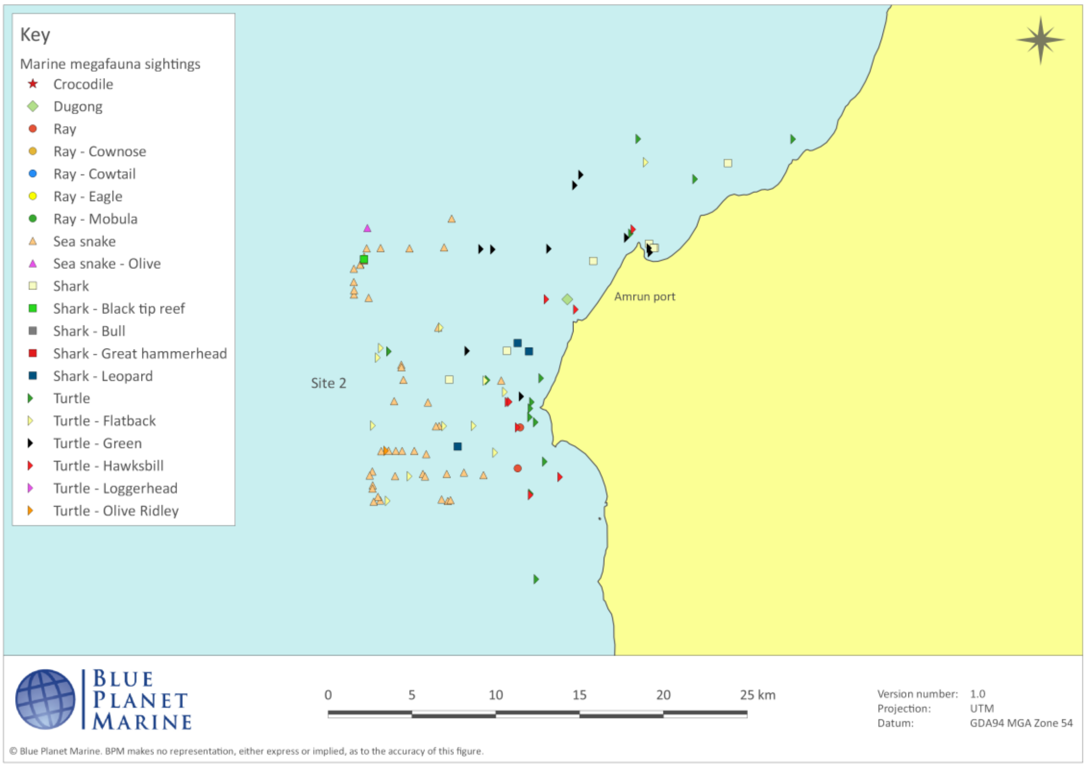

Figure 10. Locations of other marine megafauna observed both on and off effort at Site 2 during the 2018 dolphin survey.

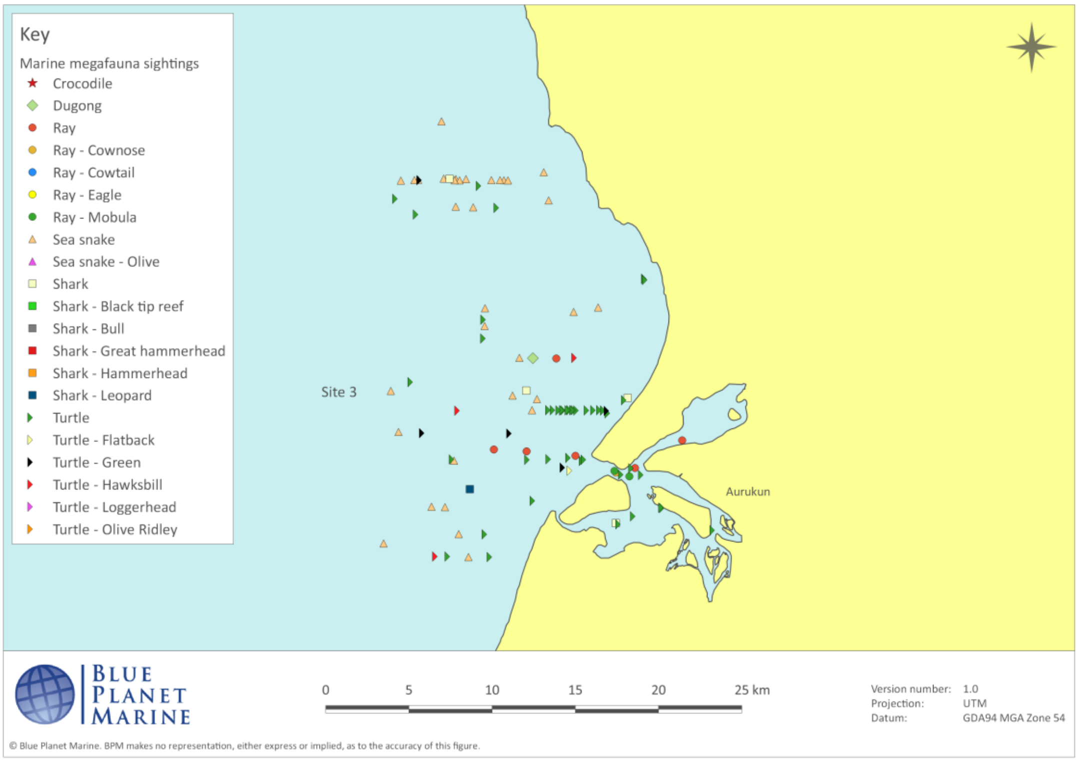

Figure 11. Locations of other marine megafauna observed both on and off effort at Site 3 during the 2018 dolphin survey.

3.1.3 Dolphin encounter rates

Linear Encounter Rates (LERs), calculated as the total number of dolphins sighted on effort divided by the total kilometres travelled on transect (1,618 km) during the 2018 survey are shown in Table 4. Mixed species groups were separated into their component species for these calculations.

Table 4. Overall on effort Linear Encounter Rates of dolphin species during the 2018 survey.

Species	Humpback	Bottlenose	Snubfin	Spinner
Groups (individuals)	33 (149)	18 (114)	1 (20)	1 (3)
Mean Linear Encounter Rate (dolphins / km of transect)	0.09	0.07	0.01	0.002

Overall Survey Area Encounter Rates (SAERs) for the 2018 survey were 0.18 humpback dolphins per km^2 on effort, 0.14 for bottlenose, 0.02 for snubfin, 0.004 for spinner and 0.001 for orca. The overall SAER for these species combined was 0.35 dolphins per km^2 of effort. SAERs per grid cell are shown for all species combined in Figure 12, for humpback dolphins in Figure 13, and for bottlenose dolphins in Figure 14. With only one on-effort sighting of snubfin dolphins in 2018, and too few encounters of other species, SAERs were not mapped separately for these species.

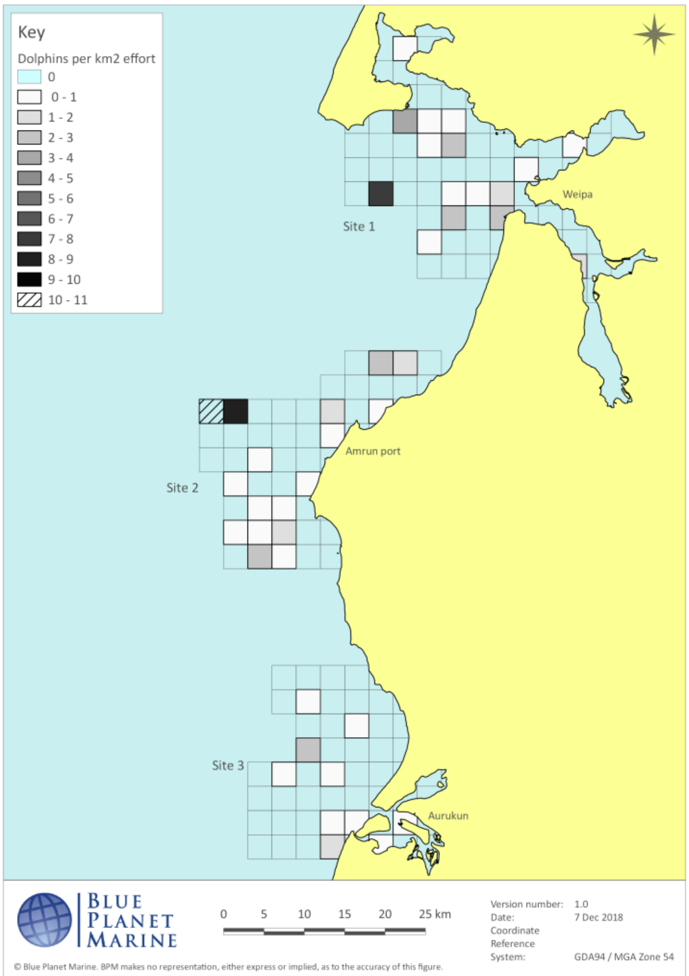

Figure 12. 2018 Survey Area Encounter Rates (dolphins per km^2 effort) for all dolphin species combined (humpback, bottlenose, snubfin, spinner and orca).

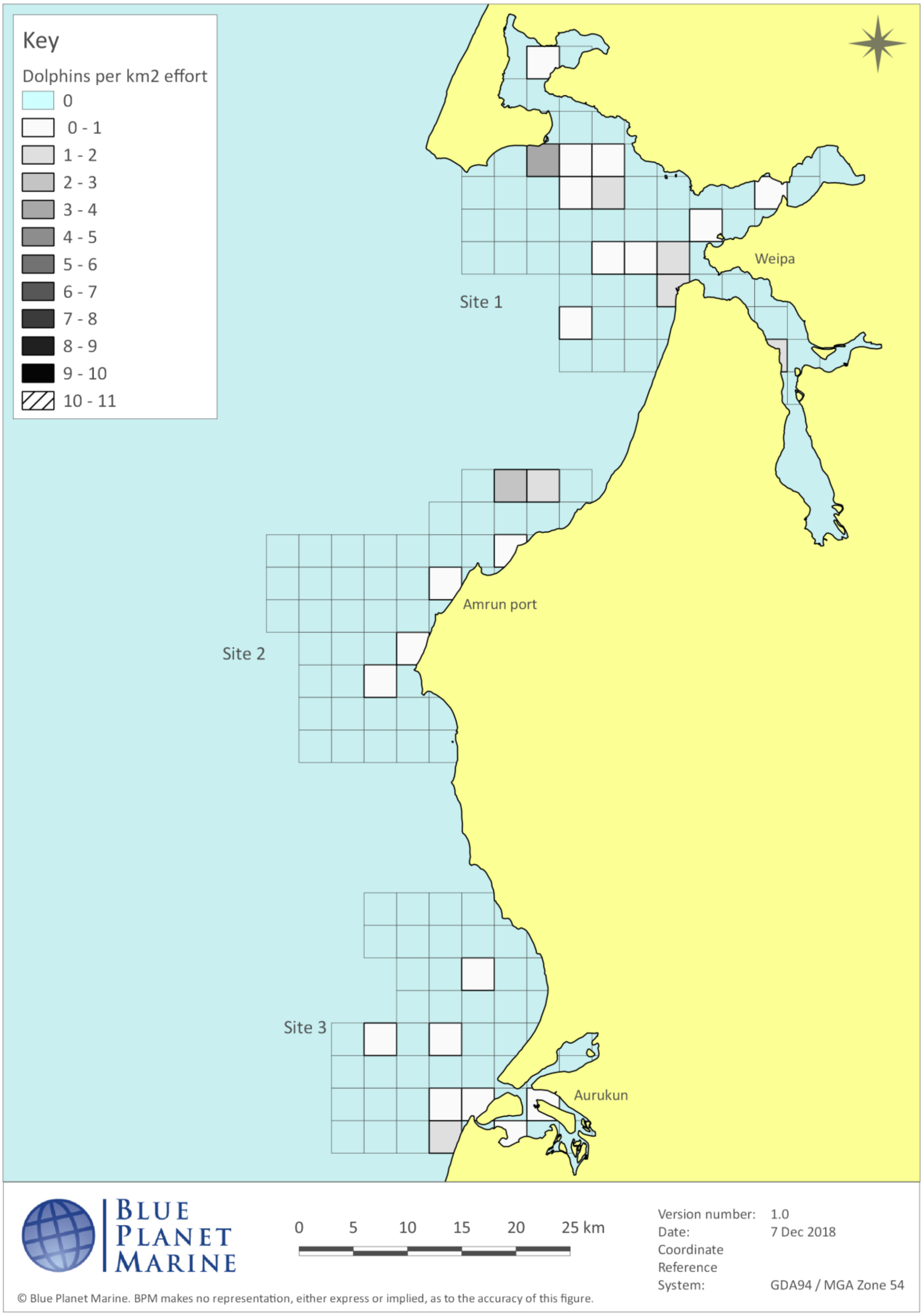

Figure 13. 2018 Survey Area Encounter Rates (dolphins per km^2 effort) for humpback dolphins.

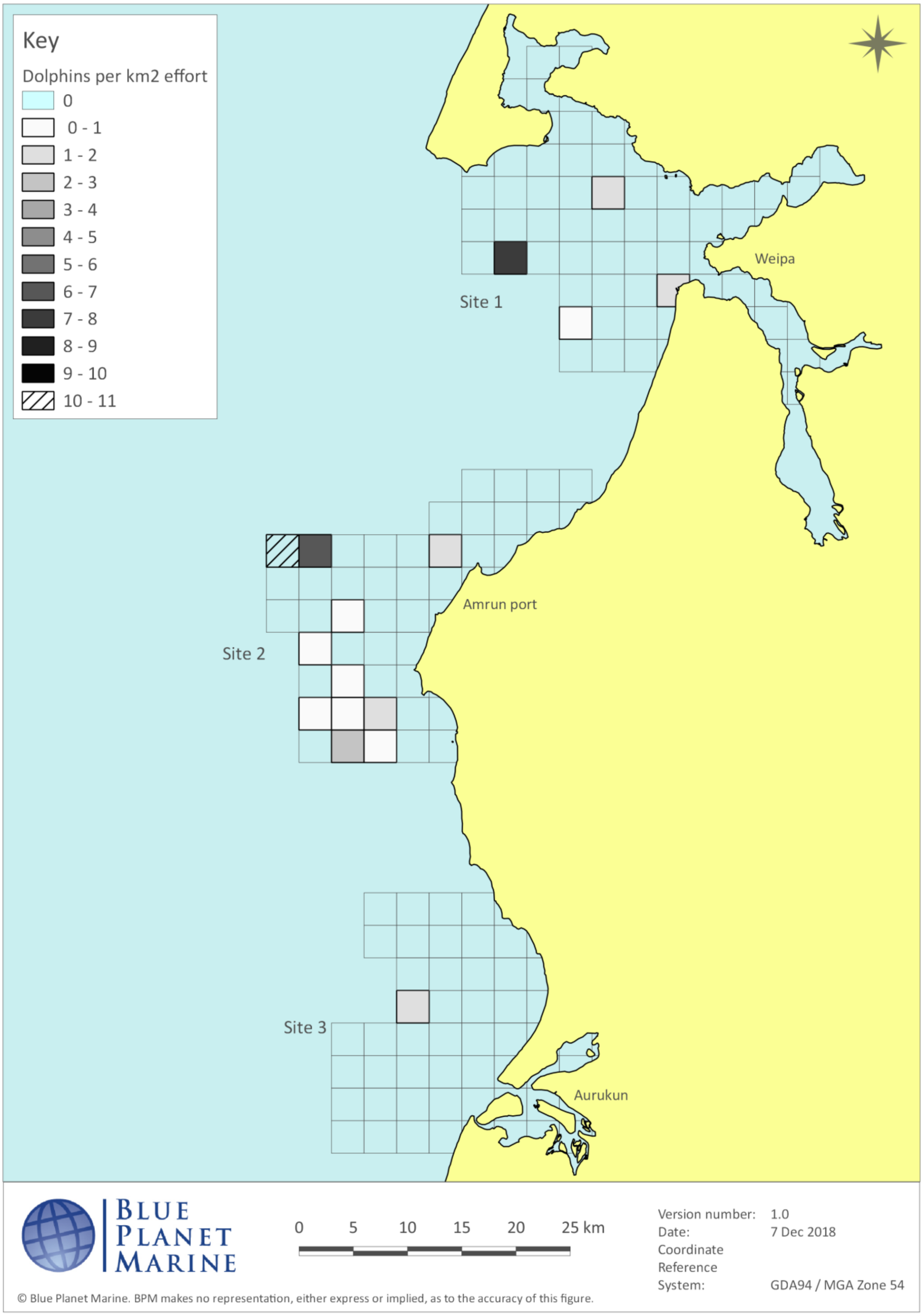

Figure 14. 2018 Survey Area Encounter Rates (dolphins per km^2 effort) for bottlenose dolphins.

3.1.4 Identification and resight rates

At least one useable identification photograph was obtained from 72 (80%) of the 90 dolphin groups sighted in 2018. Identified individuals included:

- 103 humpback dolphins used in capture-recapture (CR) analyses, including:
  - 77 photographed in one secondary sample (SS), 16 in two SS, 6 in three SS and 4 photographed in all four SS;
- 72 bottlenose dolphins used in CR analyses, including:
  - 71 photographed in one SS and 1 photographed in two SS.
- 25 snubfin dolphins, including:
  - 16 with images of sufficient quality for CR analysis;
  - one photographed in two SS; and
- 4 spinner dolphins:
  - all unmarked; and
- 1 orca.

The number of dolphins identified (IDs) per group ranged from 1 to 17 for humpback dolphins, 1 to 6 for bottlenose dolphins and 1 to 7 for snubfin dolphins. Example identification images are shown in Figure 15. An image of the orca sighted during the 2018 survey is shown in Figure 16.

Figure 15. Identification images of dolphins photographed during the 2018 survey. Clockwise from top left: snubfin, humpback, bottlenose, spinner.

Figure 16. Image of an orca sighted during the 2018 survey.

3.1.5 Abundance estimates

Capture history data were compiled separately for humpback dolphins and bottlenose dolphins in order to carry out statistical modelling. These results are detailed in Section 3.2.5. Due to the small number of photographs of snubfin dolphins, capture recapture analyses were not possible for this species.

3.1.6 Individual dolphin movements

Sighting locations of humpback dolphins (n=27) photographed on more than one day during the 2018 survey are shown in Figure 17. No humpback dolphins were photographed at more than one site in 2018.

Only one bottlenose dolphin (Ta133) was photographed on more than one day during the 2018 survey, with sighting locations at Site 2 on 18 Oct and approximately 3.0 km further north on 24 Oct 2018. One snubfin dolphin (Oh032) was also photographed on more than one day during the 2018 survey, with sighting locations at Site 2 on 15 Oct 2018 and at Site 1 on 22 Oct 2018 (Figure 18). The minimum distance between these two locations is 26.1 km.

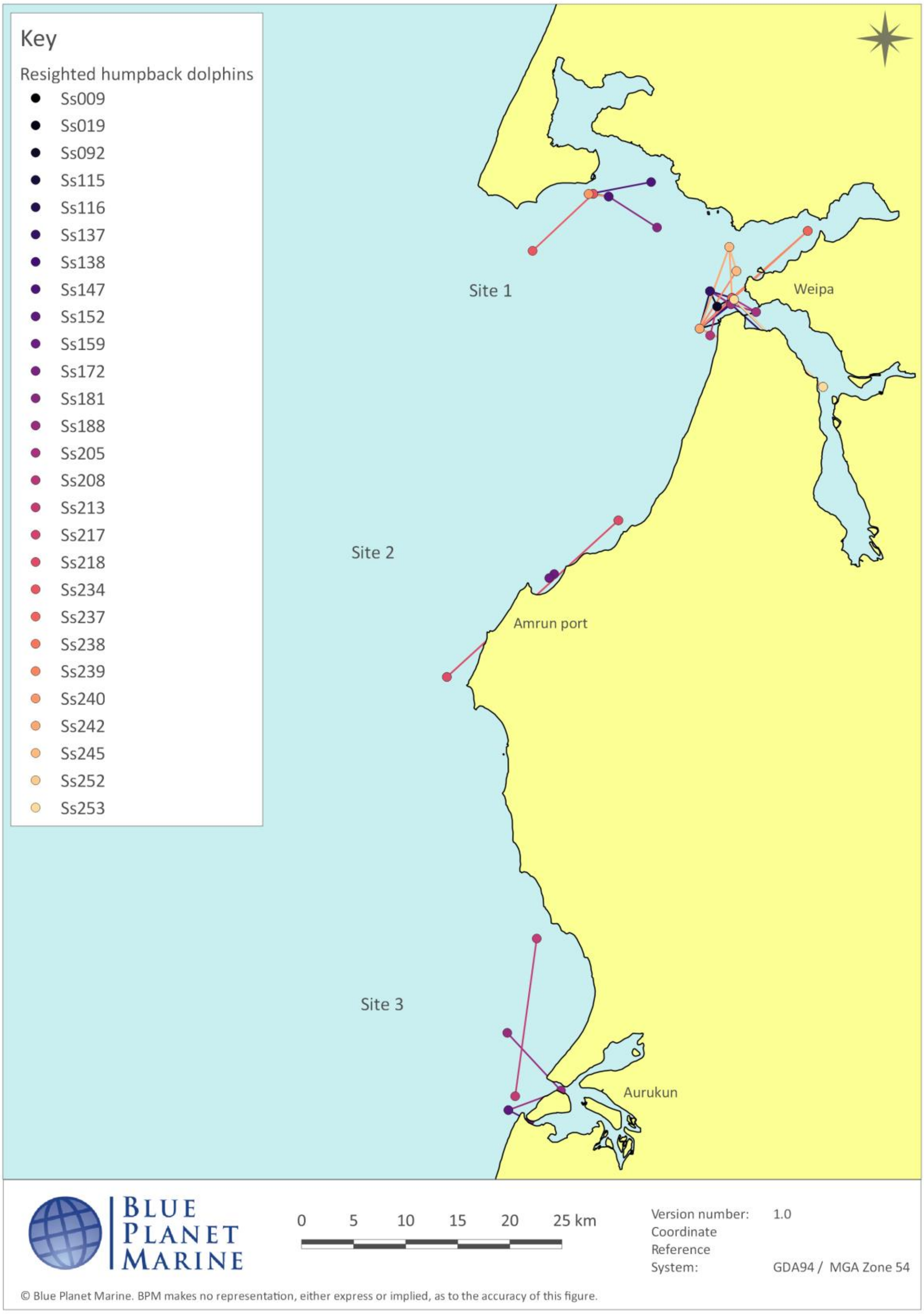

Figure 17. Sighting locations of 27 humpback dolphins photographed on more than one day during the 2018 survey. Interpolated lines drawn between sighting locations for each dolphin are "as the crow flies" and not intended to denote travel routes.

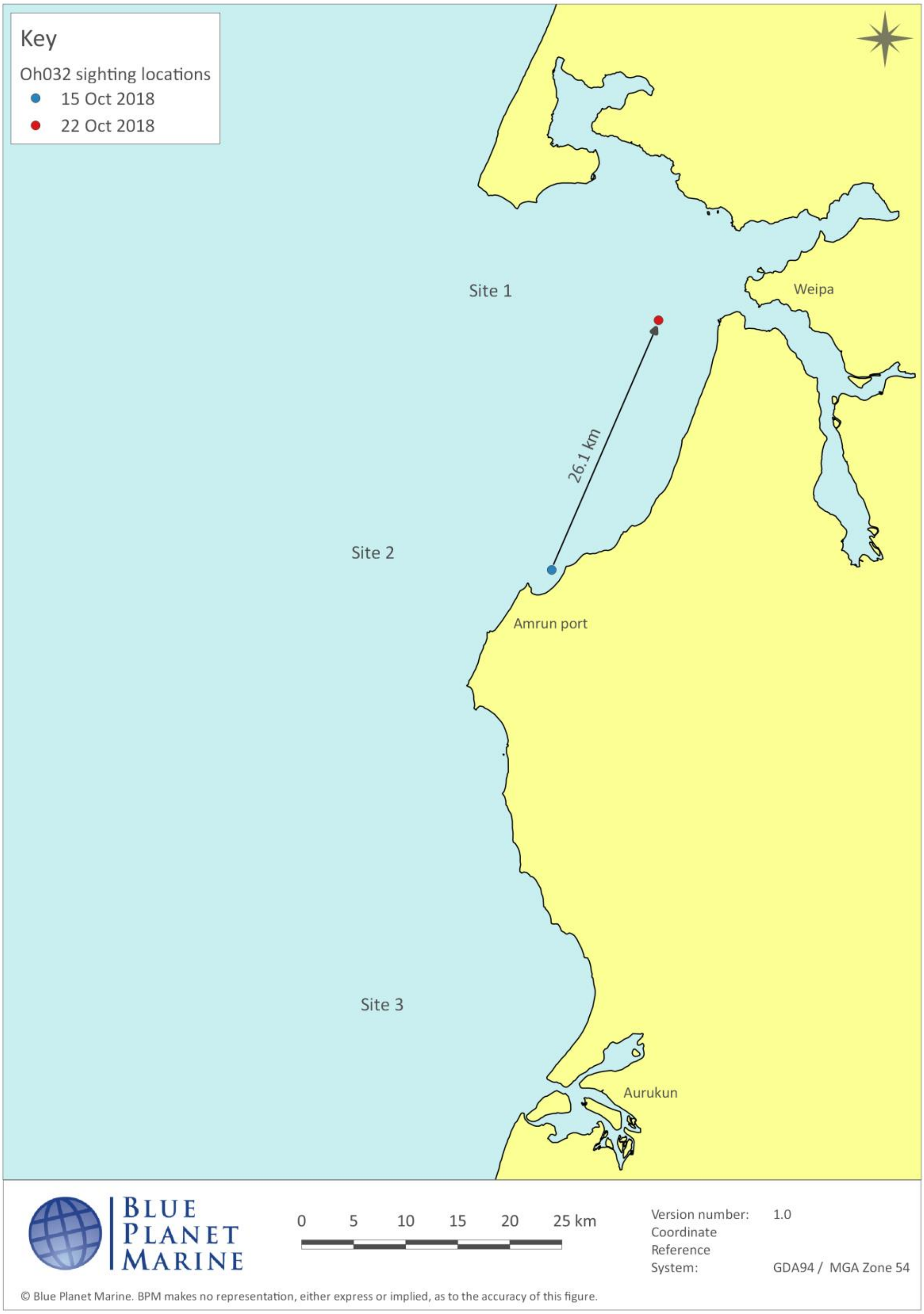

Figure 18. Sighting locations for snubfin dolphin Oh032 photographed twice during the 2018 survey. Interpolated lines drawn between the sighting locations are "as the crow flies" and not intended to denote travel route.

3.1.7 Environmental parameters and habitat preferences

Dolphin sightings per tide phase are shown in Table 5. In order to compare sightings per tide phase with effort, approximately 54.2% of the survey was completed in neap tides, with 45.8% in spring tides.

Of the 90 groups sighted during the 2018 survey, approximately two-thirds occurred on a rising tide (n=58, 64.4%), with 33.3% on a falling tide (n=30), and 2.2% at low tide (n=2). These correlated generally with effort per tidal state, with 64.1% of the survey completed in rising tides, 28.7% on falling tides, 4.3% at low tide and 3.0% at high tide. It should also be noted that some transect segments were unable to be surveyed at low tide, for example the upstream Mission River transect R14-R15 (See Figure 4). Sightings by tidal state are shown in Table 6.

Table 5. Dolphin sightings during spring and neap tides for the 2018 survey, including percentage of total sightings.

Site	Spring tide number of sightings	Percentage of total sightings (%)	Neap tide number of sightings	Percentage of total sightings (%)
1	19	21.1	20	22.2
2	21	23.3	12	13.3
3	8	8.9	10	11.1
All sites	48	53.3	42	46.7

Table 6. Dolphin sightings and tidal states during the 2018 survey.

Site	Falling (%)	Low (%)	Rising (%)	High (%)
1	11 (12.2)	0	28 (31.1)	0
2	10 (11.1)	2 (2.2)	24 (26.7)	0
3	9 (10.0)	0	6 (6.7)	0
Transit	0	0	0	0
All sites	30 (33.3)	2 (2.2)	58 (64.4)	0

After separating mixed species groups into their component species, of all the humpback dolphin sightings in 2018 (n=58), 23 (39.7%) were on a falling tide, 33 (56.9%) on a rising tide and 2 (3.4%) at low tide. For bottlenose dolphins (n=28), 4 (14.3%) sightings were on a falling tide and 24 (85.7%) on a rising tide. Bottlenose dolphins were generally sighted further offshore during rising tides than falling tides (Figure 19). Humpback dolphins were generally sighted further offshore at sites 1 and 2 during rising tides but further inshore at site 3 (Figure 20).

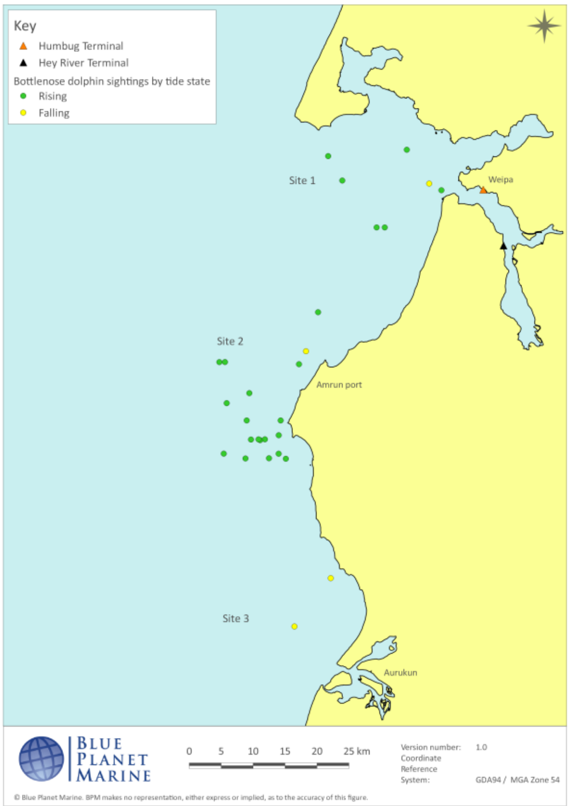

Figure 19. Bottlenose dolphin sightings by tidal state during the 2018 survey.

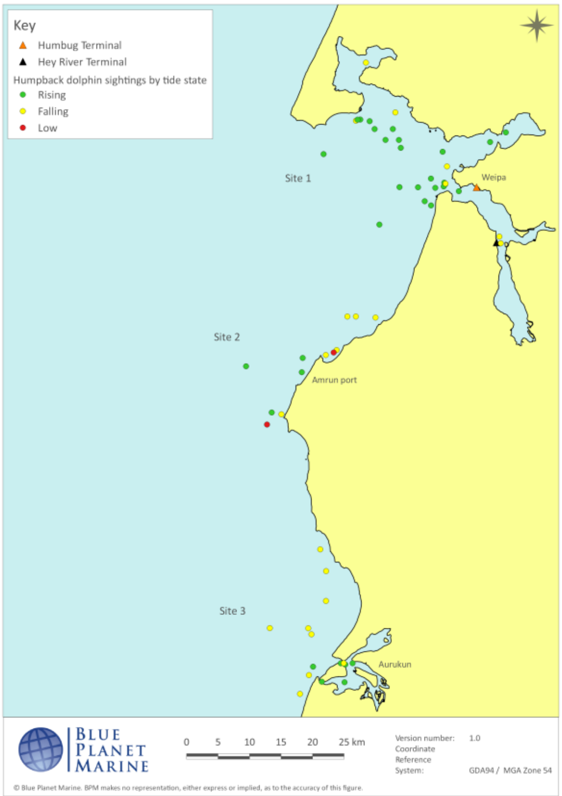

Figure 20. Humpback dolphin sightings by tidal state during the 2018 survey.

Although sample sizes were small, sightings of snubfin dolphins (n=5) occurred at the shallowest mean depth of any species (7.1 m) during the 2018 survey, with humpback dolphins (n=58) sighted at a mean depth of 7.4 m and bottlenose dolphins (n=28) at 15.0 m. Summary statistics for depths at which dolphin sightings occurred during the 2018 survey are shown in Table 7. Summary statistics for other environmental parameters (temperature, salinity, turbidity and pH) recorded at dolphin sighting locations are shown in Table 8 for the 2018 survey.

Table 7. Depth at sighting location of dolphin groups during the 2018 survey.

Species	Number of groups sighted	Depth at sighting location (m)		
		Mean (Std Dev)	Minimum	Maximum
Humpback	58	7.4 (±4.4)	1.4	17.2
Bottlenose	28	15.0 (±5.6)	4.3	23.7
Orca	1	7.8 (N/A)	7.8	7.8
Snubfin	5	7.1 (±2.6)	3.7	10.5
Spinner	1	23.2 (N/A)	23.2	23.2

Table 8. Environmental parameters recorded at dolphin sighting locations for the 2018 survey.

Species	Number of groups sighted	Mean Temperature (Std Dev) (°C)	Mean Salinity (Std Dev) (ppt)	Mean Turbidity (Std Dev) (NTU)	Mean pH (Std Dev)
Humpback	58	29.5 (±1.0)	35.5 (±0.8)	3.7 (±3.3)	8.0 (±0.1)
Bottlenose	28	28.9 (±0.8)	34.9 (±0.2)	1.3 (±2.0)	8.0 (±0.0)
Orca	1	28.7 (N/A)	35.0 (N/A)	0.6 (N/A)	8.0 (N/A)
Snubfin	5	29.3 (±0.8)	35.8 (±0.8)	2.6 (±1.5)	8.0 (±0.1)
Spinner	1	28.0 (N/A)	34.9 (N/A)	0.0 (N/A)	8.1 (N/A)

The primary behaviour of humpback dolphin groups observed during the 2018 survey are shown in Figure 21 and of bottlenose dolphin groups in Figure 22.

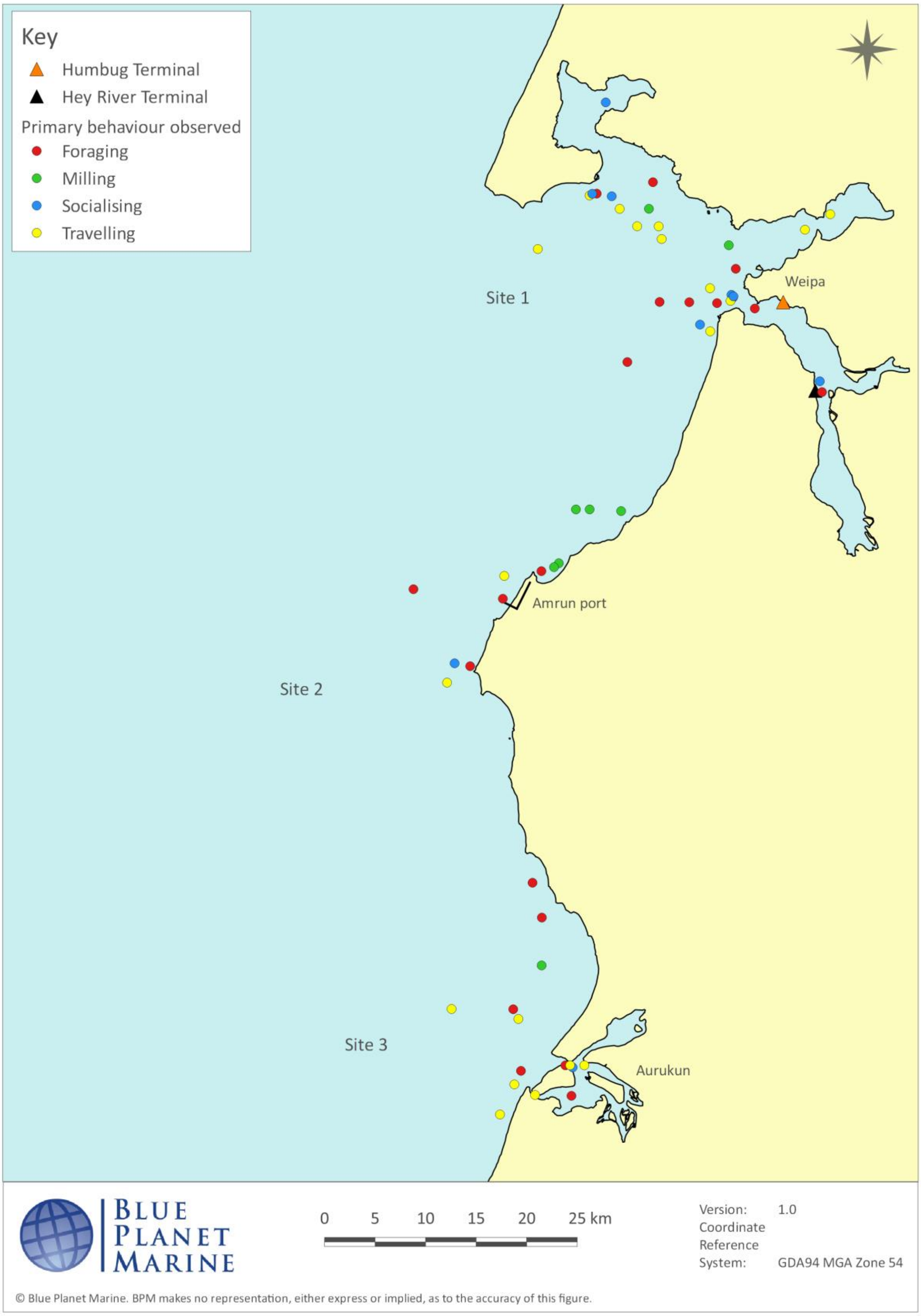

Figure 21. Sighting locations and primary behaviours of humpback dolphin groups observed during the 2018 survey.

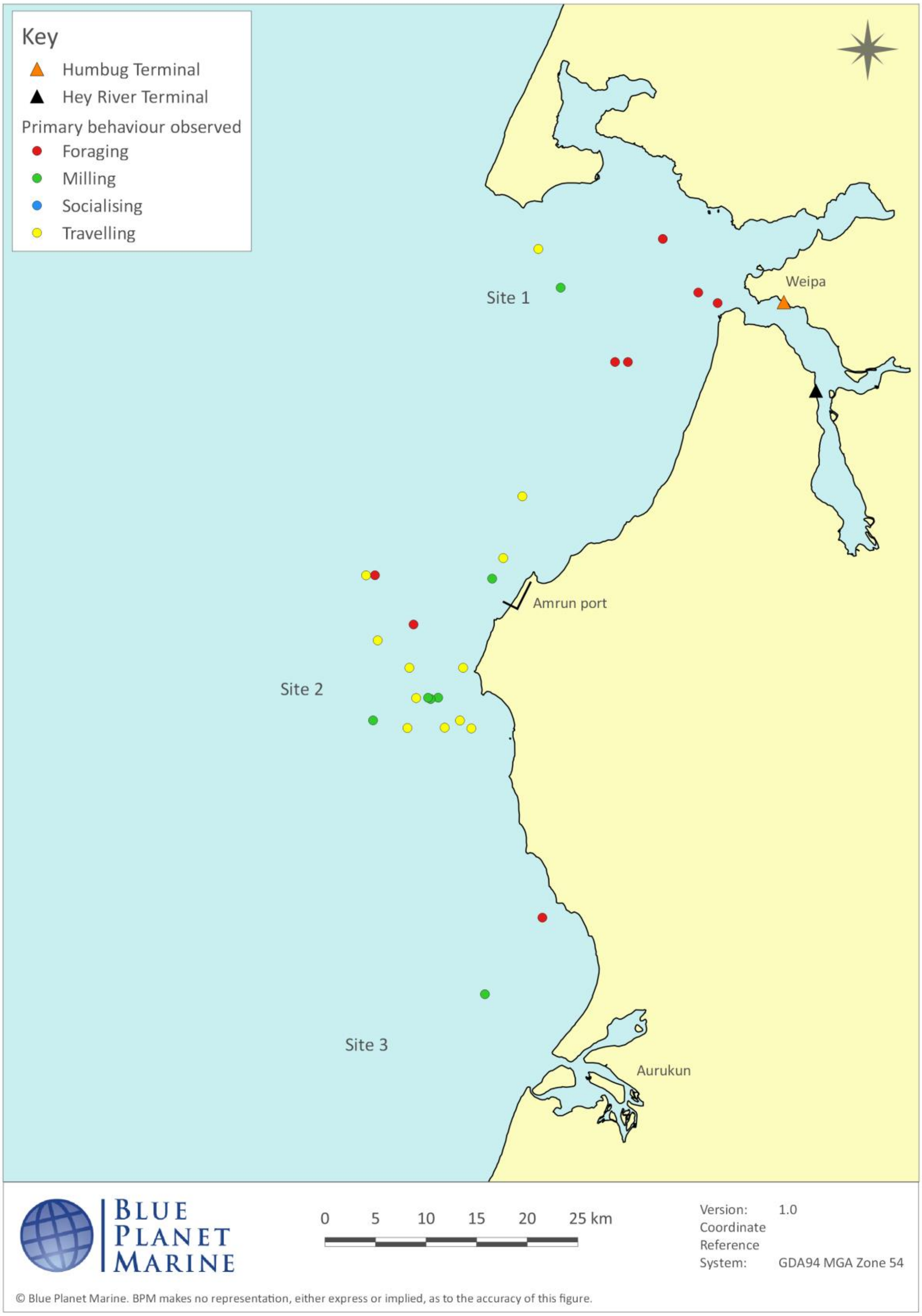

Figure 22. Sighting locations and primary behaviours of bottlenose dolphin groups observed during the 2018 survey.

3.2 2014-2018 Surveys combined

The survey dates for each of the 2014, 2016, 2017 and 2018 surveys are shown in Table 9. Over the four years of survey to date, a total of 1,281 hours and 33 minutes have been spent on the water by all vessels, including 549 hours and 56 minutes on effort. The total distance travelled by all vessels was 14,907 km, including 6,636 km on effort.

Table 9. Dates of inshore dolphin surveys for each year of the Amrun Project.

Primary Sample	Survey dates
1	7 - 19 December 2014
2	7 - 19 November 2016
3	13 - 26 October 2017
4	13 - 26 October 2018

3.2.1 Survey conditions present

A summary of the percentage of distance travelled on effort at each Beaufort sea state for each year's survey from 2014 to 2018 is shown in Table 10. A total of 60% of the on effort component of the 2014 survey was conducted in sea state conditions of Beaufort 2 or less, compared with 57% in 2016, 60% in 2017 and 72% in 2018. The mean sea state conditions when sighting a dolphin group for each survey is shown in Table 11.

Table 10. Percentage of total on effort distance travelled at each Beaufort sea state during the 2014-2018 surveys.

Year	Percentage of distance travelled at Beaufort sea state				
	0	1	2	3	4
2014	1%	7%	52%	34%	7%
2016	1%	17%	39%	38%	5%
2017	1%	28%	31%	37%	3%
2018	1%	24%	47%	26%	2%
Mean	1%	19%	42%	34%	4%

Table 11. Mean sea state conditions at time of sighting of dolphin groups for each year of survey from 2014-2018.

Year	Number of groups sighted	Mean Beaufort sea state (Std Dev)
2014	111	2.09 (±0.86)
2016	61	2.02 (±1.13)
2017	87	1.74 (±0.90)
2018	90	2.00 (±0.82)
Total	349	1.97 (±0.91)

3.2.2 Sightings

3.2.2.1 Dolphins

An overview of all dolphin sightings (including both on and off effort sightings) from 2014-18 is shown in Figure 23. Sightings for each year are shown separately in Figure 24. Details of sightings by species and year are shown in Table 12.

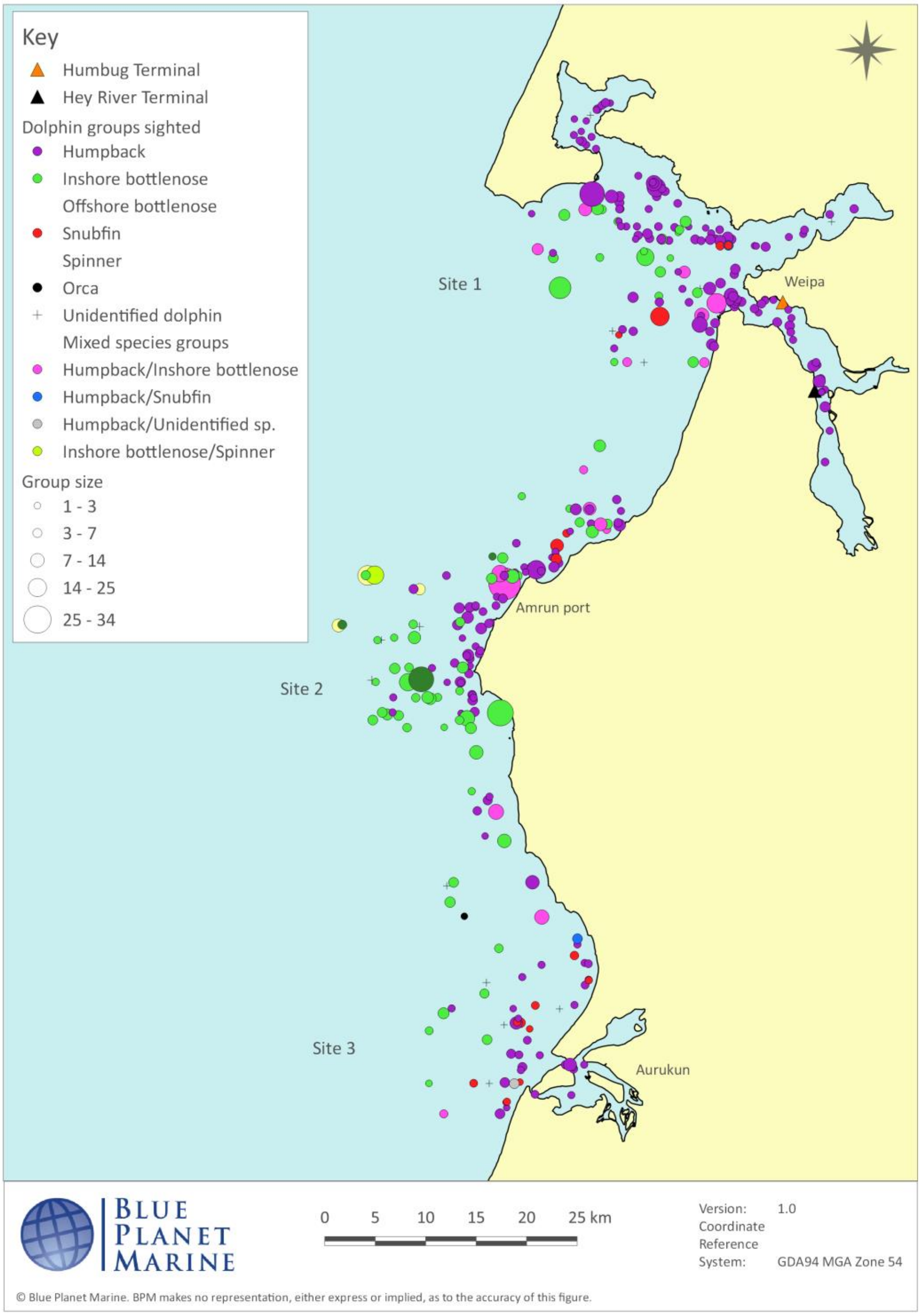

Figure 23. Overview of dolphin sightings and group sizes for the 2014-2018 surveys combined.

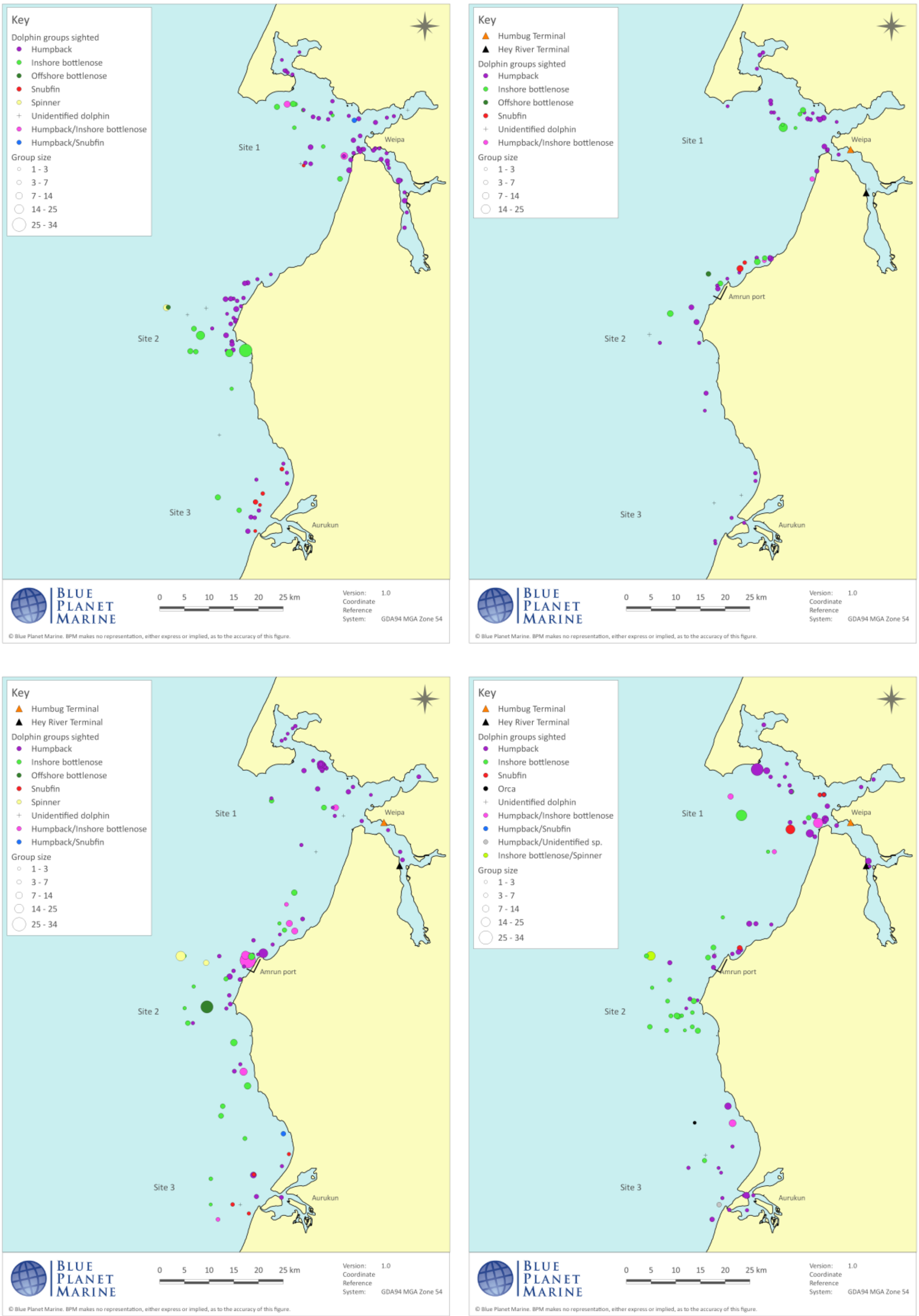

Figure 24. Dolphin groups sighted during surveys in 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right).

Table 12. Dolphin sightings by species during the 2014-2018 surveys. Mixed species groups are shown separately and have not been incorporated into the single species totals.

Species	2014		2016		2017		2018		Total	
	Groups	Animals	Groups	Animals	Groups	Animals	Groups	Animals	Groups	Animals
Humpback	78	278	43	140	49	200	52	256	222	874
Inshore bottlenose	17	140	9	66	18	104	23	135	67	445
Offshore bottlenose	1	4	1	2	1	25	0	0	3	31
Orca	0	0	0	0	0	0	1	1	1	1
Snubfin	6	16	2	14	4	10	4	34	16	74
Spinner	1	9	0	0	3	29	0	0	4	38
Unidentified dolphin	5	7	4	7	3	3	3	6	15	23
Humpback / Inshore bottlenose	2	20	2	8	8	92	4	40	16	160
Humpback / Snubfin	1	5	0	0	1	5	1	5	3	15
Humpback / Unidentified dolphin	0	0	0	0	0	0	1	5	1	5
Inshore bottlenose / Spinner	0	0	0	0	0	0	1	16	1	16
Total	111	479	59	230	87	468	90	498	349	1682

Further details of dolphin sightings from the 2014-2018 surveys are shown in Appendix I, including:

1) On and off effort sightings of each species after separating mixed groups into their component species (Tables 30-34);
2) Sightings by species for each survey at each site (Tables 35-37);
3) A summary of age classes by species for 2014-2018 sightings combined (Table 38);
4) A summary of group sizes by species for 2014-2018 sightings combined (Table 39); and
5) Mean group size of humpback dolphins (Table 40) and bottlenose dolphins (Table 41) sighted by year after separating mixed species groups into their component species (i.e. only accounting for conspecifics in the group size calculations).

The number of groups containing at least one humpback, bottlenose and snubfin dolphin calf for each year of the survey is shown in Table 13. An image of a bottlenose dolphin calf photographed during the 2018 survey is shown in Figure 25. Sighting locations of groups containing at least one humpback dolphin calf are shown in Figure 26, at least one bottlenose dolphin calf in Figure 27, and at least one snubfin dolphin calf in Figure 28.

Table 13. Summary of dolphin groups sighted with at least one humpback, bottlenose and snubfin dolphin calf present during the 2014-2018 surveys.

Species	Year	Total groups with humpback dolphin(s) present	Number with humpback dolphin calf present	Percentage with humpback dolphin calf present
Humpback	2014	81	9	11.1
	2016	45	1	2.2
	2017	58	9	15.5
	2018	58	20	34.5
	Total	242	39	16.1
Inshore bottlenose	2014	19	2	10.5
	2016	11	2	18.2
	2017	26	8	30.8
	2018	28	15	53.6
	Total	84	27	32.1
Snubfin	2014	7	0	0
	2016	2	1	50.0
	2017	5	2	40.0
	2018	5	2	40.0
	Total	19	5	26.3

Figure 25. Bottlenose dolphin calf photographed at Site 2 on 21 Oct 2018.

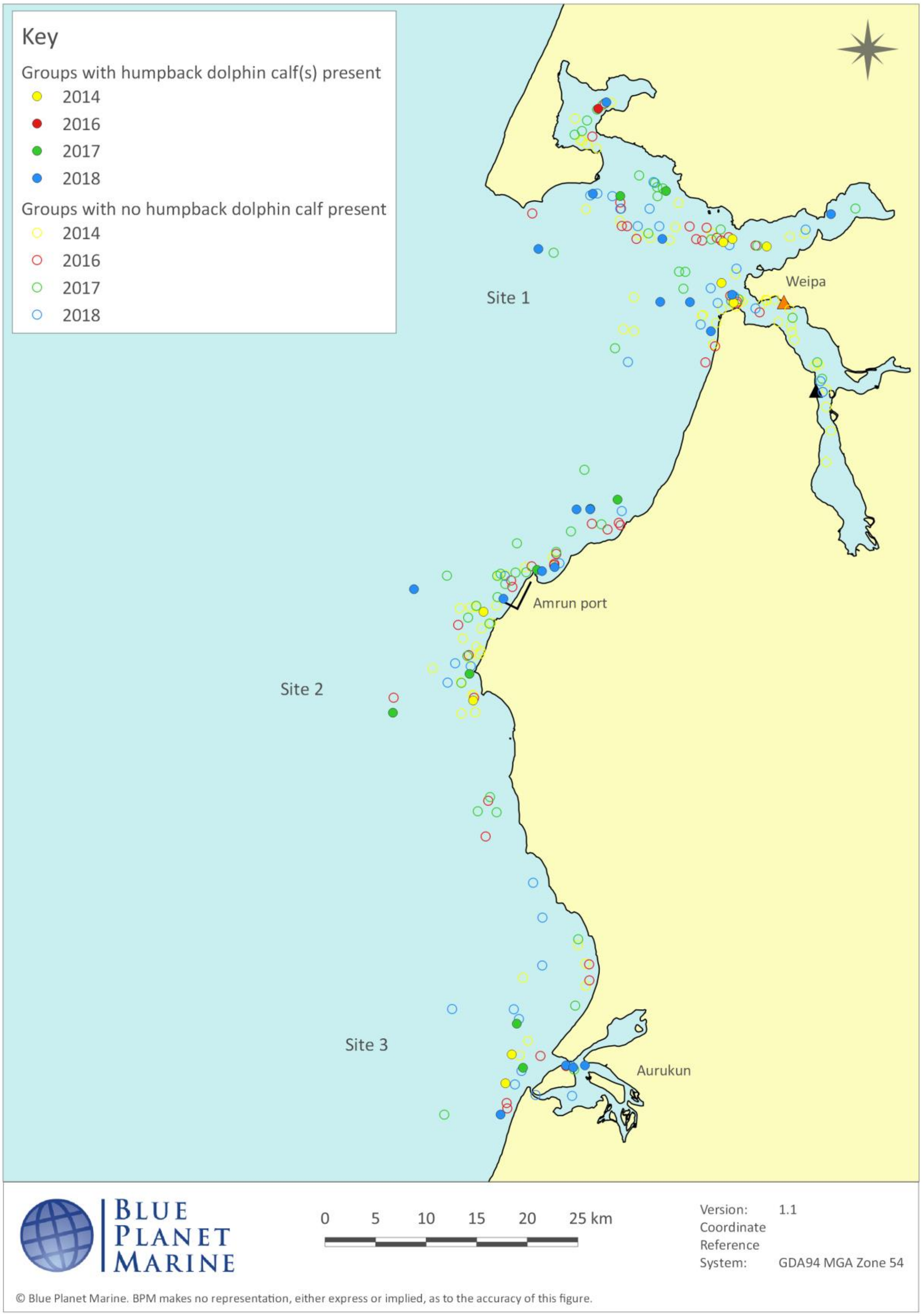

Figure 26. Sighting locations of groups with at least one humpback dolphin present, denoting groups with and without a calf, during the 2014-2018 surveys.

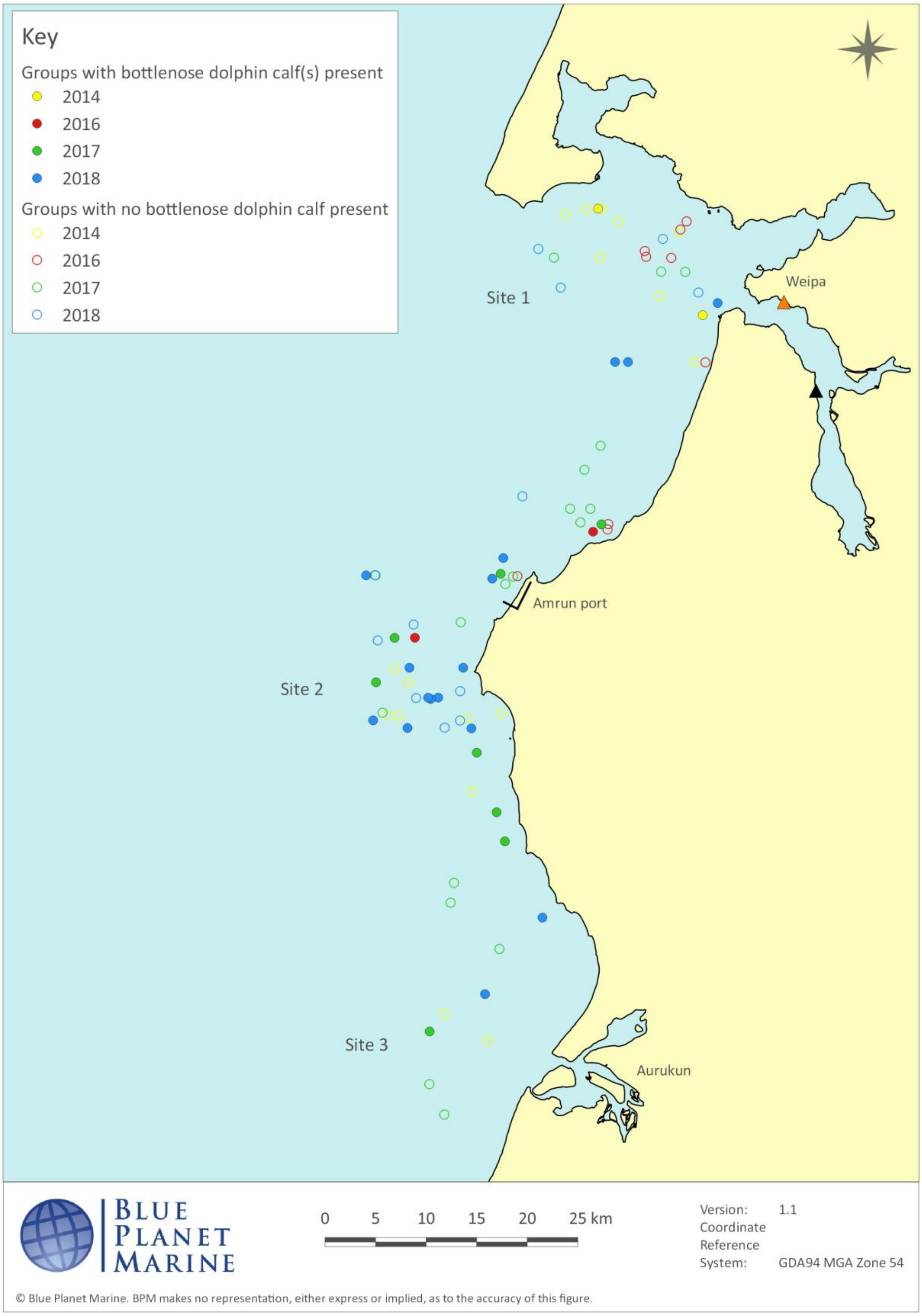

Figure 27. Sighting locations of groups with at least one bottlenose dolphin present, denoting groups with and without a calf, during the 2014-2018 surveys.

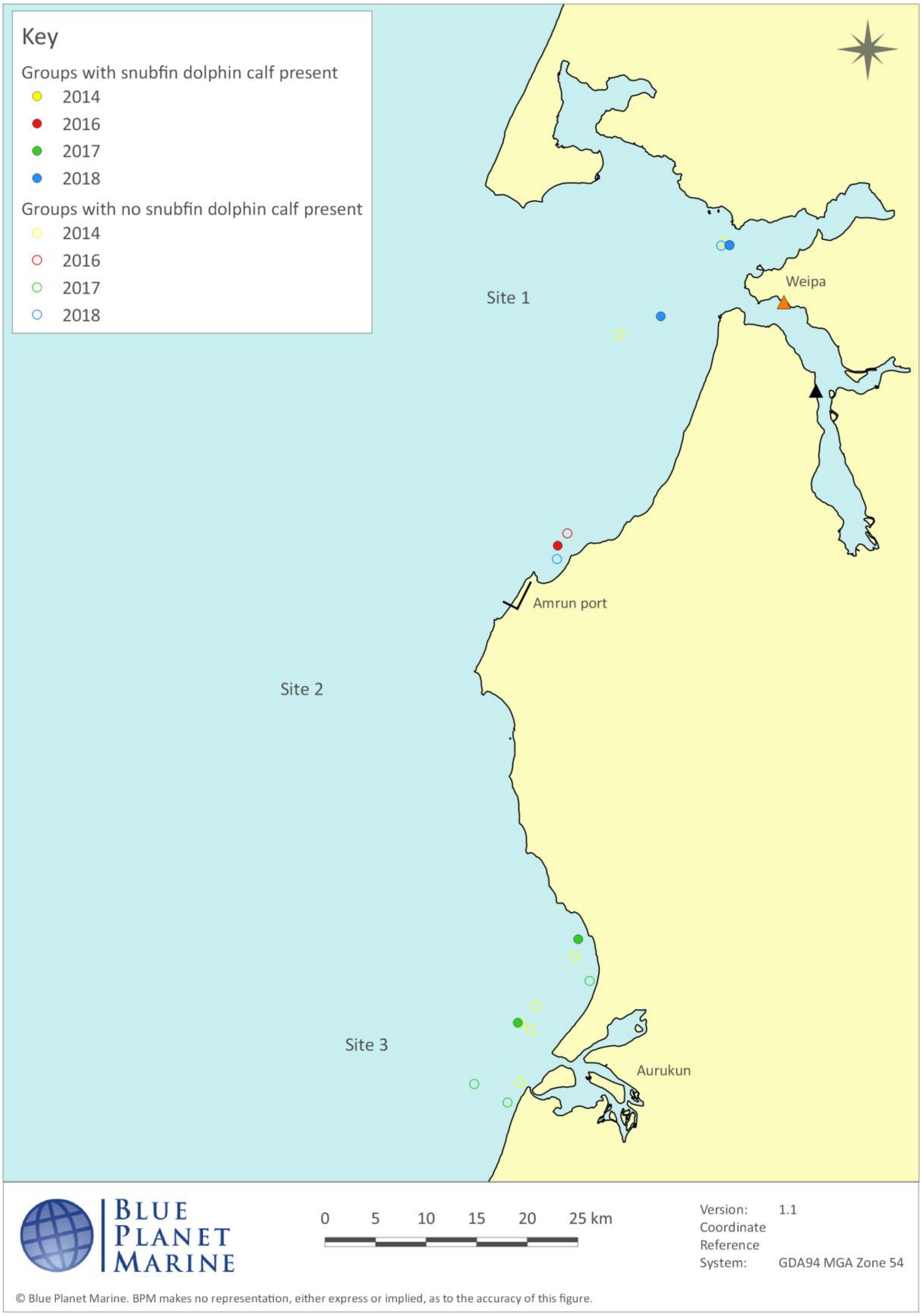

Figure 28. Sighting locations of groups with at least one snubfin dolphin present, denoting groups with and without a calf, during the 2014-2018 surveys.

3.2.2.2 Non-dolphins

A summary of other marine megafauna sightings for each year of the survey is shown in Table 14.

Table 14. Summary of non-dolphin marine megafauna sightings during the 2014 to 2018 surveys.

Species	Site	2014	2016	2017	2018	2014-2018 Total
Crocodile	1	2	0	0	1	3
	2	0	0	0	0	0
	3	1	2	1	0	4
	Transit	0	0	0	0	0
	Species total	3	2	1	1	7
Dugong	1	1	0	0	1	2
	2	4	0	0	2	6
	3	4	1	2	0	7
	Transit	0	0	0	0	0
	Species total	9	1	2	3	15
Ray	1	21	10	14	13	58
	2	3	3	0	4	10
	3	6	7	25	7	45
	Transit	1	0	0	0	1
	Species total	31	20	39	24	114
Sea snake	1	33	29	44	48	154
	2	44	18	29	54	145
	3	13	11	21	26	71
	Transit	1	0	0	0	1
	Species total	91	58	94	128	371
Shark	1	6	14	17	10	47
	2	2	2	8	15	27
	3	2	3	25	6	36
	Transit	1	0	1	0	2
	Species total	11	19	51	31	112
Turtle	1	72	27	32	48	179
	2	44	20	33	52	149
	3	39	70	54	47	210
	Transit	3	2	1	0	6
	Species total	158	119	120	147	544
Sailfish	2	0	0	1	0	1
	Species total	0	0	1	0	1
All species	Total	303	219	308	334	1164

3.2.3 Dolphin encounter rates

A comparison of overall encounter rates (LERs and SAERs) of humpback dolphins for the four years of the survey are shown in Table 15, and bottlenose dolphins in Table 16.

Table 15. Comparison of encounter rates of humpback dolphins from the 2014, 2016, 2017 and 2018 Amrun dolphin surveys. Note: 2014 rates were recalculated from GHD (2015) to enable direct comparisons of rates between surveys.

Year	Groups sighted ON effort	Number of dolphins sighted ON effort	Distance travelled ON effort (km)	LER (Dolphins/km)	Total km^2 effort	SAER (Dolphins/km^2)
2014	57	205	1662	0.12	831	0.25
2016	24	68	1590	0.04	795	0.09
2017	31	100	1617	0.06	809	0.12
2018	33	149	1618	0.09	809	0.18

Table 16. Comparison of encounter rates of bottlenose dolphins from the 2014, 2016, 2017 and 2018 Amrun dolphin surveys. Note: 2014 rates were recalculated from GHD (2015) to enable direct comparisons of rates between surveys.

Year	Groups sighted ON effort	Number of dolphins sighted ON effort	Distance travelled ON effort (km)	LER (Dolphins/km)	Total km^2 effort	SAER (Dolphins/km^2)
2014	14	96	1662	0.06	831	0.12
2016	5	22	1590	0.01	795	0.03
2017	14	58	1617	0.04	809	0.07
2018	18	114	1618	0.07	809	0.14

SAERs per grid cell for the pre-construction survey (2014) compared with the combined construction phase surveys (2016, 2017 and 2018) are shown for humpback dolphins in Figure 29 and bottlenose dolphin in Figure 30. SAERs are shown separately for each year of survey for humpback dolphins in Appendix I (Figure 47) and bottlenose dolphins (Figure 48).

With only 10 on effort sightings of snubfin dolphins across the four years of surveys from 2014-2018, encounter rates were not mapped separately for this species. SAERs for all four years of snubfin dolphin data combined are shown in Figure 31.

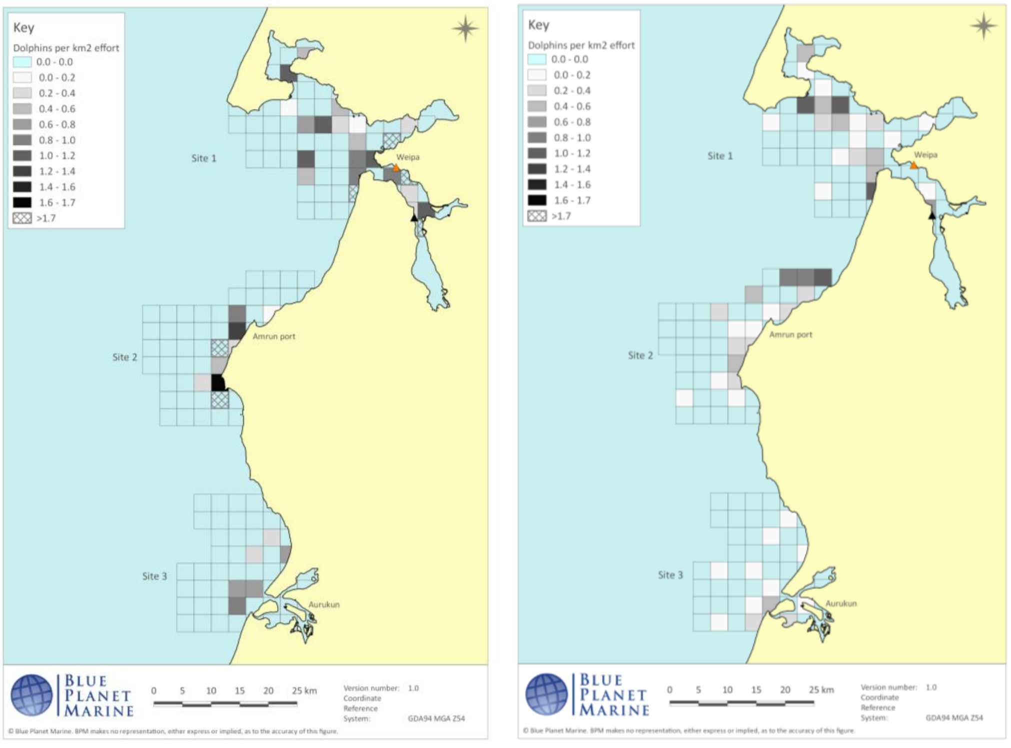

Figure 29. Survey Area Encounter Rates of humpback dolphins (per km^2 effort) during the pre-construction (2014) survey (L) and the combined construction (2016-2018) surveys (R).

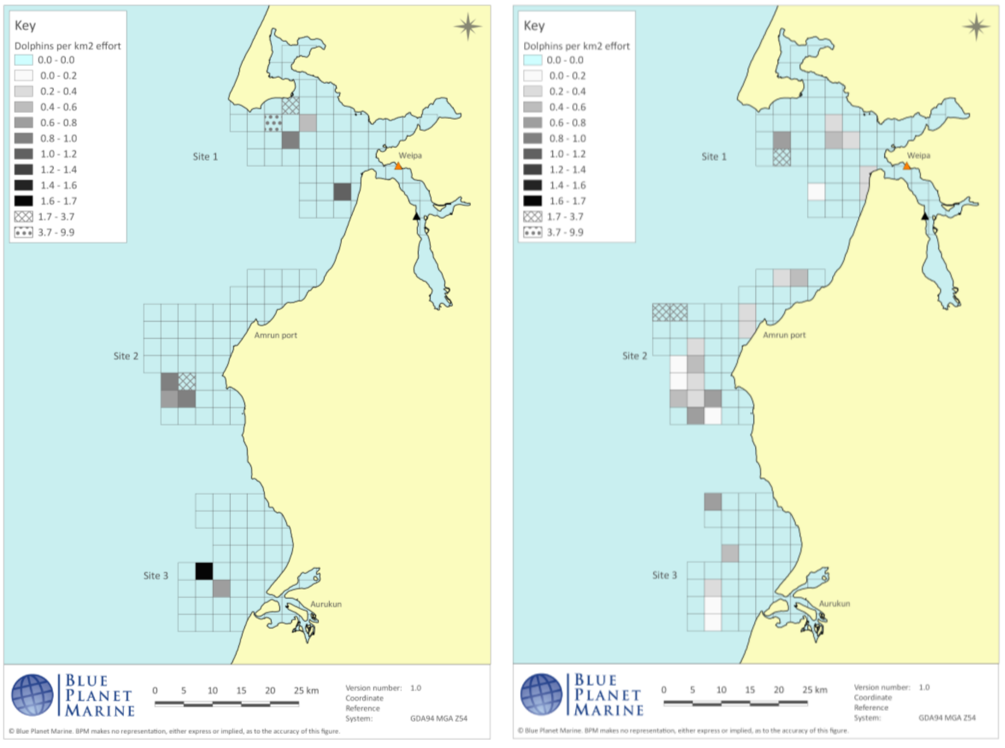

Figure 30. Survey Area Encounter Rates of bottlenose dolphins (per km^2 effort) during the pre-construction (2014) survey (L) and the combined construction (2016-2018) surveys (R).

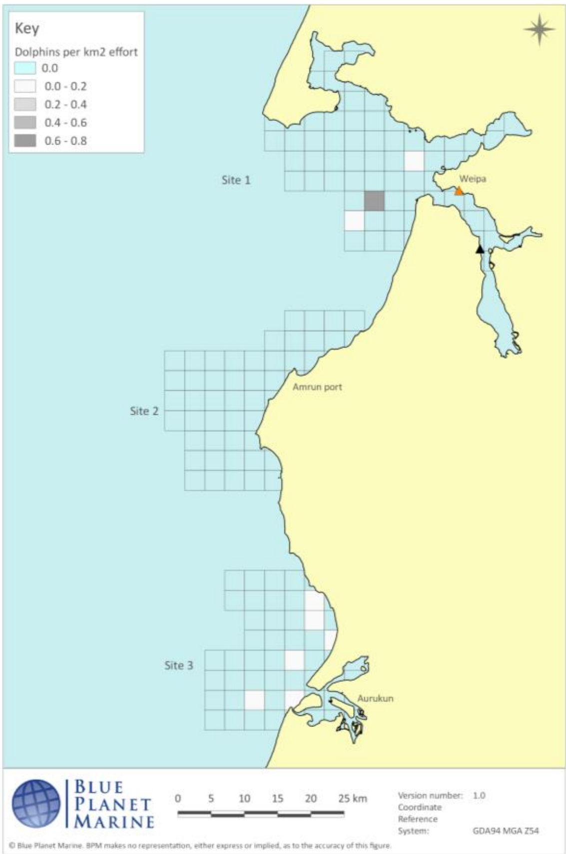

Figure 31. Survey Area Encounter Rates of snubfin dolphins (per km^2 effort) during the four surveys combined (2014, 2016, 2017 and 2018).

3.2.4 Individual identification and resight rates

Combining all photo-identification data from the four primary samples in 2014, 2016, 2017 and 2018, the number of new humpback, snubfin and bottlenose dolphins identified for each day of the survey is shown in Figure 32.

Restricting the dataset to images of sufficient photo quality for CR analysis, the number of years individual humpback, bottlenose and snubfin dolphins were captured (i.e. photographed) is shown in Table 17. The highest number of secondary samples an individual dolphin was captured in was seven (out of the 16 secondary samples conducted over the four years) (Table 18).

Table 17. Number of years in which individual humpback, bottlenose and snubfin dolphins were captured from the four primary samples surveyed in 2014, 2016, 2017 and 2018.

Number of years captured	Individual humpback dolphins (%)	Individual bottlenose dolphins (%)	Individual snubfin dolphins (%)
1	196 (74%)	138 (78%)	25 (96%)
2	53 (20%)	30 (17%)	1 (4%)
3	14 (5%)	5 (3%)	0
4	1 (0.4%)	5 (3%)	0
Total	264 (100%)	178 (100%)	26 (100%)

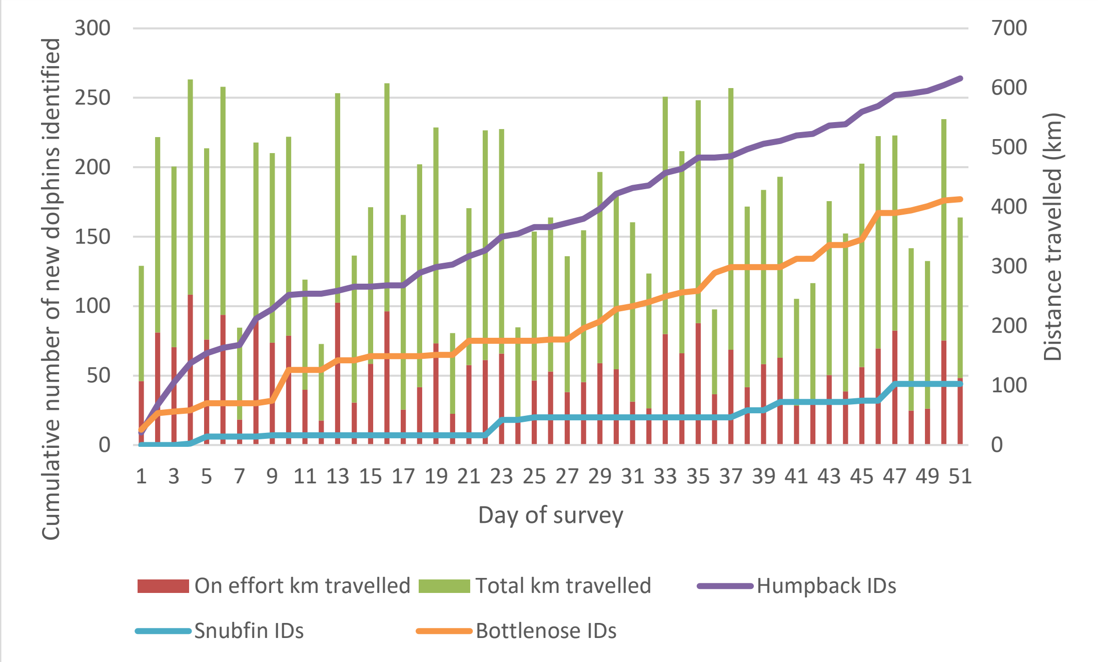

Figure 32. Cumulative number of new identifications (including on and off effort) of humpback, snubfin and bottlenose dolphins for each day of survey from 2014-2018 (Days 1-11: 2014, 12-24: 2016, 25-37: 2017 and 38-51: 2018).

Table 18. Number of secondary samples in which individual humpback, bottlenose and snubfin dolphins were captured from the 16 samples surveyed across 2014, 2016, 2017 and 2018.

Number of years captured	Individual humpback dolphins (%)	Individual bottlenose dolphins (%)	Individual snubfin dolphins (%)
1	153 (58%)	131 (74%)	24 (92%)
2	69 (26%)	29 (16%)	2 (8%)
3	26 (10%)	9 (5%)	0
4	9 (3%)	5 (3%)	0
5	6 (2%)	4 (2%)	0
6	0	0	0
7	1 (0.4%)	0	0
Total	264 (100%)	178 (100%)	26 (100%)

3.2.5 Abundance estimates

Following the discovery of false positive and false negative errors in the photoidentification data from 2014 for both humpback and bottlenose dolphins (see section 2.3.1 and Appendix I: Figure 39-Figure 42), a reanalysis was conducted to correct any misidentification errors before collating capture histories for statistical modelling.

3.2.5.1 Humpback dolphins

The number of individuals captured (i.e. photo-identified) and the total number of captures (including recaptures) at each of the three sites and for all sites combined are reported for each of the four years 2014, 2016, 2017 and 2018 in Table 19.

While the data for Weipa (Site 1) may have been sufficient to support an analysis for that site separately, the data for the other two sites, Boyd Point (Site 2) and Aurukun (Site 3), were not. This is due not only to there being relatively few individuals captured at these sites, but also to there being very few captured more than once at those sites. The data for all sites combined were used for the analysis. The number of individuals captured, and the number of captures, were greater for the years 2014 and 2018 than for 2016 and 2017. Consequently, the 2014 and 2018 data contributed more information to the models than the 2016 and 2017 data.

Table 19. Number of humpback dolphin individuals and captures for the 2014-2018 surveys for each site. Note: Weipa = Site 1, Boyd Point = Site 2, Aurukun = Site 3.

	Individuals				Captures			
Year|Site	Weipa	Boyd Point	Aurukun	All sites	Weipa	Boyd Point	Aurukun	All sites
2014	61	38	10	109	88	47	10	145
2016	30	22	6	58	32	23	7	62
2017	40	26	12	78	51	29	12	92
2018	66	23	14	103	100	26	17	143

There were too few data for the years 2016 and 2017 to estimate apparent survival and temporary emigration separately. A model was therefore fitted with apparent survival constant (i.e. equal for all years). Similarly, the temporary emigration parameters, γ'' and γ', were fitted as equal and constant over years, which imposes a constant random temporary emigration pattern on the estimates. Capture probabilities varied widely over secondary samples, particularly in 2016 and 2017, and capture probability was modelled as varying over all primary and secondary samples.

The goodness of fit test from U-Care showed a close fit of the data to the model with a clearly non-significant p-value of 0.608 for the overall test of lack of fit (overdispersion). None of the three component tests was significant ($p>0.451$), indicating no evidence of transience or behavioural response to first capture (i.e. trap-shyness, trap-happiness).

Model parameter estimates, their standard errors (SEs) and 95% confidence intervals (CIs) are reported in Table 20. The estimated total population sizes are also shown based on an estimate of 0.89 (SE = 0.014) of the population being distinctively marked.

Coefficients of variation (CVs) of the total population estimates were 0.12, 0.23, 0.17 and 0.10 for the years 2014, 2016, 2017 and 2018 respectively. Except for the estimate for the year 2016, all meet the common target of CV < 0.20 for abundance estimates from capture-recapture studies.

Estimates of the total population in all three sites combined, with their 95% confidence intervals, are plotted for the years 2014, 2016, 2017 and 2018 in Figure 33.

Abundances were fairly consistent over time with a minimum (lower 95% CI) of 146 individual dolphins present during any primary sample. Typically, more than 180 dolphins use the sampling areas at Weipa, Boyd Point and Aurukun during a two-week period between October and December.

Apparent survival was estimated at 67% per annum with a relatively small standard error. This is a relatively low estimate that probably indicates a quite high rate of permanent emigration rather than of mortality. If biological survival is assumed to be 0.975 p.a. (Huang et al. 2012), the rate of permanent emigration is estimated at 31.3%. The temporary emigration rate was, in contrast, small and estimated with a quite wide standard error.

Table 20. Humpback dolphin CRD model parameter estimates, standard errors (SE) and 95% confidence intervals (LCI and UCI). Parameters include apparent survival (S), temporary emigration ($\gamma''=\gamma'$), capture probability (p) per secondary sample, estimated size of the distinctively marked proportion of the population (N Marked), and estimated size of the total population including unmarked individuals (N Total).

Parameter	Estimate	SE	LCI	UCI
S All intervals	0.67	0.04	0.59	0.73
$\gamma'' = \gamma'$ All intervals	0.03	0.03	0.00	0.20
p 2014_1	0.24	0.04	0.17	0.34
p 2014_2	0.13	0.03	0.09	0.20
p 2014_3	0.23	0.04	0.16	0.32
p 2014_4	0.16	0.03	0.11	0.24
p 2016_1	0.02	0.01	0.00	0.05
p 2016_2	0.02	0.01	0.01	0.06
p 2016_3	0.13	0.03	0.08	0.21
p 2016_4	0.15	0.04	0.09	0.24
p 2017_1	0.09	0.02	0.05	0.14
p 2017_2	0.13	0.03	0.08	0.20
p 2017_3	0.20	0.04	0.13	0.28
p 2017_4	0.03	0.01	0.02	0.07
p 2018_1	0.17	0.03	0.12	0.25
p 2018_2	0.20	0.04	0.14	0.28
p 2018_3	0.29	0.04	0.22	0.39
p 2018_4	0.21	0.04	0.15	0.30
N Marked 2014	188	22	155	243
N Marked 2016	204	48	137	331
N Marked 2017	202	34	152	287
N Marked 2018	163	16	139	202
N Total 2014	211	25	168	266
N Total 2016	230	54	146	361
N Total 2017	227	38	164	315
N Total 2018	183	18	151	221

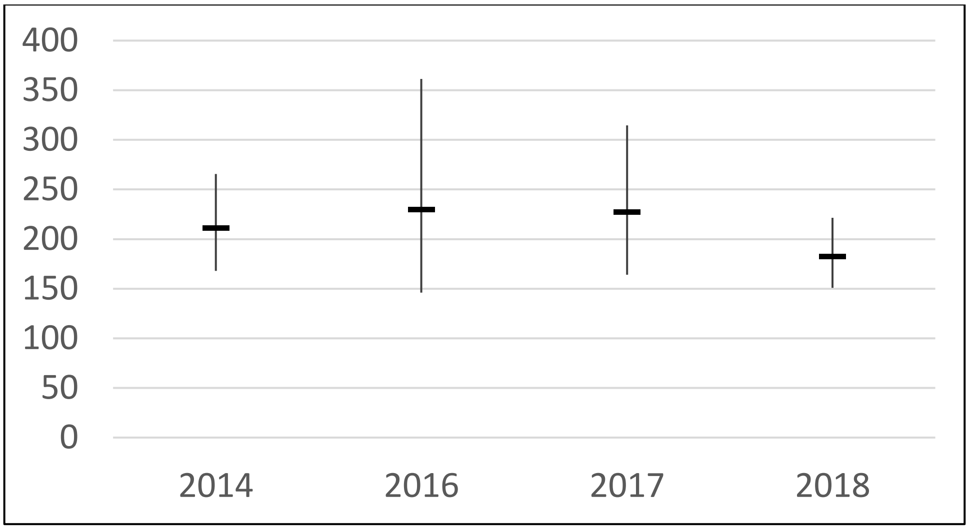

Figure 33. Estimated number of individual humpback dolphins present at Site 1 (Weipa), Site 2 (Boyd Point) and Site 3 (Aurukun) during the 2014, 2016, 2017 and 2018 sampling periods with 95% confidence interval.

3.2.5.2 Bottlenose dolphins

The number of individuals captured and the total number of captures at each of the three sites and for all sites combined are reported for each of the four years 2014, 2016, 2017 and 2018 in Table 21.

Considering the sites separately, relatively few individuals were captured and, with few exceptions, very few individuals were captured more than once; indeed, none were captured more than once in at least one year at every site. The data for all sites combined were used for the analysis, although only one individual was captured more than once in the years 2016 and 2018. While this is what would be expected were the population very large, it is not a sound basis on which to build a capture-recapture model.

Table 21. Number of bottlenose dolphin individuals and captures for the 2014-2018 surveys for each site. Note: Weipa = Site 1, Boyd Point = Site 2, Aurukun = Site 3.

Year|Site	Individuals				Captures			
	Weipa	Boyd Point	Aurukun	All sites	Weipa	Boyd Point	Aurukun	All sites
2014	19	23	12	54	32	24	12	68
2016	14	20	0	34	15	20	0	35
2017	9	44	19	72	9	48	22	79
2018	22	40	10	72	22	41	10	73

Overall, there were insufficient data to attempt to estimate apparent survival or temporary emigration separately for each year. Consequently, given that capture probabilities varied greatly between primary and secondary samples, a model was fitted with apparent survival constant (equal for all years), the temporary emigration parameters, γ'' and γ', fitted as equal and constant over years and capture probabilities varying over all primary and secondary samples.

The goodness of fit test from U-CARE indicated a reasonable fit of the data to the model with a non-significant p-value (p=0.167) for the overall test of lack of fit (overdispersion).

Model parameter estimates, their standard errors and 95% confidence intervals are reported in Table 22. The estimated total population sizes are also shown based on an estimate of 0.88 (SE = 0.014) of the population being distinctively marked. Coefficients of variation of the total population estimates were 0.20, 0.30, 0.22 and 0.25 for the years 2014, 2016, 2017 and 2018 respectively. None of these CVs meets the target of CV < 0.20 for abundance estimates from capture-recapture studies.

Table 22. Bottlenose dolphin CRD model parameter estimates, standard errors (SE) and 95% confidence intervals (LCI and UCI). Parameters include apparent survival (S), temporary emigration (γ''=γ'), capture probability (p) per secondary sample, estimated size of the distinctively marked proportion of the population (N Marked), and estimated size of the total population including unmarked individuals (N Total).

Parameter	Estimate	SE	LCI	UCI
S All intervals	0.91	0.06	0.68	0.98
γ'' = γ' All intervals	0.00	0.00	0.00	1.00
p 2014_1	0.23	0.06	0.13	0.37
p 2014_2	0.10	0.04	0.05	0.20
p 2014_3	0.10	0.03	0.05	0.19
p 2014_4	0.22	0.06	0.12	0.36
p 2016_1	0.10	0.04	0.05	0.20
p 2016_2	0.02	0.01	0.01	0.08
p 2016_3	0.13	0.04	0.06	0.23
p 2016_4	0.02	0.01	0.01	0.08
p 2017_1	0.06	0.02	0.03	0.12
p 2017_2	0.15	0.04	0.09	0.24
p 2017_3	0.03	0.01	0.02	0.07
p 2017_4	0.08	0.02	0.05	0.15
p 2018_1	0.02	0.01	0.01	0.04
p 2018_2	0.05	0.01	0.03	0.09
p 2018_3	0.09	0.02	0.05	0.15
p 2018_4	0.05	0.01	0.03	0.09
N Marked 2014	105	21	78	163
N Marked 2016	134	40	81	246
N Marked 2017	243	53	166	381
N Marked 2018	383	94	246	626
N Total 2014	119	24	81	175
N Total 2016	152	45	86	270
N Total 2017	276	61	181	422
N Total 2018	435	107	271	700

Estimates of the total population in all three sites combined, with their 95% confidence intervals, are plotted for the years 2014, 2016, 2017 and 2018 in Figure 34.

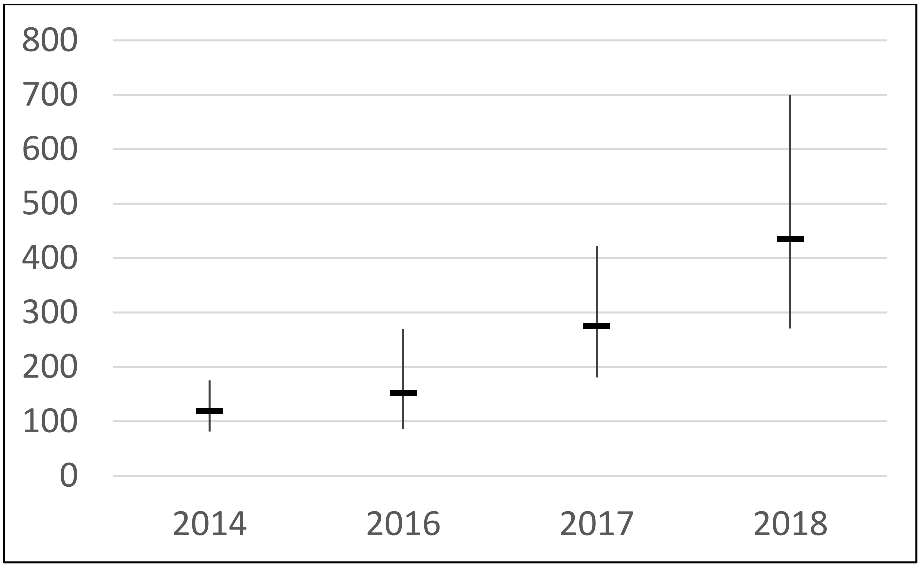

Figure 34. Estimated number of individual bottlenose dolphins present at Site 1 (Weipa), Site 2 (Boyd Point) and Site 3 (Aurukun) during the 2014, 2016, 2017 and 2018 sampling periods with 95% confidence interval.

The estimated rate of apparent survival was relatively high at 0.91 per annum, indicating a relatively low rate of permanent emigration of 4.2% per annum assuming a biological survival rate of 0.95 (Taylor *et al.* 2007 – see Brooks et al 2017). Temporary emigration was not satisfactorily estimated by the model, although an estimate of zero temporary emigration was returned.

3.2.5.3 Snubfin dolphins

A total of 44 snubfin dolphins were photographed from 2014-2018, but only 26 of these were of sufficient photo quality and distinctiveness for reliable, inter-year identification of individuals. This is not uncommon for snubfin dolphins as they are difficult to photograph and often require calm sea conditions to obtain good quality photographs. Only one snubfin dolphin was photographed in more than one secondary sample in any year of the study, and only one individual was photographed in more than one year. In light of the low number of captures and recaptures, abundance estimates were not possible for this species.

3.2.6 Individual dolphin movements

Sixty-eight humpback dolphins were photographed in more than one year of the project from 2014-2018. Of these, 14 dolphins were photographed in three years and one was photographed in all four years. None of these individuals was sighted at more than one site. Sighting locations for the 15 humpback dolphins photographed in at least three years of the project are shown in Figure 35.

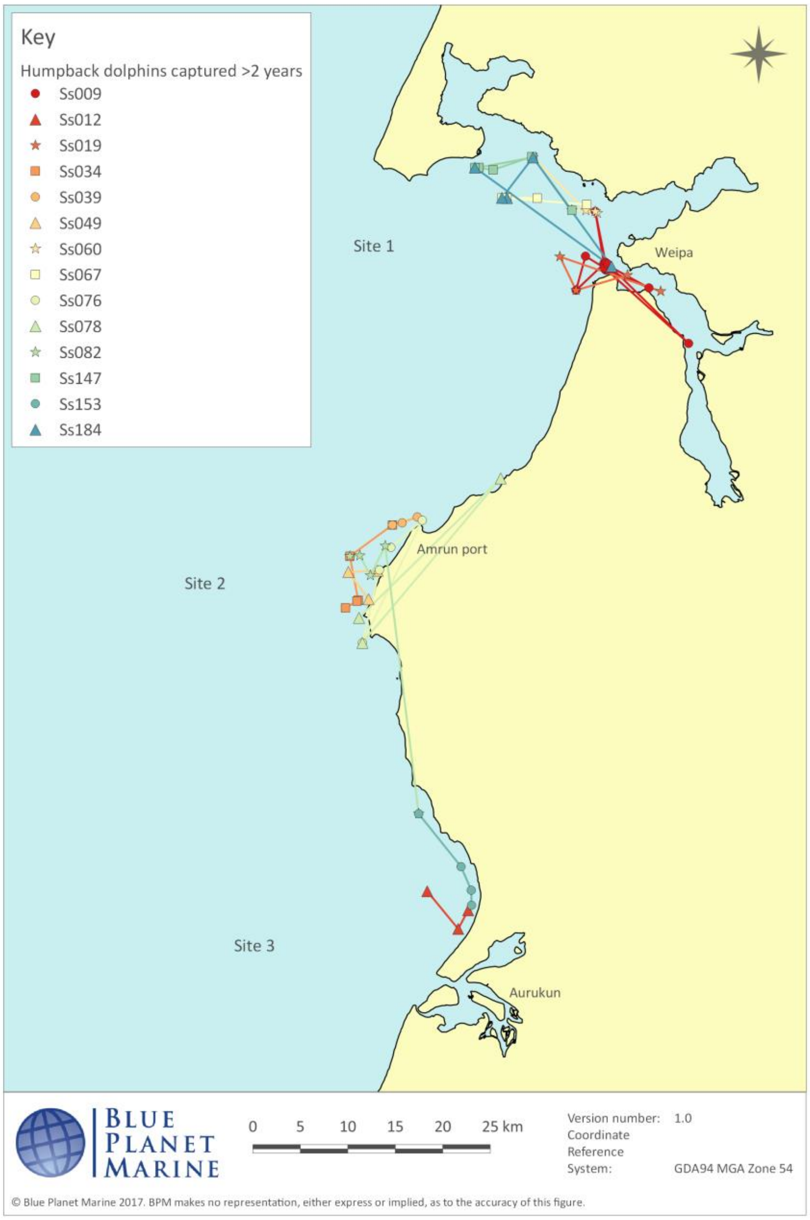

Figure 35. Sighting locations of 15 humpback dolphins photographed in at least three years of the project from 2014-2018, with interpolated lines drawn between sightings.

Of all 68 humpback dolphins photographed in more than one year of the project, the mean distance from the first sighting location one year to the first sighting location in the next sighting year was 9.2 km (S.D. = 11.0) with a minimum of 200 m and a maximum of 76.2 km between sighting locations. Six individuals were sighted at a distance greater than 30 km from their previous sighting location (Figure 36).

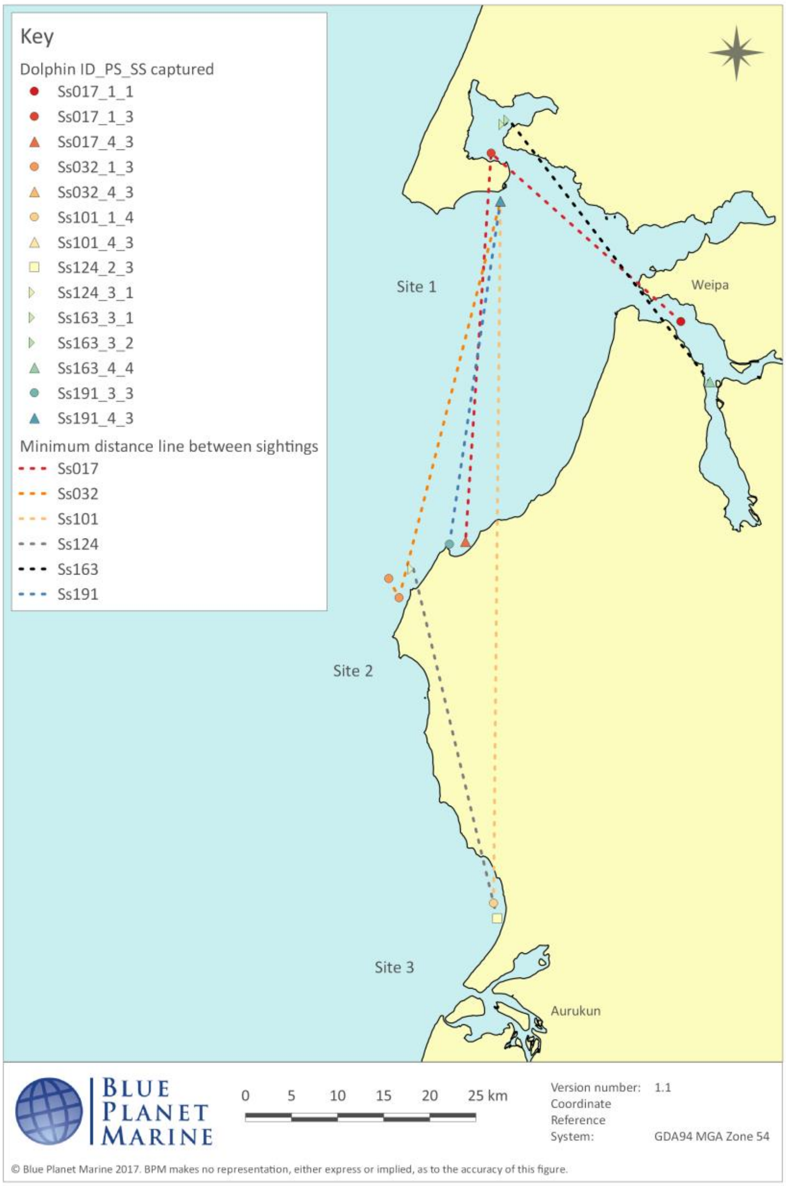

Figure 36. Humpback dolphins resighted at a distance greater than 30 km from their previous sighting location from 2014-2018. Interpolated lines drawn between sighting locations for each dolphin are "as the crow flies".

Forty bottlenose dolphins were photographed in more than one year of the project from 2014-2018 (Figure 37), including 5 photographed in three years and 5 photographed in all four years. Of the 40 bottlenose dolphins photographed in more than one year of the project, the mean distance from the first sighting location one year to the first sighting location in the next sighting year was 9.2 km (S.D. = 6.0) with a minimum of 960 m and a maximum of 30 km between sighting locations.

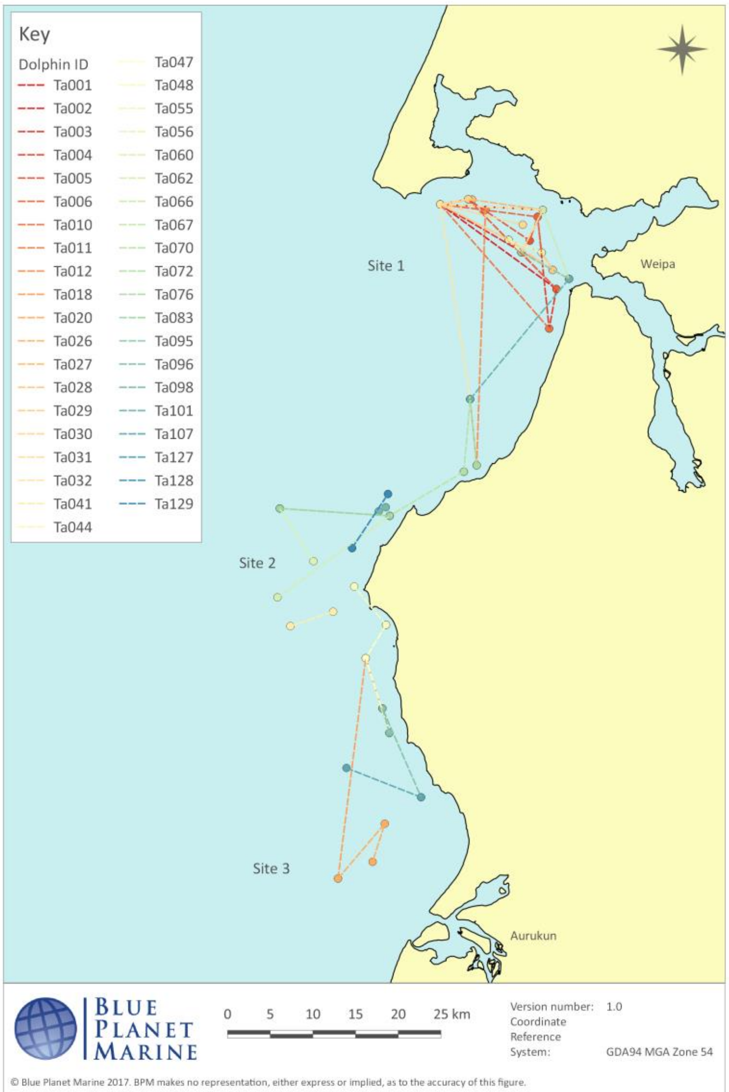

Figure 37. Sighting locations of 40 bottlenose dolphins photographed in more than one year of the project from 2014-2018, with interpolated lines drawn between sightings.

One snubfin dolphin (Oh018) was photographed in more than one year of the project, having been photographed during sample 4 in 2016 and in sample 3 in 2018 (Figure 38).

Figure 38. Sighting locations of snubfin dolphin Oh018 that was photographed in 2016 and 2018, with an interpolated line between sightings.

3.2.7 Environmental parameters and habitat preferences

Combining sightings from all years (2014, 2016, 2017 and 2018), sightings by tidal state are shown in Appendix I for humpback dolphins (Figure 49), bottlenose dolphins (Figure 50), and snubfin dolphins (Figure 51). A summary of depths at which dolphin sightings occurred for all years combined (2014, 2016, 2017 and 2018) are shown in Table 23. Depths at which sightings occurred during the pre-construction survey (2014) compared with the combined construction-phase surveys (2016-2018) are shown for humpback, inshore bottlenose and snubfin dolphins in Table 24.

A summary of other environmental parameters recorded at dolphin sighting locations is shown in Table 25 for the 2014-2018 surveys combined. Mean values for each parameter across all sightings per year are shown in Table 26, and for each species in Table 27.

Table 23. Depth at sighting location of dolphin groups during the 2014, 2016, 2017 and 2018 surveys combined.

Species	Number of groups sighted	Depth at sighting location (m)		
		Mean (Std Dev)	Minimum	Maximum
Humpback	240	8.3 (5.2)	0.8	21.9
Inshore bottlenose	84	12.4 (6.3)	3.1	24.9
Offshore bottlenose	3	22.7 (2.1)	20.8	25.0
Snubfin	19	5.5 (2.4)	2.4	10.4
Spinner	5	23.3 (1.4)	21.5	25.0

Table 24. Depth at sighting location of humpback, inshore bottlenose and snubfin dolphin groups during the pre-construction (2014) and construction phase surveys (2016-2018).

Species	Phase	Sightings	Mean depth (Std Dev) (m)
Humpback	Pre-construction	81	9.0 (5.3)
	Construction	159	7.9 (5.2)
Inshore bottlenose	Pre-construction	19	9.5 (6.0)
	Construction	65	13.3 (6.1)
Snubfin	Pre-construction	7	5.3 (2.6)
	Construction	12	5.7 (2.3)

Table 25. Environmental parameters recorded at dolphin sighting locations for the 2014-2018 surveys combined.

Species	No. of groups sighted	Mean Temperature (Std Dev) (°C)	Mean Salinity (Std Dev) (ppt)	Mean Turbidity (Std Dev) (NTU)	pH (Std Dev)
Humpback	240	30.3 (1.6)	35.1 (1.1)	4.0 (6.3)	8.0 (0.3)
Inshore bottlenose	84	29.7 (1.6)	34.8 (0.8)	1.5 (2.3)	8.0 (0.3)
Offshore bottlenose	3	30.8 (2.3)	35.1 (0.8)	0.3 (0.2)	8.0 (0.2)
Orca	1	28.7 (N/A)	35.0 (N/A)	0.6 (N/A)	8.0 (N/A)
Snubfin	19	30.4 (1.6)	35.2 (0.9)	5.5 (8.7)	8.0 (0.2)
Spinner	5	29.5 (1.7)	35.0 (0.4)	0.1 (0.2)	8.2 (0.4)

Table 26. Mean values for environmental parameters across all dolphin sightings per year of survey.

Year	Mean temperature (°C)	Mean salinity (ppt)	Mean turbidity (NTU)	Mean pH
2014	31.9	34.6	6.0	8.1
2016	29.8	33.9	2.5	7.9
2017	29.1	35.8	1.5	8.1
2018	29.3	35.3	2.9	8.0

Table 27. Mean values for environmental parameters per species per year of survey.

Species	Mean temperature (°C)	Mean salinity (ppt)	Mean turbidity (NTU)	Mean pH
Humpback (2014-18)	**30.3**	**35.1**	**4.0**	**8.0**
2014	32.0	34.7	6.5	8.1
2016	29.7	34.1	2.8	7.9
2017	29.1	35.9	2.0	8.1
2018	29.5	35.5	3.7	8.0
Inshore bottlenose (2014-18)	**29.7**	**34.8**	**1.5**	**8.0**
2014	31.7	34.6	2.8	8.1
2016	29.9	33.6	1.7	7.9
2017	29.0	35.3	0.7	8.0
2018	28.8	34.9	1.3	8.0
Snubfin (2014-18)	**30.4**	**35.2**	**5.5**	**8.0**
2014	32.2	34.3	14.1	8.0
2016	28.5	34.8	2.5	7.9
2017	29.8	35.9	1.1	8.1
2018	29.3	35.8	2.6	8.0

The primary behaviour and sighting location of humpback dolphin groups observed during each of the 2014-2018 surveys is shown in Appendix I (Figure 52), and of bottlenose dolphin groups in Appendix I (Figure 53). Behaviours and sighting locations of snubfin dolphins for all years combined are shown in Appendix I (Figure 54).

4. Discussion

The 2018 inshore dolphin survey was the third and final construction-phase survey and the fourth overall survey completed as part of the *Amrun Project Inshore Dolphin Offset Strategy*. The targeted outcomes, benchmarks and goals associated with these surveys were in line with the overall Strategy objectives, namely that through its implementation:

- knowledge on the distribution and abundance of the local and regional populations of the Australian snubfin and Australian humpback dolphin in the Western Cape York area would be increased;
- knowledge on habitat utilised by these species would be increased; and
- nominated local aboriginal people would have the opportunity to be trained in marine mammal observation and participate in dolphin surveys.

The 2018 survey was successful in completing all transects during four secondary samples and in involving local Traditional Owners (TOs) in the survey and training days for the project. Having successfully completed surveys to meet the Strategy objectives in 2014, 2016, 2017 and 2018, the combined datasets and analyses provide an important contribution to knowledge on inshore dolphins locally and in the broader Western Cape York region. Additionally, the data allow for more informed management and ongoing planning decisions for the project. The importance of this research is further highlighted by the recent assessments of both Australian humpback and snubfin dolphins as Vulnerable under the IUCN Red List of Threatened Species (Parra *et al.* 2017a, b).

4.1 Traditional Owner involvement

As per the Strategy, Traditional Owners were given the opportunity and encouraged to participate in each year of the survey from 2014 to 2018. For the 2018 survey, TOs Trini Kerindun, Miles Kerindun, and Percy Callope were involved in all aspects of data collection and helped to successfully complete the survey. The Traditional Owners directed the team with respect to sites of cultural importance to be avoided throughout the survey, imparted local knowledge and contributed significantly to observations of dolphins and other marine megafuna. By assisting with this project, all participants gained training and increased experience in monitoring inshore dolphin populations and marine fauna observation. A number of other TOs (Tianna Chevathen, Daniel Bandicootcha, Pearl Matthew) also attended the training days for the 2018 survey, gaining training in observation, equipment and methods used to monitor inshore dolphin populations.

4.2 Sightings and encounter rates

The most frequently sighted dolphin species during all four surveys from 2014 to 2018 was the Australian humpback dolphin, with 240 of the 347 groups (69%) sighted including at least one member of this species. Inshore bottlenose dolphins were sighted in 24% of groups, with snubfin dolphins in only 5% of groups. All other cetaceans sighted to date were seen only rarely (<1.5% of groups). The relative abundance of these species is consistent with other studies in Queensland coastal zones (Beasley *et al.* 2013, 2014).

While low numbers of snubfin dolphins were sighted in all years of survey from 2014-2018 (range = 12-36), the total number of humpback and bottlenose dolphins sighted each year varied between surveys. The number of humpback dolphins sighted in 2014 (284) and 2018 (279) were similar, with fewer in 2017 (222) and the lowest number recorded in 2016 (137). A similar pattern was observed for bottlenose dolphins, with 158 individuals sighted in 2014, 70 in 2016, 177 in 2017 and 172 in 2018. These patterns were also reflected in the encounter rates for these species (Table 15, Table 16). Furthermore, only a single humpback dolphin calf was observed in 2016, which was considerably lower than the numbers seen in 2014 (12), 2017 (13), and 2018 (27). There are several possible explanations for the lower encounter rates and fewer sightings of humpback and bottlenose dolphins during the 2016 survey:

- potential seasonal differences between years, with the 2016 survey conducted during November (7-19), 2014 during December (7-19), and 2017 and 2018 during October (13-26). Although the surveys were all conducted within a 68-day window respective to the day of the year, it is possible that the 2016 survey coincided with a period where lower numbers of dolphins were present in the study area due to seasonal factors;
- animals moving in and out of the study area, for example due to prey availability. With only a 13-14 day period in which surveys were conducted each year, it is possible that the 2016 survey coincided with a period where a large number of dolphins moved out of the study area;
- sea conditions present during the surveys may have been a factor in the number of sightings. Although 2016 saw the lowest percentage of survey conducted in Beaufort sea state of 2 or less (57%) compared with the other years (2014: 60%, 2017: 60%, 2018:72%), and the most variability in sea state conditions when dolphin groups were sighted (Table 11), the differences were unlikely to be enough to account for the substantially lower numbers of humpback and bottlenose dolphins sighted in 2016. Environmental parameters recorded during survey periods did not vary widely, although turbidity was higher in 2014 compared with other years and warrants further investigation;
- the influence of other environmental factors such as rainfall and flood events prior to survey periods may also have contributed to these differences, however, these have not been investigated to date;
- potential displacement of animals as a result of construction and vessel activities associated with the Amrun Port and river facilities. Although dredging and piling activities for the Hey River Terminal and Humbug Terminal had been completed at least two months prior to the 2016 survey, increased vessel traffic associated with both the Amrun Project and with Green Coast Resources having started shipping bauxite from their Hey Point barge loading facility in the month leading up to the 2016 survey should be noted. It is possible that the increased vessel and construction activities may have contributed to the lower numbers of humpback dolphin groups in this area (Figure 24). Potential displacement of bottlenose dolphins is less likely considering the differences in habitats and proximity to construction activities in which the two species were generally found throughout all years of survey, with bottlenose dolphins generally further offshore (Figure 24);
- sampling methods may have been a factor, for example due to differing amounts of time spent with encountered groups. It should be noted that the 2016 survey was restricted to spending no more than 30 minutes within 50 m of encountered groups, whereas the limit was 60 minutes for the 2014, 2017 and 2018 surveys. Although this is likely to have affected the number of IDs obtained per group, it would presumably have a reduced effect on the number of sightings overall;
- factors related to the 2016 survey research team having less local experience than in other years;
- in addition to humpback and bottlenose dolphins, lower numbers of sea snakes, and to a lesser extent other non-dolphin species, were sighted in 2016 (Table 14), suggesting that other factors must be considered. These include whether sampling methods, weather, or some other factor influenced the 2016 survey and resulted in lower sightings across the board, or if there were simply fewer animals in the study area during that year's survey.

It is notable that abundance estimates for humpback dolphins did not suggest significantly lower numbers of these dolphins present in the study area during the 2016 survey compared with other years, although confidence intervals were wide. These estimates are detailed in section 4.3.1.

In considering the results of the 2014-2018 surveys in a broader context, the overall linear encounter rates (LER) for humpback dolphins from these surveys varied from 0.04 (2016) to 0.12 (2014) dolphins per kilometre of transect surveyed and were comparable to LERs from previous studies of this species (Table 28).

Table 28. Humpback dolphin Linear Encounter Rates, calculated by dividing on effort sightings of dolphins by total transect length surveyed, for various regions in northern Australia.

Site (State)	Transect length (km)	Encounter rate	Source
Roebuck Bay 2013 (WA)	419	0.04	Brown et al. 2016
Roebuck Bay 2014 (WA)	389	0.00	Brown et al. 2016
Beagle Bay 2012 (WA)	322	0.05	Brown et al. 2016
Beagle Bay 2013 (WA)	337	0.06	Brown et al. 2016
Cygnet Bay 2012 (1) (WA)	316	0.05	Brown et al. 2016
Cygnet Bay 2012 (2) (WA)	307	0.16	Brown et al. 2016
Cygnet Bay 2013 (1) (WA)	306	0.12	Brown et al. 2016
Cygnet Bay 2013 (2) (WA)	302	0.1	Brown et al. 2016
Cone Bay 2014 (WA)	297	0.07	Brown et al. 2016
Inner Cambridge Gulf 2012 (WA)	313	<0.01	Brown et al. 2016
Port Essington (NT)	2279	0.12	Palmer et al. 2014
Cardwell 2013 (QLD)	804	0.03*	Cited in GHD 2015
Cardwell 2014 (QLD)	433	0.08*	Cited in GHD 2015
Princess Charlotte Bay (QLD)	56	0.14*	Cited in GHD 2015
Karumba (QLD)	460	0.08*	Cited in GHD 2015
Weipa-Aurukun 2014 (QLD)	1662	0.12	Recalculated from GHD 2015
Weipa-Aurukun 2016 (QLD)	1590	0.04	BPM 2019 (this study)
Weipa-Aurukun 2017 (QLD)	1617	0.06	BPM 2019 (this study)
Weipa-Aurukun 2018 (QLD)	1618	0.09	BPM 2019 (this study)

*Rates as reported in GHD 2015. It is unclear if these include both on and off effort sightings or on-effort-only.

4.3 Abundance estimates, identification and resight rates

Sufficient numbers of identification photographs and resights were obtained for both humpback and bottlenose dolphins to allow modelling to be completed for these species. However, it should be noted that capture probabilities were very low in some instances, and both on and off effort sightings were included in CR analyses to increase sample sizes. It is possible that inclusion of off-effort sightings could introduce heterogeneity of individual capture rates, for example if certain individuals frequented areas where the vessels were also more frequent. However, the Goodness of Fit tests showed no violation of assumptions, suggesting that this did not occur. To the degree that it may have occurred to some extent, abundance estimates would be somewhat lower than the true number of dolphins present.

The cumulative number of new identifications obtained for each day of survey from 2014-2018 showed a continual increase for each of humpback, bottlenose and snubfin dolphins (Figure 32), indicating not all individuals using the study area had been identified.

4.3.1 Humpback dolphins (*Sousa sahulensis*)

Estimated abundance of humpback dolphins present in the study area (1,014 km^2) during each of the primary samples was 211 in 2014, 230 in 2016, 227 in 2017 to 183 in 2018. Overall, abundances were fairly consistent over time with a minimum (lower 95% CI) of 146 individual dolphins present during any primary sample. Typically, it is likely that more than 180 dolphins use the sampling areas at Site 1 (Weipa), Site 2 (Boyd Point) and Site 3 (Aurukun) during a two-week period between October and December. These abundance estimates represent some of the highest recorded for this species at any location in Australia to date (Table 29).

Table 29. Summary of abundance estimates of humpback dolphins from study sites in Queensland (Qld), Northern Territory (NT) and Western Australia (WA). Adapted and updated from Parra *et al.* (2017a).

Study site	Approx. study area (km2)	Population estimate (95% CI)	Reference
Weipa, Qld	1014	183 (151-221) - 230 (146-361)	BPM 2019 (this study)
Cleveland Bay, Qld	310	34 (24-49) - 54 (38-77)	Parra et al. 2006
Capricorn coast, Qld	980	104 (88-120) - 115 (100-130)	Cagnazzi 2013
Curtis coast, Qld	510	45 (30-61) - 84 (73-95)	Cagnazzi 2013
Great Sandy Strait, Qld	1000	137 (121-154) - 162 (157-167)	Cagnazzi et al. 2011
Northern Great Sandy Strait, Qld	560	59 (48-72) - 79 (74-84)	Cagnazzi et al. 2011
Southern Great Sandy Strait, Qld	440	68 (59-78) - 78 (65-94)	Cagnazzi et al. 2011
Moreton Bay, Qld	1315	119 (81-166) – 163 (108-251)	Corkeron et al. 1997
Moreton Bay, Qld	1245	128 (67-247) - 139 (71-274)	Meager & Hawkins 2017
Bynoe Harbour, NT	460	18 (7-29) - 40 (29-52)	Brooks et al. 2017
Darwin Harbour, NT	471	29 (20-37) - 49 (36-62)	Brooks et al. 2017
Shoal Bay, NT	154	13 (13-13) - 34 (21-46)	Brooks et al. 2017
Port Essington, NT	325	48 (24-95) - 207 (113-379)	Palmer et al. 2014
Cygnet Bay, WA	130	15 (12-20) - 20 (18-24)	Brown et al.2016
North West Cape, WA	130	65 (56-75) - 102 (74-140), {superpopulation estimate 129 (117-141)}	Hunt et al. 2017
Onslow, WA	69	No estimate (25 individuals IDed)	Raudino et al. 2018a
Thevenard Island, WA	59	No estimate (23 individuals IDed)	Raudino et al. 2018a
Montebello Islands, WA	?	No estimate (28 individuals IDed)	Raudino et al. 2018b

It should be noted that capture probabilities varied widely across secondary samples, with a range of 0.02 – 0.29. Similar wide ranges in capture probabilities have been found in other studies of this species at North West Cape, WA (0.01 – 0.40 – Hunt *et al.* 2017) and Moreton Bay, Qld (0.04 – 0.25 - Meager and Hawkins 2017). Although it is not clear why they vary so much between secondary samples, one possibility is that the dolphins range outside of the sampling area and the number that are offsite during the secondary samples may vary with the weather, tides, prey availability or other factors, such as the duration of the sample and rates of movement into and out of the study area. Capture probabilities of 0.10 or greater are generally considered to be the minimum required for reliable estimation. This rate was achieved in 12 of the 16 secondary samples for this study, but lower capture probabilities in 2016 and 2017 were reflected in the larger standard errors for those years, and in an inability to estimate apparent survival and temporary emigration separately.

As a result of these limitations, the model had to be fitted with apparent survival and temporary emigration constant (i.e. equal for all years). Apparent survival was estimated at 67% per annum with a relatively small standard error. Similar rates of apparent survival, albeit with larger confidence intervals, were found for humpback dolphins surveyed at Port Curtis (S=0.67, 95% CI=0.33-0.89; Cagnazzi 2017) and during the late dry season (Sep-Nov) in the Darwin region (S=0.71, 95% CI=0.47-0.87; Brooks *et al.* 2017). If biological survival is assumed to be 0.975 p.a. (Huang *et al.* 2012), the rate of permanent emigration is estimated at 31.3%. Given the relatively modest changes in the total abundance estimates, it is apparent that there are correspondingly high rates of immigration to the area. Overall, it appears that there is considerable interchange of individuals between the sample area and adjacent parts of western Cape York.

The temporary emigration rate was, in contrast, small and estimated with a quite wide standard error (0.03, 95% CI=0.03-0.20). This suggests that dolphins that leave the area for a period of approximately two weeks during October to December are more likely to stay away permanently than return a year or so later. Future surveys in the region are required to provide more information about the broader population in western Cape York. However, considering the recent assessment of *Sousa sahulensis* as Vulnerable under the IUCN Red List of Threatened Species, with evidence suggesting that this species is found in small, localised subpopulations connected by limited gene flow (Brown *et al.* 2014, Parra *et al.* 2017), the western Cape York population is likely to represent an important subpopulation of Australian humpback dolphins.

4.3.2 Bottlenose dolphins (*Tursiops* spp.)

A model was able to be fitted to the capture history data for bottlenose dolphins, however the uncertainty introduced into the estimates by very small numbers of individuals captured more than once in the same year was expressed in wide confidence intervals. That there was only one individual captured more than once in two of the four primary samples (2016 and 2018) was not a good basis on which to build a capture-recapture model and relatively large estimates of abundance were expected. As shown in Table 22, the estimates of total population size show a steady increase from 2014 to 2018, with over 400 individual bottlenose dolphins estimated to have used the sampling areas at Site 1 (Weipa), Site 2 (Boyd Point) and Site 3 (Aurukun) during a two-week period in October 2018. Consequently, while it is not clear how much confidence should be placed on the model estimates, it seems clear that the local population is certainly not decreasing and may be increasing rapidly. The rate of increase in the between-year estimates is far greater than could result from *in situ* births and indicates a very high rate of immigration. With an estimated rate of apparent survival at a relatively high 0.91 per annum, this indicates a relatively low rate of permanent emigration of 4.2% per annum assuming a biological survival rate of 0.95 (Taylor *et al.* 2007, see Brooks et al 2017). Although there were insufficient data for the model to estimate temporary emigration satisfactorily, an estimate of zero temporary emigration was returned.

4.3.3 Snubfin dolphins (*Orcaella heinsohni*)

An insufficient number of identification photographs and resights of snubfin dolphins were obtained during the four years of survey for CR analysis and abundance estimation, with only one dolphin photographed in more than one year and one photographed in two secondary samples within a year. However, the presence of a group of 20 individuals in 2018, and the number identified overall (44, with 26 of sufficient photo quality and distinctiveness for CR), suggest that a small population inhabits the area. This is consistent with existing information about this species, which is typically found in populations of fewer than 150 individuals (Parra *et al.* 2017). Several anecdotal reports of snubfin dolphins being regularly seen in the river systems north and south of the study area were also received during the construction phase surveys, including reports by the local Traditional Owners amongst the team. Future surveys in these locations may prove worthwhile, and although the number of snubfin dolphins identified in western Cape York to date is small, further data collection may allow population estimates to be obtained in the future.

4.4 Environmental parameters and habitat preferences

Sightings of humpback dolphins were highest at Site 1 in all years of the survey, bottlenose dolphins were seen in greatest numbers at Site 2, and the small number of snubfin dolphin groups sighted were spread across the three sites, but primarily at sites 3 and 1. Of all dolphins observed in this study, snubfin dolphins were encountered at the shallowest mean depth (5.5 m), followed by humpback (8.3 m), inshore bottlenose (12.4 m), offshore bottlenose (22.7 m) and spinner dolphins (23.3 m). These depths are consistent with the known habitat preferences of these species, with snubfin and humpback dolphins generally found in shallow, protected coastal and estuarine waters (Parra *et al.* 2006, 2017a, 2017b), inshore bottlenose dolphins generally found in shallow coastal waters over the continental shelf (e.g. Hammond *et al.* 2012a) and offshore bottlenose and spinner dolphins ranging relatively further offshore (Hammond *et al.* 2012b, Braulik and Reeves 2018). No major differences were found between pre-construction and construction phase mean depths at the sighting locations of any species of dolphin in this study.

As per Parra *et al.* (2006) for studies on the eastern side of the Cape York peninsula, all snubfin dolphin groups (n=19) in this study were found in waters less than 15 m deep and within 10 km of the coast. However, Parra *et al.* (2006) found snubfins to generally occur no more than 20 km from the nearest river mouth. Most sightings of snubfin dolphins in this study met this criterion, except for three groups observed at Site 2 near Boyd Bay, which is approximately 40 km from the nearest river mouth.

Parra *et al.* (2017) summarised existing evidence on habitat preferences of humpback dolphins, suggesting that this species utilises a wide range of near-shore habitats and shows high adaptability to local environment characteristics with some differences in habitat selection among subpopulations. With humpback dolphins across Australia having been observed feeding in rivers and creeks, exposed banks, shallow flats, rock and coral reefs, as well as over submerged reefs in waters at least up to 40 m deep (Parra *et al.* 2017), similarly, sightings of humpback dolphins observed foraging during this study ranged across a variety of habitats in the study area, including estuaries at sites 1 and 3 in particular, and rocky reefs at site 2 (Appendix I - Figure 52). Despite the apparent adaptability of humpback dolphins to their local environment, regional specialisation and preferences for specific foraging habitat have been shown to be consistent over the long-term in some instances. Meager *et al.* (2018) found that, while humpback dolphins in Moreton Bay, Queensland, showed evidence of shifting area usage due to changes in habitat integrity (e.g. lower water quality, high nutrient loads and sedimentation), areas close to estuaries were consistently used as foraging habitats for more than a decade. Future monitoring of humpback dolphins in the study area may provide further insights into the consistency of use of foraging areas over time.

The results of this study showed little variation across sampling periods in the environmental parameters of salinity and pH recorded at dolphin sighting locations (Table 26, Table 27). In contrast, mean temperature and turbidity values recorded at dolphin sighting locations in 2014 were higher than in other years, especially in the rivers at Site 1, and this may warrant further investigation (Table 26, Table 27). However, it should also be taken into consideration that different brands of water quality meters were used for the 2014 survey compared with the 2016-2018 surveys, and calibration issues may have also been a factor. Although it is beyond the scope of the current study, further investigations may be conducted by modelling behaviours and environmental parameters recorded at dolphin sighting locations in future.

4.5 Mitigation

With construction activities complete and the Amrun Project now moving into the operational phase, it is important to consider potential impacts on the inshore dolphins found in the region and how these might best be mitigated on an ongoing basis. Humpback, snubfin and bottlenose dolphins have been sighted in every year of the survey so far, and these represent the three main species of focus. In particular, with some of the largest abundance estimates recorded for Australian humpback dolphins at any location in Australia to date, it is clear that the Weipa region is habitat for a relatively large and important subpopulation of this Vulnerable species (Parra et al. 2017a).

Each of the three main dolphin species was found in the same general areas in each year of the survey from 2014-2018, including in proximity to the river and port facilities. However, the lack of humpback dolphins sighted in the Hey River in 2016 was notable. Although there are several possible explanations for this result, as discussed in section 4.2, the small sample sizes and limited survey effort over the four years of survey prevent strong conclusions from being drawn about the causes. Nevertheless, increased sightings of humpback dolphins in the Hey River in 2017 and 2018 suggest that any decline in dolphins at this location may have been a temporary shift in distribution rather than a permanent one. Considering fewer dolphins were sighted in the Hey River in 2017 and 2018 than in 2014, this should be monitored in future. Post-construction surveys will provide further evidence regarding this issue.

Between 71% and 95% of all dolphins were sighted at Sites 1 and 2 in all years of the survey. It is therefore essential to ensure mitigation measures continue at both sites. The Project already has in place a vessel speed limit of 6 knots in waters less than 2.5 m deep, as well as transit lanes for Project vessels in the Hey and Embley Rivers. These are regulatory conditions and will remain in effect for the life of the project. Minimum approach distances and maximum speed limits for vessels in proximity to dolphins will also be in place. Dolphin presence in potential impact zones, including the shipping channel and around the port facility, will also be monitored during the operational phase surveys.

The presence of humpback dolphin calves (Figure 26), and to a lesser extent bottlenose (Figure 27) and snubfin (Figure 28) calves, in the vicinity of the port facility requires further investigation. Although numbers were low, that more than 11% of humpback dolphin calves encountered throughout the study (n=6/53) were sighted in Boyd Bay, consideration should be given to mitigating potential impacts from vessels at this location, and calf presence close to the port should be closely monitored. As the operation of the port facility and associated shipping activities will result in higher levels of ambient noise in the vicinity, noise impacts on these dolphins should also be taken into consideration. Lastly, any maintenance dredging for the Project will include marine fauna observer and dredge management procedures to avoid impacts on turtles and marine mammals, including dolphins.

4.6 Survey design

Although population estimates were possible for humpback and bottlenose dolphins after combining four years of data (2014, 2016, 2017 and 2018), there were limitations to the modelling. This was reflected by very wide CVs for some samples and an inability to estimate some population parameters, such as temporary emigration, in some instances. Separate estimates were not possible for the different Sites for either humpback or bottlenose dolphins, and both on and off effort captures were included in analyses to increase sample sizes. Coefficients of variation (CVs) of the total population estimates for humpback dolphins were 0.12, 0.23, 0.17 and 0.10 for the years 2014, 2016, 2017 and 2018 respectively. Except for the estimate for the year 2016, all meet the common target of CV < 0.20 for abundance estimates from capture-recapture studies. However, abundance estimate CVs for bottlenose dolphins ranged from 0.20 – 0.30 over the four years of survey, and capture probabilities varied widely between secondary samples for both species and were very low in 2016 in particular. Capture probabilities of ~0.2 are adequate to obtain reliable estimates, with 0.1 considered to be the minimum for estimation (White *et al.* 1982). Capture probabilities of >0.2 were only achieved in 2 of

16 samples for bottlenose dolphins, and 6 of 16 for humpbacks. Capture probabilities of ≥0.1 were achieved in 7/16 samples for bottlenose dolphins and 12 of 16 for humpback dolphins. Such limitations may be a reflection of the proportion of study area covered by transects, as well as sampling effort. The Strategy recommends re-evaluating the requirement for each primary sample to consist of four secondary samples per survey. However, given the limitations outlined above with respect to capture probabilities, four secondary samples per survey would be the recommended minimum for the operational phase surveys.

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Appendix I

Figure 39. Example of a false positive error of a humpback dolphin, with two images of different individuals being recorded as the same individual. Both images were from the same group encounter in 2014.

Figure 40. Example of a false negative error of a humpback dolphin, with two images of the same individual being recorded as different individuals. These images were from encounters on separate days in 2014.

Figure 41. Example of a false positive error of a bottlenose dolphin, with two images of different individuals being recorded as the same individual.

Figure 42. Example of a false negative error of a bottlenose dolphin, with two images of the same individual being recorded as different individuals.

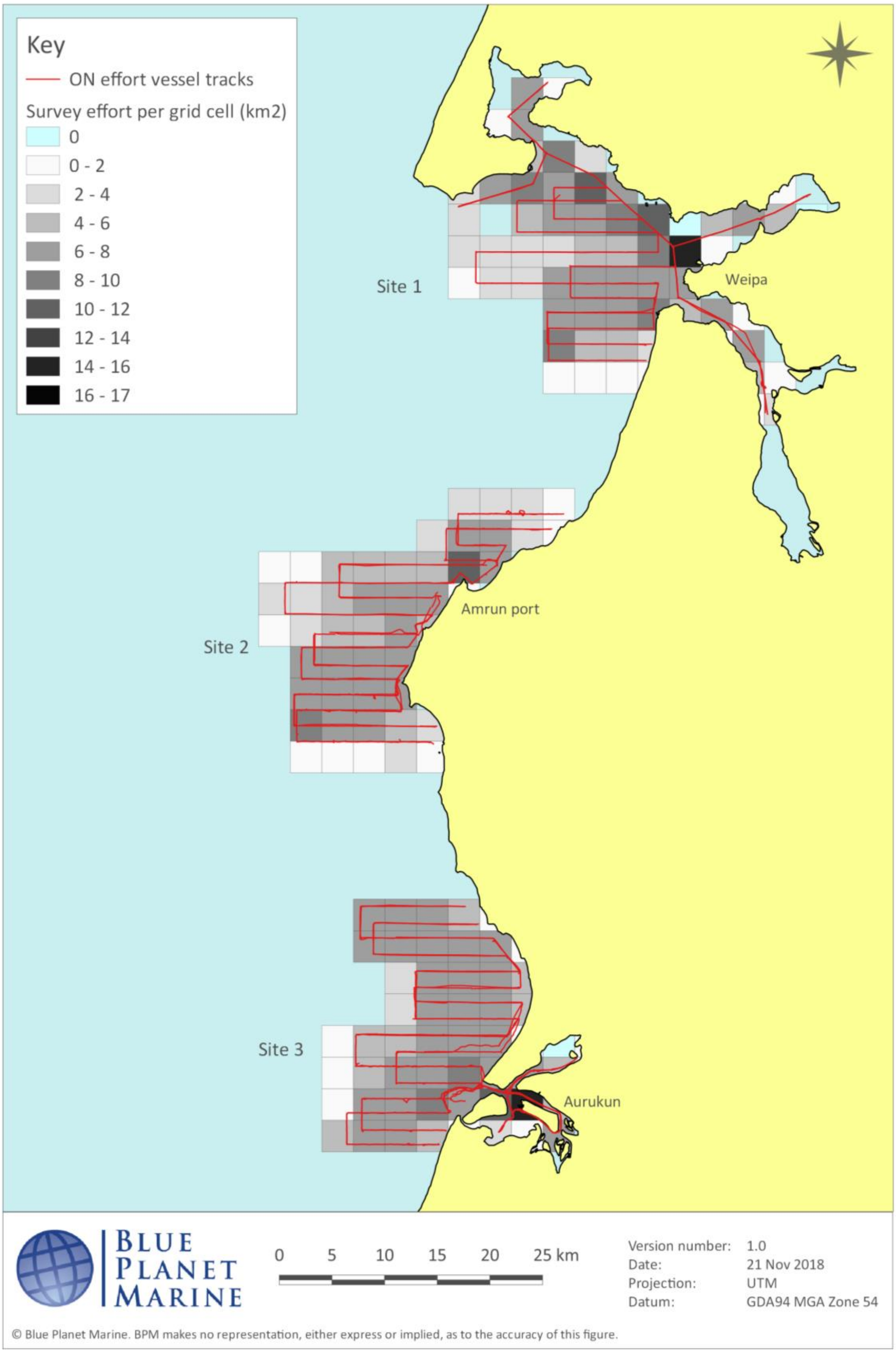

Figure 43. Survey effort with 3 x 3km grid overlay showing effort per grid cell for the 2018 survey.

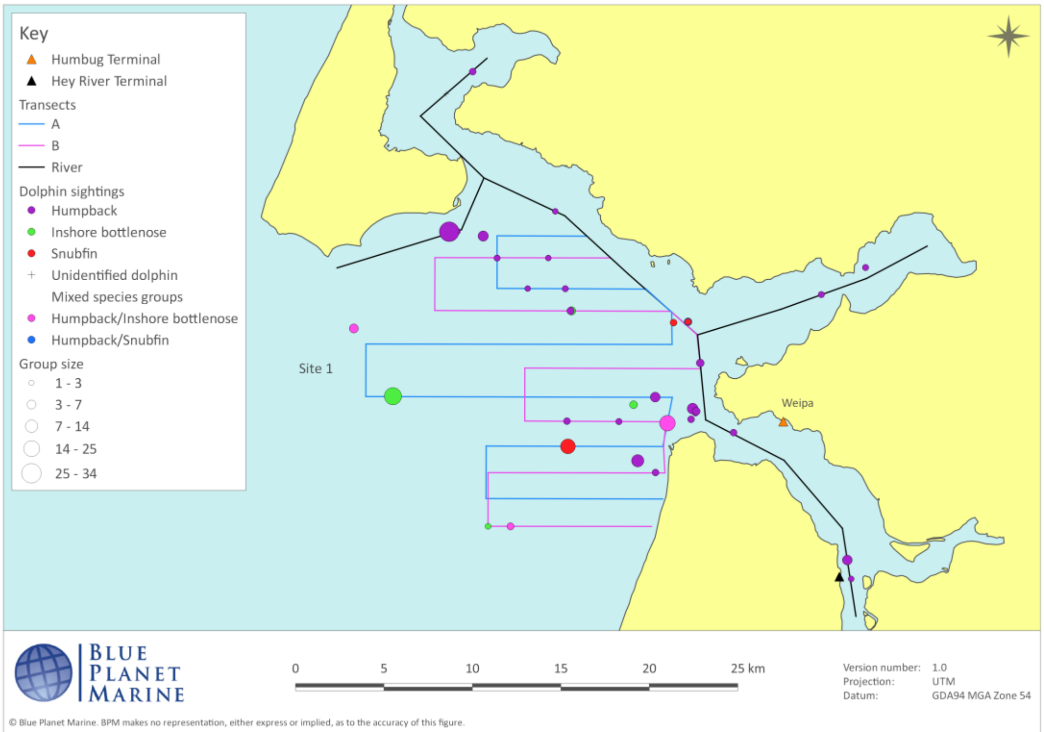

Figure 44. On and off effort sightings of dolphins during the 2018 survey at Site 1.

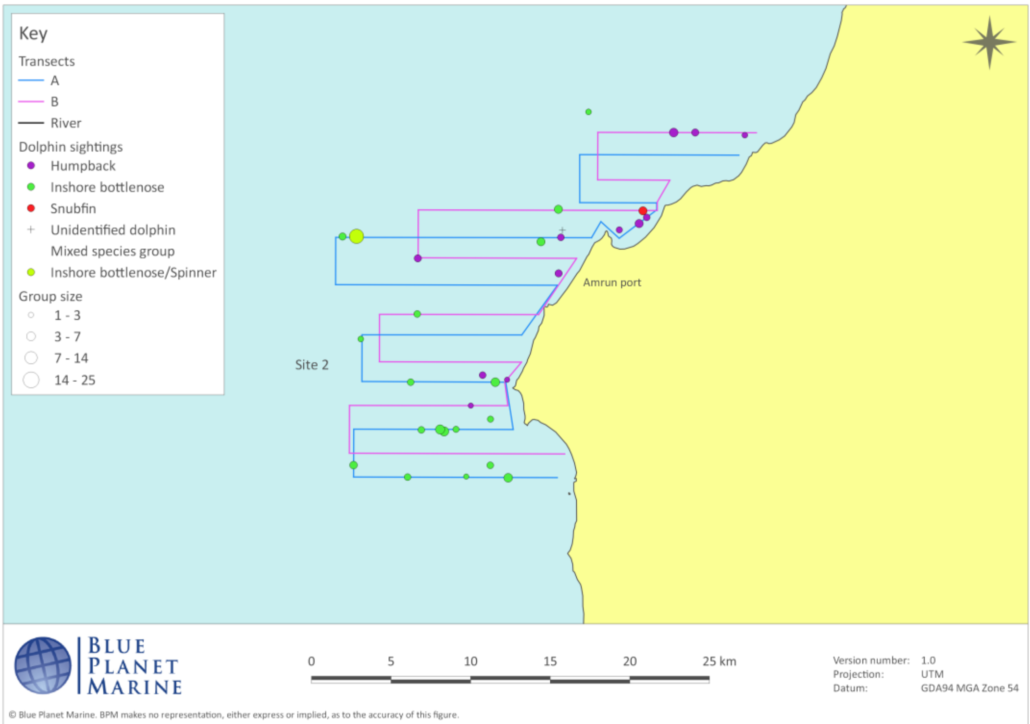

Figure 45. On and off effort sightings of dolphins during the 2018 survey at Site 2.

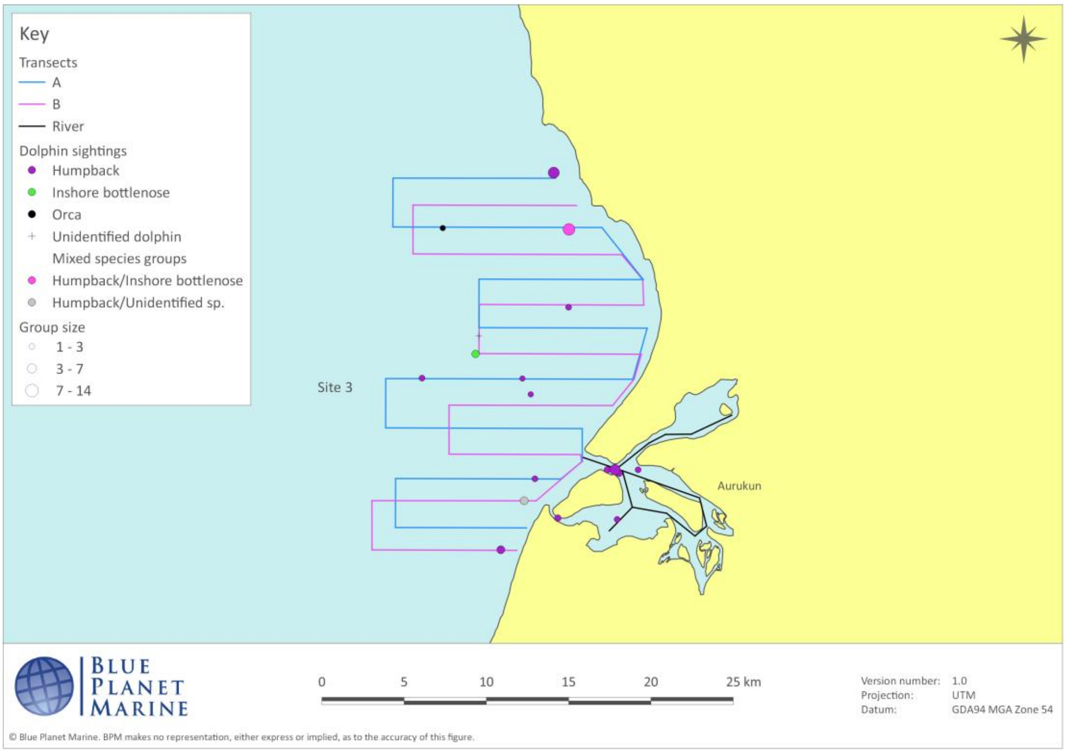

Figure 46. On and off effort sightings of dolphins during the 2018 survey at Site 3.

Table 30. On and off effort sightings of humpback dolphins (including those sighted in mixed species groups) during the 2014-2018 surveys.

Humpback	ON + OFF effort sightings		ON effort sightings	
	Groups	Individuals	Groups	Individuals
2014	81	284	57	205
2016	47	149	24	68
2017	58	221	31	100
2018	58	279	33	149
Total	244	933	145	522

Table 31. On and off effort sightings of inshore bottlenose dolphins (including those sighted in mixed species groups) during the 2014-2018 surveys.

Inshore bottlenose	ON + OFF effort sightings		ON effort sightings	
	Groups	Individuals	Groups	Individuals
2014	18	156	14	96
2016	12	72	5	22
2017	26	178	14	58
2018	28	172	18	114
Total	84	578	51	290

Table 32. On and off effort sightings of offshore bottlenose dolphins (including those sighted in mixed species groups) during the 2014-2018 surveys.

Offshore bottlenose	ON + OFF effort sightings		ON effort sightings	
	Groups	Individuals	Groups	Individuals
2014	1	4	1	4
2016	1	2	1	2
2017	1	25	1	25
2018	0	0	0	0
Total	3	31	3	31

Table 33. On and off effort sightings of snubfin dolphins (including those sighted in mixed species groups) during the 2014-2018 surveys.

Snubfin	ON + OFF effort sightings		ON effort sightings	
	Groups	Individuals	Groups	Individuals
2014	7	17	6	11
2016	2	14	0	0
2017	5	12	3	7
2018	5	36	1	20
Total	19	79	10	38

Table 34. On and off effort sightings of spinner dolphins (including those sighted in mixed species groups) during the 2014-2018 surveys.

Spinner	ON + OFF effort sightings		ON effort sightings	
	Groups	Individuals	Groups	Individuals
2014	1	9	1	9
2016	0	0	0	0
2017	3	29	3	29
2018	1	3	1	3
Total	5	41	5	41

Table 35. Sightings of humpback dolphins by site during the 2014-2018 surveys.

Humpback	Site 1		Site 2		Site 3		TRANSIT		Grand total Groups	Grand total Individuals
	Groups	Individuals	Groups	Individuals	Groups	Individuals	Groups	Individuals		
2014	50	171	23	87	8	26	0	0	81	284
2016	23	74	16	59	6	11	0	0	45	144
2017	27	109	20	57	10	54	1	2	58	222
2018	31	174	12	49	15	56	0	0	58	279
Total	131	528	69	245	39	147	1	2	242	929
% of grand total	54.6	57.3	28.8	26.6	16.3	15.9	0.4	0.2	100	100

Table 36. Sightings of inshore bottlenose dolphins by site during the 2014-2018 surveys.

Inshore bottlenose	Site 1		Site 2		Site 3		TRANSIT		Grand total Groups	Grand total Individuals
	Groups	Individuals	Groups	Individuals	Groups	Individuals	Groups	Individuals		
2014	10	56	6	86	2	14	1	2	19	158
2016	6	35	5	35	0	0	0	0	11	70
2017	3	19	12	92	9	56	2	10	26	177
2018	7	54	19	103	2	15	0	0	28	172
Total	26	164	42	316	13	85	3	12	84	577
% of grand total	31.0	28.4	50.0	54.8	15.5	14.7	3.6	2.1	100	100

Table 37. Sightings of snubfin dolphins by site during the 2014-2018 surveys.

Snubfin	Site 1		Site 2		Site 3		TRANSIT		Grand total Groups	Grand total Individuals
	Groups	Individuals	Groups	Individuals	Groups	Individuals	Groups	Individuals		
2014	2	2	0	0	5	15	0	0	7	17
2016	0	0	2	14	0	0	0	0	2	14
2017	0	0	0	0	5	12	0	0	5	12
2018	4	29	1	7	0	0	0	0	5	36
Total	6	31	3	21	10	27	0	0	19	79
% of grand total	31.6	39.2	15.8	26.6	52.6	34.2	0.0	0.0	100	100

Table 38. Number of individual dolphins observed from each age class for each species during surveys from 2014-2018.

Species	Year	Groups	Individuals	Adults	Subadults	Calves	Neonates	Unknowns
Humpback	2014	81	284	231	41	12	0	0
	2016	45	144	100	30	1	0	0
	2017	58	221	191	32	13	0	10
	2018	58	288	222	16	27	0	23
	Total	242	937	744	119	53	0	33
Inshore bottlenose	2014	19	158	128	28	2	0	0
	2016	11	70	60	8	2	0	0
	2017	26	178	124	23	15	0	6
	2018	28	163	116	11	28	1	10
	Total	84	569	428	70	47	1	16
Offshore bottlenose	2014	1	4	4	0	0	0	0
	2016	1	2	2	0	0	0	0
	2017	1	25	21	4	0	0	0
	2018	0	0	0	0	0	0	0
	Total	3	31	27	4	0	0	0
Snubfin	2014	7	17	15	2	0	0	0
	2016	2	14	11	0	1	0	0
	2017	5	12	8	0	2	0	0
	2018	5	36	33	1	2	0	0
	Total	19	79	67	3	5	0	0
Spinner	2014	1	9	9	0	0	0	0
	2016	0	0	0	0	0	0	0
	2017	3	29	22	7	0	0	0
	2018	1	3	3	0	0	0	0
	Total	5	41	34	7	0	0	0

Table 39. Group size of dolphins sighted during the 2014-2018 surveys combined.

Species	Groups	Mean group size (Std Dev)	Min. group size	Max. group size
Snubfin	16	4.6 (4.8)	1	20
Humpback	220	3.9 (3.5)	1	30
Humpback/Snubfin	3	5.0 (0.0)	5	5
Humpback/Inshore bottlenose	16	10.0 (7.7)	3	34
Inshore bottlenose	67	6.6 (5.4)	1	32
Inshore bottlenose/Spinner	1	16.0 (N/A)	16	16
Offshore bottlenose	3	10.3 (12.7)	2	25
Spinner	4	9.5 (6.0)	4	18

Table 40. Mean, standard deviation, minimum and maximum group size of humpback dolphins sighted during each year of survey from 2014-2018 after separating mixed species groups into their component species (and only accounting for conspecifics in group size calculations).

Year	Number of groups	Mean group size (Std Dev)	Min. group size	Max. group size
2014	81	3.5 (1.9)	1	9
2016	43	3.2 (2.3)	1	9
2017	58	3.8 (3.9)	1	20
2018	58	4.8 (4.7)	1	30
Total	240	3.8 (3.4)	1	30

Table 41. Mean, standard deviation, minimum and maximum group size of bottlenose dolphins sighted during each year of survey from 2014-2018 after separating mixed species groups into their component species (and only accounting for conspecifics in group size calculations).

Year	Number of groups	Mean group size (Std Dev)	Min. group size	Max. group size
2014	19	8.3 (7.1)	1	32
2016	11	6.4 (5.1)	1	18
2017	26	6.8 (6.0)	1	31
2018	28	6.1 (4.8)	1	25
Total	84	6.9 (5.8)	1	32

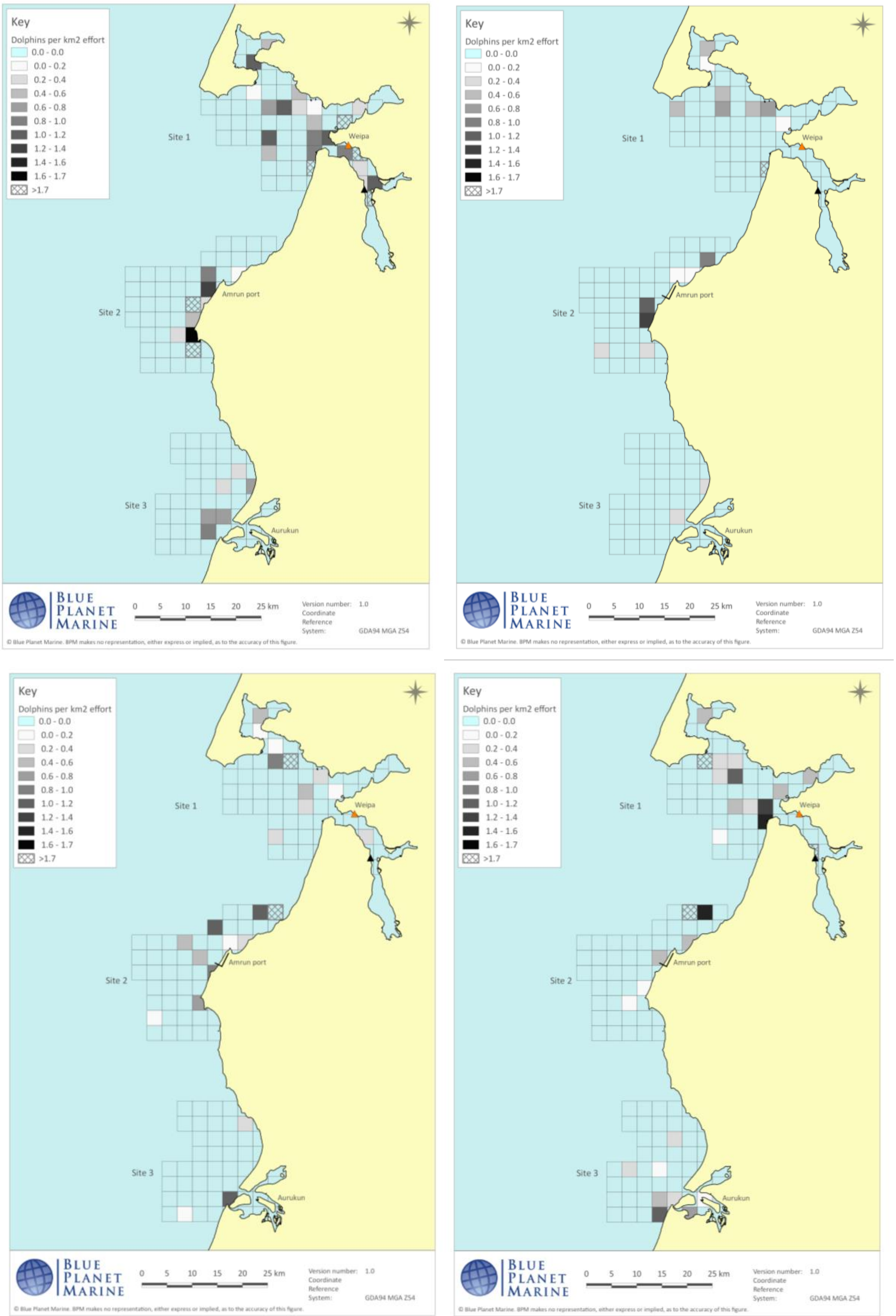

Figure 47. Survey Area Encounter Rates of humpback dolphins (per km^2 on effort) during surveys in 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right).

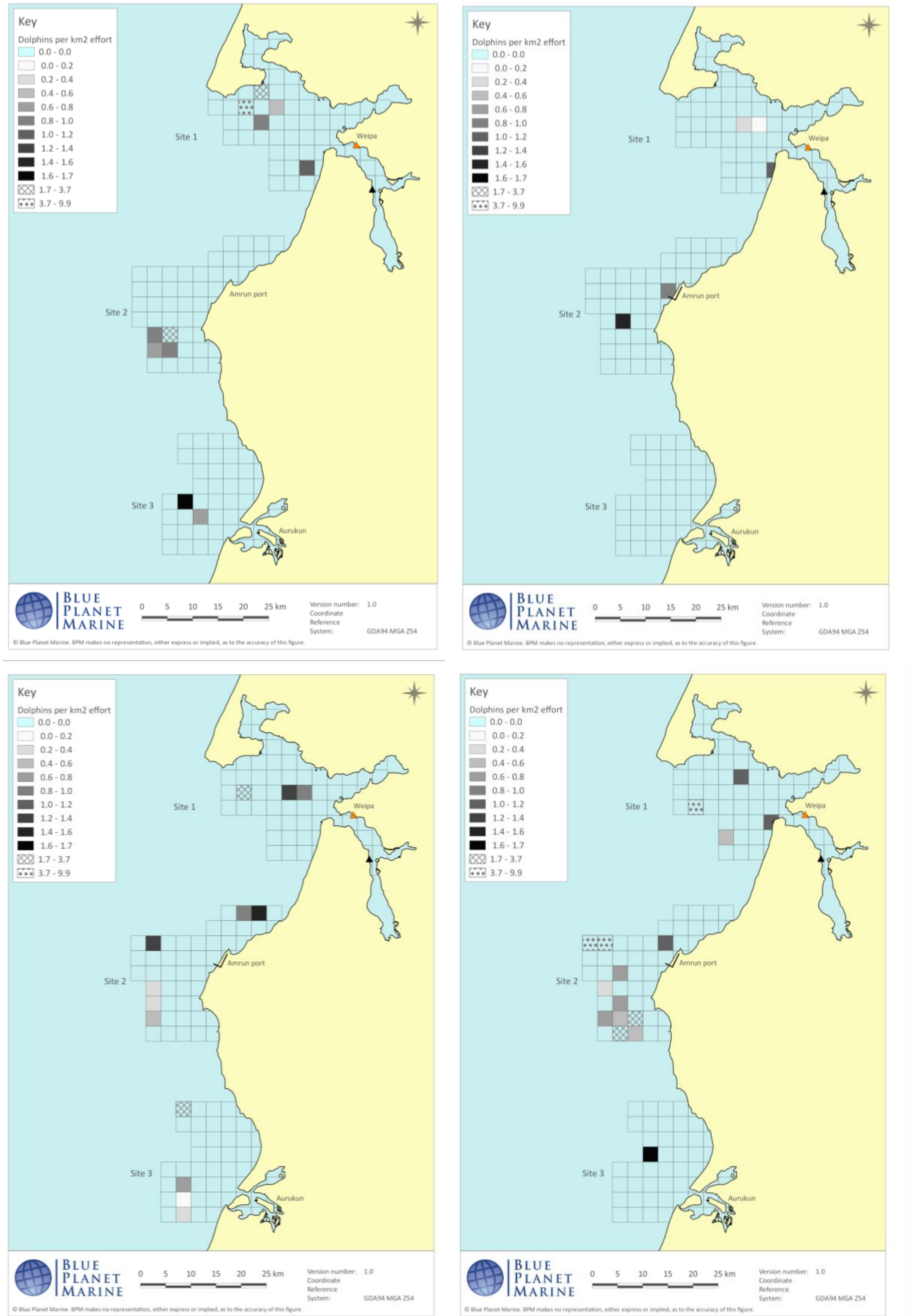

Figure 48. Survey Area Encounter Rates of bottlenose dolphins (per km^2 on effort) during surveys in 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right).

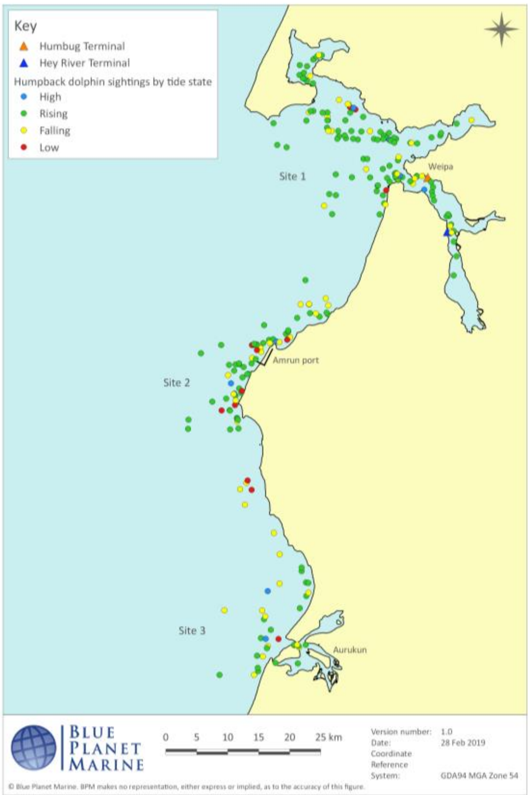

Figure 49. Humpback dolphin sightings by tidal state during the 2014, 2016, 2017 and 2018 surveys.

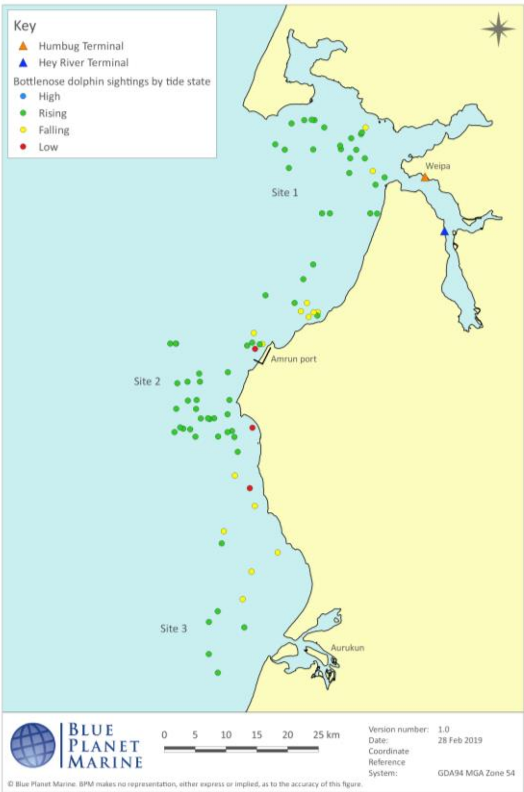

Figure 50. Bottlenose dolphin sightings by tidal state during the 2014, 2016, 2017 and 2018 surveys.

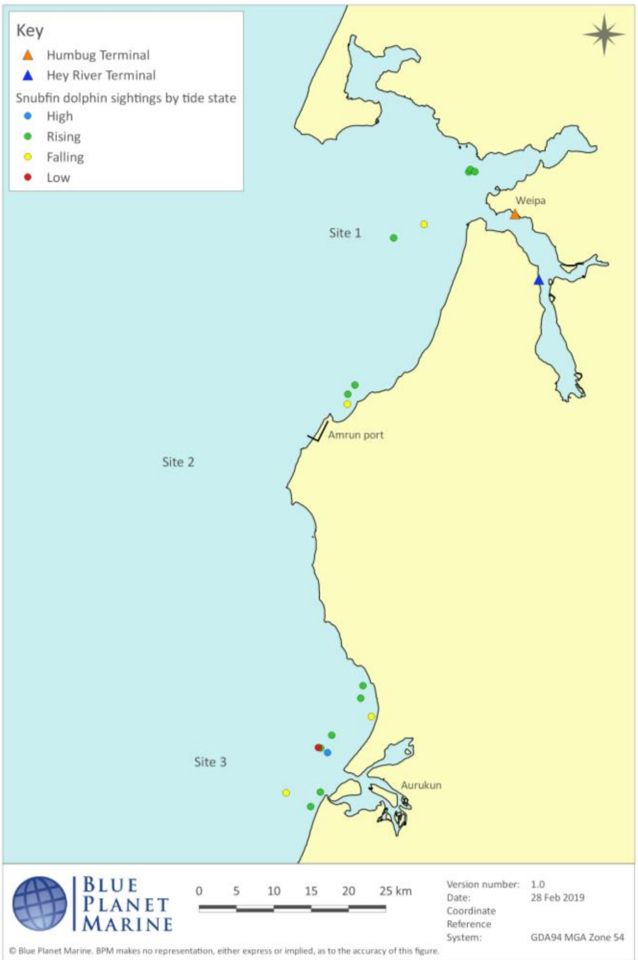

Figure 51. Snubfin dolphin sightings by tidal state during the 2014, 2016, 2017 and 2018 surveys.

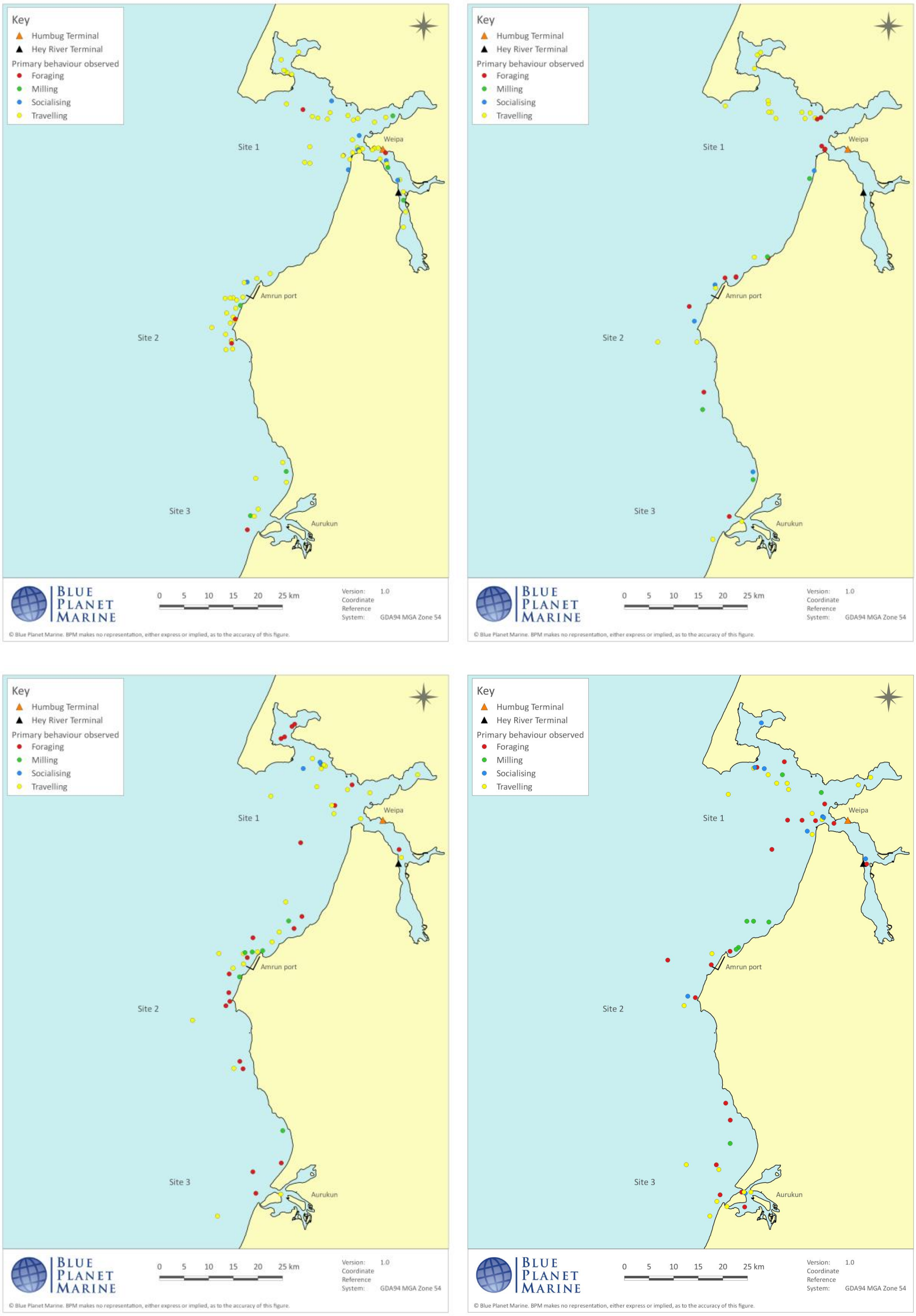

Figure 52. Sighting locations and primary behaviours of humpback dolphin groups observed during the 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right) surveys.

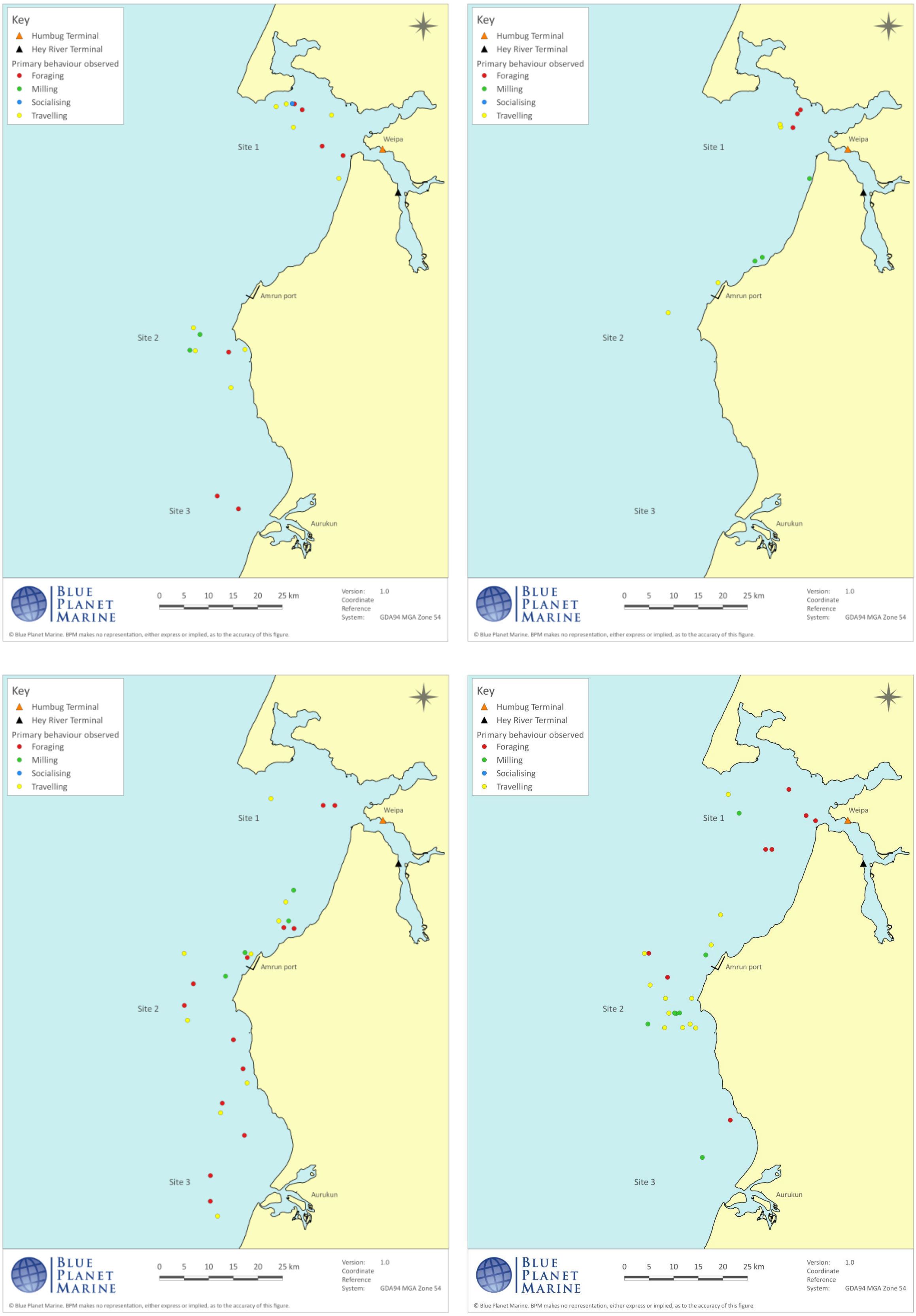

Figure 53. Sighting locations and primary behaviours of bottlenose dolphin groups observed during the 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right) surveys.

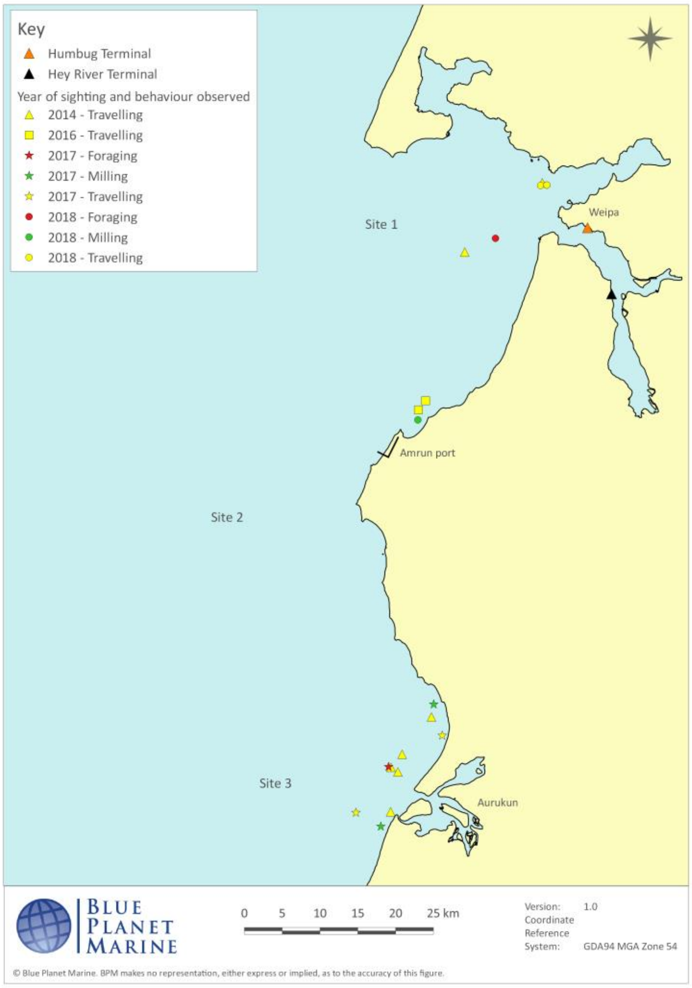

Figure 54. Sighting locations and primary behaviours of snubfin dolphin groups observed during the 2014 - 2018 surveys.