Amrun Project
2019 Inshore Dolphin Survey Report

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Executive Summary

Rio Tinto Weipa (RTW)'s Amrun Project involves the construction and operation of a bauxite mine and associated processing facilities, barge and ferry terminals, 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.

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), as well as a post-construction survey in October 2019. This report provides details about the 2019 survey, as well as analyses of the combined 2014-2019 data.

The methods used for the 2019 survey followed those of the 2014-2018 surveys. Three vessels undertook simultaneous, predetermined line-transect surveys from 11-25 October 2019 to collect sighting, photo-identification and habitat data on inshore dolphins encountered at three sites ranging from Pine River in the north (latitude 12.48^{o}S) to Aurukun in the south (13.39^{o}S). A total of 335 hours and 57 minutes were spent on the water for the 2019 survey, with all vessels at all sites totalling 4,424 kilometres travelled. Of this time, 122 hours and 2 minutes were spent 'on effort' (i.e., observing for dolphins while on transect) (1,585 km).

Including both on and off effort sightings, the research team sighted a total of 118 dolphin groups consisting of 584 individuals, including twelve mixed species groups. As per previous surveys in 2014, 2016, 2017 and 2018, humpback dolphins were encountered in the highest number of groups and totalled the most individual sightings (humpback dolphins: 84 groups, 297 individuals; inshore bottlenose: 29/156, snubfin: 11/87, spinner: 3/39, unidentified dolphin 2/2 and offshore bottlenose dolphin 1/3). In total, 17 humpback dolphin calves plus two neonates and 22 inshore bottlenose calves plus one neonate were sighted during the 2019 survey. No snubfin dolphin calves were encountered during the 2019 survey. The observer team also sighted 352 individuals of other (i.e., non-dolphin) marine megafauna species during the 2019 survey, the most numerous of which were marine turtles (n=166) and sea snakes (n=100).

At least one useable identification photograph was obtained from 87 (74%) of the 118 dolphin groups encountered in 2019. Images of marked animals that were of sufficient photo quality to be used in capture recapture (CR) analyses included: 124 humpback dolphins (91 of which were photographed in one secondary sample (SS), 29 in two SS, 4 in three SS and none photographed in all four SS); 67 bottlenose dolphins (59 photographed in one SS, 6 photographed in two SS, 2 photographed in 3 SS and none in all four SS); 36 snubfin dolphins (20 photographed in one SS, 11 photographed in two SS, 4 photographed in 3 SS and one in all four SS); and 6 spinner dolphins, all of which were photographed in one secondary sample.

Over the five years of survey from 2014-2019, dolphin species sighted include humpback dolphins (326 groups / 1,226 individuals), inshore bottlenose dolphins (113/735), offshore bottlenose dolphins (4/34), snubfin dolphins (30/166), and spinner dolphins (8/80). Humpback dolphins were encountered at the highest rate per km travelled on effort in all five surveys, with Linear Encounter Rates (LERs) of this species highest in 2014 and 2019 (0.12 dolphins per km 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 while on effort in all five surveys (2014 = 0.007, 2016 = 0.000, 2017 = 0.004, 2018 = 0.012 and 2019 = 0.011 dolphins per km).

Humpback, snubfin and bottlenose dolphins were sighted in every year of the survey from 2014-2019, and 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 notable exception at a fine-scale level was the lack of humpback dolphins sighted in the Hey River in 2016 (one group consisting of two individuals) compared with other years. Although small sample sizes and limited survey effort prevent strong conclusions from being drawn about the causes of this observation, and encounter rates of humpback dolphins were lower across the study area in 2016, there are several possible explanations for the lack of sightings in the Hey River in 2016, including:

- animals moving in and out of the study area due to variation in natural drivers; for example, 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 permitted limit was 60 minutes for the 2014, 2017, 2018 and 2019 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 owned by Green Coast Resources at Hey Point. 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 (piling for the Humbug and Hey River terminals was completed in August 2016, with the dolphin survey conducted from 7-19 November), 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, subsequent to 2016, sightings of humpback dolphins in the Hey River increased each year from 2017 to 2019, suggesting that any decline in dolphins at this location may have been a temporary shift in distribution rather than a permanent one. Nonetheless, fewer dolphins were sighted in the Hey River in 2017 (3 groups, 9 dolphins), 2018 (4 groups, 17 dolphins) and 2019 (11 groups, 37 dolphins) than in 2014 (15 groups, 54 dolphins), and this should continue to be monitored in future. It should be noted that snubfin and bottlenose dolphins were not sighted in the Hey River in any year of survey from 2014-2019.

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, 2018 and 2019 surveys for capture-recapture population modelling. Sample sizes were sufficient to obtain abundance estimates for humpback dolphins (n=330 individuals identified with sufficient quality to be used in capture-recapture modelling) and bottlenose dolphins (n=211) for the years 2014-2019, however precision was low for bottlenose dolphins. Samples sizes were insufficient to estimate abundance of snubfin dolphins for the years 2014-2018, but a larger number of encounters and captures in 2019 enabled abundance to be estimated for the final year with reasonable precision.

Estimated abundance of humpback dolphins present in the study area (1,014 km^2) during each of the primary samples was 214 (95% Confidence Interval (CI): 184-248) in 2014, 242 (182-322) in 2016, 242 (182-322) in 2017, 193 (161-231) in 2018 and 245 (208-290) in 2019. Therefore, typically, it is likely that more than 200 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. Parameter estimates also suggested high rates of permanent emigration and immigration for this species. Overall, it appears that there is considerable interchange of individuals between the sample area and adjacent parts of 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 2014 to 2018, with 118 (95% CI 84-165) in 2014, 157 (84-293) in 2016, 284 (187-432) in 2017 and 451 (271-749) individual bottlenose dolphins estimated to have used the study area during a two-week period in October 2018. However, the estimate for 2019 was lower at 254 (147-438) and apparent survival was estimated to have reduced from 0.93 per annum for 2014-2018 to 0.77 per annum for 2019. This suggests that the rate of permanent emigration had increased from 2.1% per annum to 18.9% after 2018. Not only was apparent survival high during the growth period 2014-2018, but the rate of growth was also too great to be accounted for by in situ births alone, suggesting a relatively high rate of immigration from elsewhere. Similarly, but in contrast, the rate of decline following 2018 was too great to be accounted for by the reduction in apparent survival (increase in permanent emigration) alone, suggesting that the previous rate of immigration was not maintained.

A total of 44 snubfin dolphins were photographed from 2014-2018, but only 24 of these were captured with sufficient photo quality and distinctiveness for reliable, inter-year identification of individuals. Abundance estimates were therefore not possible for this species for the years 2014-2018. In 2019 however, a total of 36 individuals were captured a total of 58 times. With this number of recaptures, a closed population model was able to be fitted to estimate the abundance of snubfin dolphins in 2019. Accounting for the estimated marked proportion of the population (0.85, SE = 0.055), the estimated total population size of snubfin dolphins using the study area in 2019 was 52 (SE = 6.35, 95%CI = 41-66).

It appears that, for all three species, the study area may be part of a larger area over which these dolphins range, although, the patterns of visitation to the study site (Weipa, Boyd Point and Aurukun) appear to vary between species. The factors driving which dolphins come and which go is unknown, but it is clear that movements into and out of the sampling area are reasonably long term for humpback and bottlenose dolphins, with very low rates of temporary emigration suggesting when these dolphins leave the area, they stay away permanently or for an extended period of time. There was no evidence to suggest that the variation in abundance estimates was related to the timing of construction activities associated with the Amrun Project, other than the potential issues already outlined for 2016. It is unclear why humpback dolphins permanently emigrated and immigrated at quite high rates in all intervals from 2014-2019; bottlenose dolphins immigrated at quite a high rate and emigrated at a low rate from 2014-2018 but then immigrated at a low rate and emigrated at a high rate after 2018; and snubfin dolphins were seen in low numbers from 2014-2018 but a larger number was encountered in 2019 and numerous dolphins remained in the study area for a longer period.

The variation in capture probabilities and encounter rates for each of these species over years may be related to variation in the use of the sampling area and areas outside of the sampling area by these dolphins. Future surveys are required to provide more information about the broader range of dolphin populations in western Cape York.

Having successfully completed surveys and met the Strategy objectives in 2014, 2016, 2017, 2018 and 2019, the combined datasets and analyses from this study provide an important contribution to knowledge about humpback, bottlenose and snubfin dolphins in the region, in particular that the sampling area is part of larger systems for all three species. These data allow for more informed management and planning decisions to be made as the Project continues in its operational phase, as well as to provide information to help assess the conservation status of inshore dolphin species in northern Australian waters. Importantly, Wik Waya Traditional Owners (TOs) have been involved in all five surveys, gaining skills and experience in monitoring of dolphin populations and increasing capacity for any future dolphin survey and monitoring opportunities.

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1. Introduction

Rio Tinto 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.

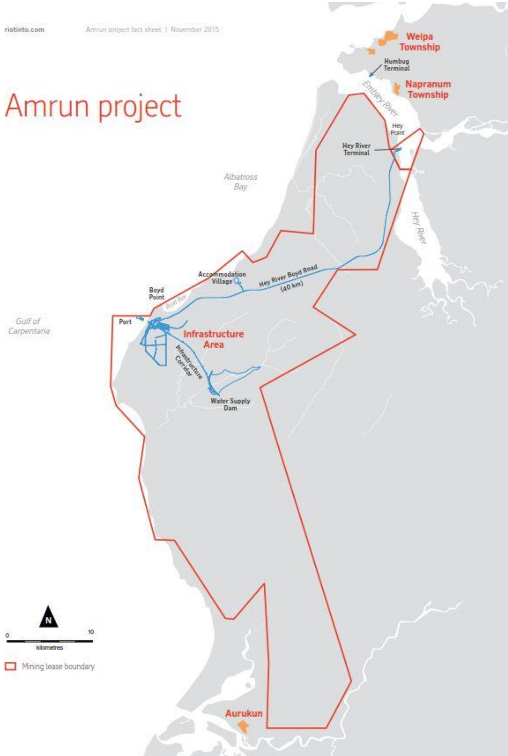

Figure 1. Overview of the Amrun Project. Source: Rio Tinto Weipa.

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 were the primary focus of the surveys, information was 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) and post-construction phase in 2019. 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.

The 2019 dolphin survey constituted the post-construction phase survey for the Amrun Project. This report provides details about the 2019 survey and analyses of the combined 2014-2019 data.

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 Heritage 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 State permit was updated for the 2019 survey under permit number WA0018015 issued by the Queensland Department of Environment and Science.

The conditions of the original State and Commonwealth research permits in 2016 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 2017-2019 surveys.

Animal ethics approval (CA 2016/09/1000) for the 2016-2019 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 2019 survey followed those of the 2014-2018 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 was 410 km^2, site 2 was 287 km^2 and site 3 was 317 km^2 for a total study area of 1,014 km^2. The transect lines used for the 2019 survey were the same as those used for the 2014-2018 surveys, with some minor adjustments made in 2017-18 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 2019 survey, BPM's 7m RHIB, *Koopa*, was used to survey site 1, while the 24m live-aboard vessel, *Escape*, 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 based on 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 2014-2019 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.

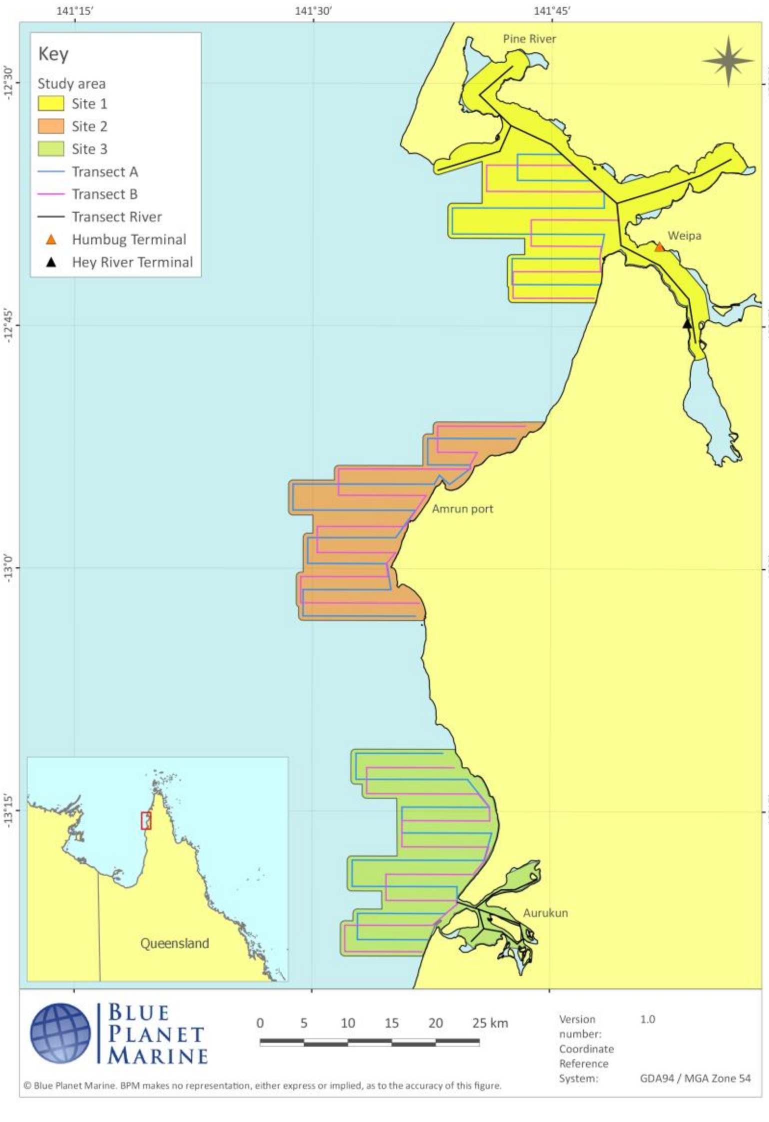

Figure 2. Overview of transects for the Inshore Dolphin Survey undertaken in October 2019.

Figure 3. BPM Research vessels *Koopa* (top left), *Coda* (top right) and *Escape* (bottom) used for the 2019 survey.

Table 1. Transects completed per secondary sample during the 2014-2019 surveys. Refer to Figures 4-6 for transect point details.

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

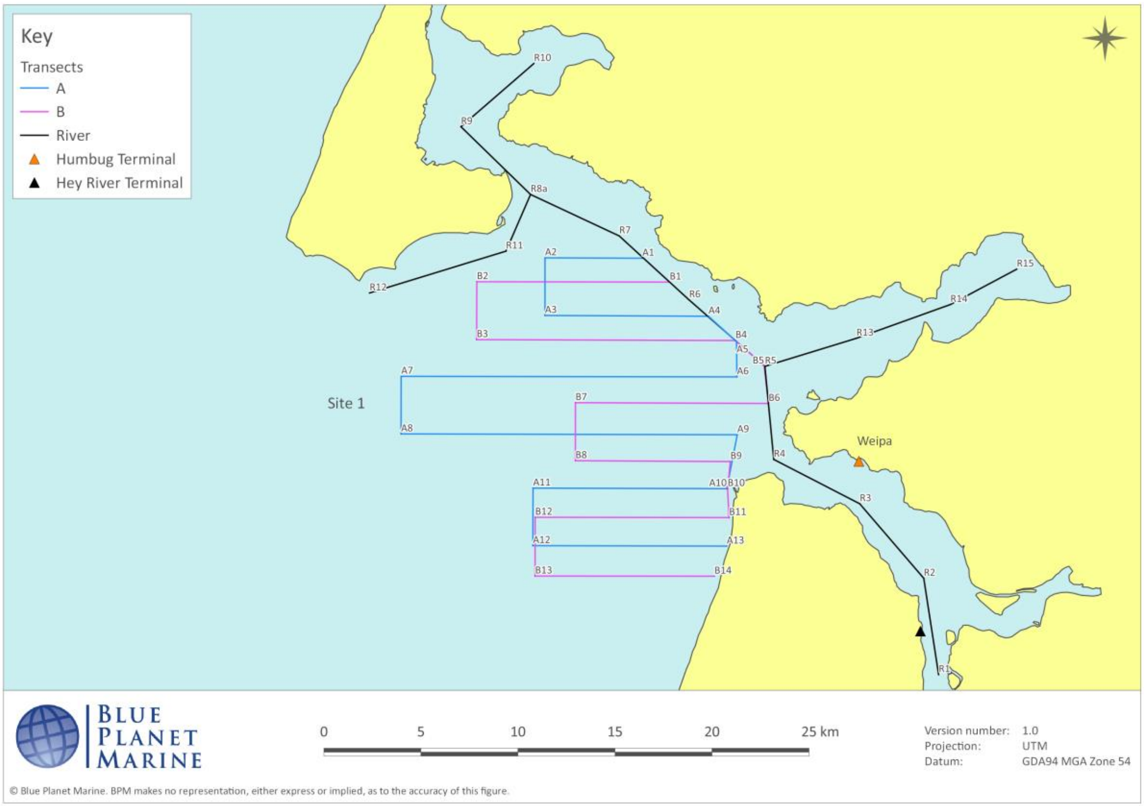

Figure 4. Site 1 transects.

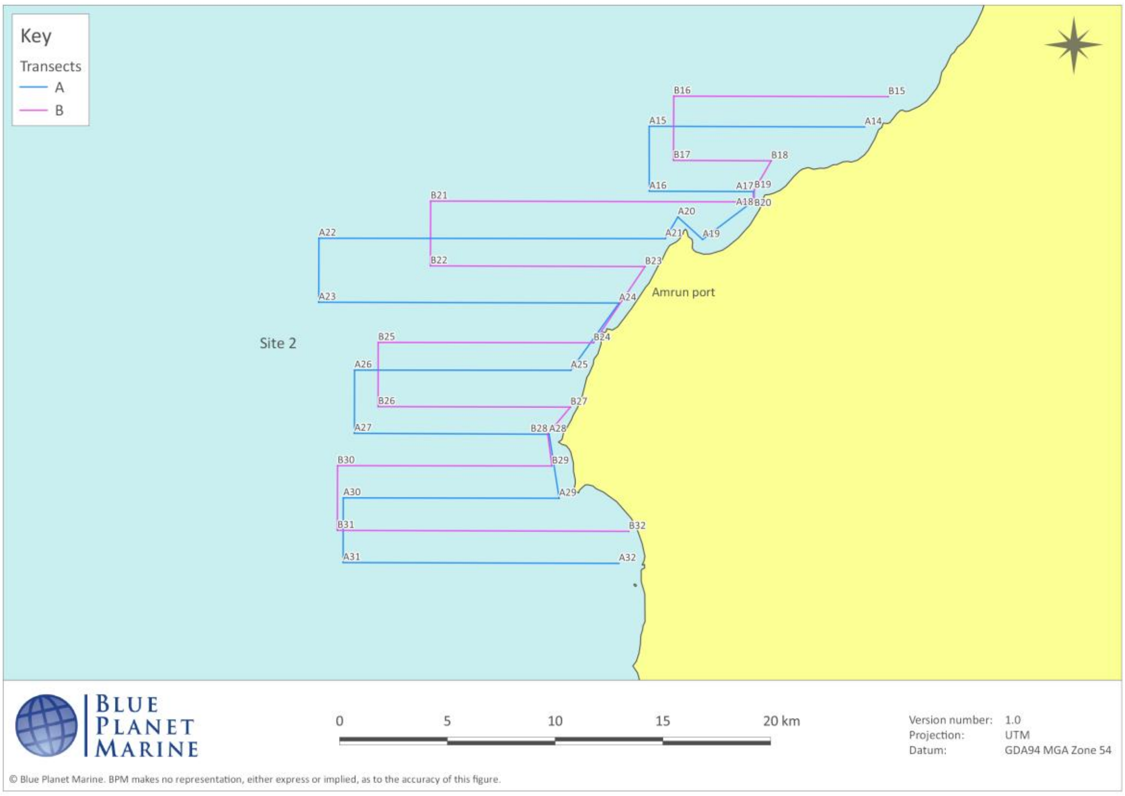

Figure 5. Site 2 transects.

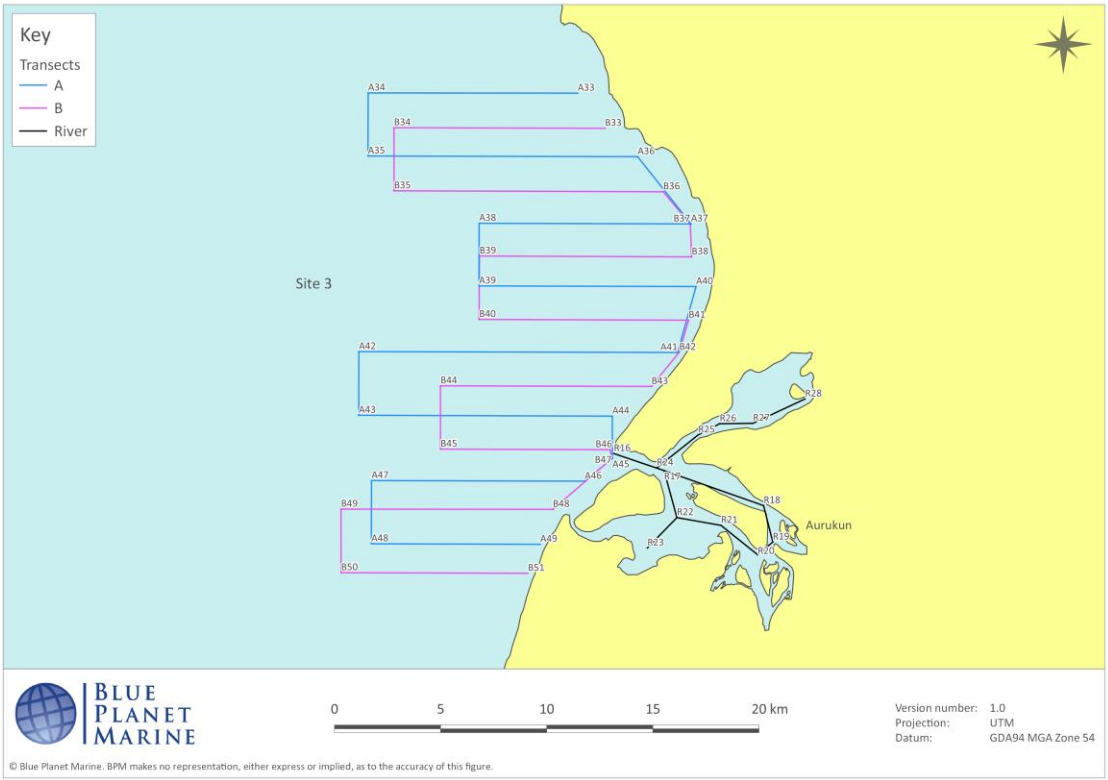

Figure 6. Site 3 transects.

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 analyses.

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. All parameters were collected at site 1 during the 2019 survey, however, due to equipment availability, logistics and the lack of variation in recorded parameters in previous years, temperature, salinity, pH and turbidity were not collected at sites 2 and 3 during the 2019 survey.

Once all required data had been collected for a dolphin sighting, or the maximum permitted contact time with a group had been reached, the vessel returned 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 for 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 interval of one minute between location points, 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. If conditions increased to Beaufort 4 during a transect, in some instances the remainder of the transect was completed 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 9-10 October 2019 followed by the survey itself which was completed over 15 days from 11 – 25 October 2019. A research team of 24 people undertook the survey in 2019 (Figure 7), including Traditional Owners from the Land and Sea Management Program (LSMP): Jerry Wapau, Miles Kerindun, Darrus Wolmby, Mitchell Bandicootcha, Anthony Yunkaporta, Tianna Chevathen, Bridgette Bandicootcha and Anton Binjuda; the Land and Rehabilitation (L&R) team: Robert Adidi and Walter Convent, along with other L&R members Darren Lee and Marcus Payne, members of RTW's Health, Safety and Environment (HSE) team Linda Wells, Jacinta Smith, Khory Hancock, Sherie Hinschen and Benji Jacobs, and BPM's Dave Paton, Liz Hawkins, Corey Lardner, Andrew Paton, Andrew Nichols, Chris Witty and Dan Burns.

Figure 7. Members of the 2019 dolphin survey team. L to R: Dan Burns, Andrew Nichols, Liz Hawkins, Walter Convent, Bridgette Bandicootcha, Robert (Bob) Adidi, Sherie Hinschen, Dave Paton, Chris Witty, Andrew Paton, Corey Lardner, Anton Binjuda, Tianna Chevathen.

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 ($\hat{M}_p$):

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

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

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

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 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). Misidentification errors 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 five years 2014, 2016, 2017, 2018 and 2019. Matches were checked by two experienced researchers during the final collation stage to minimise the potential for matching errors.

For species for which there were adequate data (humpback, bottlenose), Robust Design models (CRD; Kendall *et al.*1995, Kendall and Nichols 1995, Kendall *et al.* 1997) were 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 (in principle) between primary samples. A simple closed population model was fitted to the data on snubfin dolphins for 2019, the only year in which there were enough captures and recaptures to support a capture-recapture model. Program CAPTURE as implemented in program Mark was used for this analysis.

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'. The parameter γ''

estimated the probability of presence in the previous sample and absence in the present sample, and parameter 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 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. Dispersion was estimated as the model chi-square divided by its degrees of freedom ($\hat{c} = \chi^2 / df$). Where detected, significant overdispersion ($\hat{c} > 1$) was included the model to yield correct standard errors for the estimates.

The modelling process involves fitting a set of models with alternative parameter structures and comparing them for fit to data and parsimony. Models were compared with the Akaike Information Criterion corrected for small sample sizes (AIC_c, Burnham and Anderson 2002), with smaller values of AIC_c indicating better fitting models, and with AIC_c weights, which measure the relative likelihoods of the models in the set. When the model set is adjusted for overdispersion by fitting a variance inflation factor ($\hat{c} > 1$), the Quasi Akaike Information Criterion corrected for small sample sizes ($QAIC_c$, Burnham and Anderson 2002) was employed for model comparisons.

When one model in the set had a clearly lower AIC_c than all others and attracted the major proportion of the AIC_c weight, the parameter estimates from this 'best' model are reported; when several models have similar AIC_c values and shared the AIC_c weight, model-averaging may be applied (Buckland et al. 1997) whereby a weighted average of the parameter estimates from several models are reported.

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 as already described.

2.3.2 Encounter rates

Linear Encounter Rates (LER) for the 2019 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 the 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 the surveys. In order to compare pre-construction SAERs with construction and post-construction-phase SAERs, an additional analysis was conducted by combining effort and sightings data for the three construction-phase surveys (2016, 2017 and 2018).

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[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, restricting calculations to on-effort-only data provides a more accurate statistic.

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 each year of survey, for the construction phase surveys combined, and for all surveys combined. Dolphins sighted per grid cell were then used to calculate SAERs across the study area for the 2019 survey and to compare SAERs between years and project phases. All mapping was conducted using QGIS software (QGIS Development Team (2020)).

2.3.3 Environmental parameters associated with sightings

The 2019 survey commenced on 11 October with spring tides leading up to the full moon on 14 October. The third quarter moon occurred on 21 October and new moon on 28 October. For the purposes of analysis, tides from 11-17 October were considered spring tides, with neap tides from 18-24 October and the last day of survey (25 Oct) returning to a spring tide. 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, otherwise they were considered 'rising' or 'falling'.

2.3.4 Distance from shore

The minimum distance to the closest point of land was calculated for all dolphin groups sighted from 2014-2019 using QGIS software.

3. Results

3.1 2019 Survey

3.1.1 Survey effort and conditions present

A total of 335 hours and 57 minutes were spent on the water for the 2019 survey, with all vessels at all sites totalling 4,424 kilometres travelled. Of this time, 122 hours and 2 minutes were spent 'on effort' (i.e. observing for dolphins while on transect) (1,585 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 2019 survey.

Beaufort sea state	Distance travelled (km)	Pecentage of total distance travelled (%)
0	0.0	0.0
1	167.5	10.6
2	529.2	33.4
3	833.0	52.6
4	55.2	3.5
Total	1584.9	100.0

3.1.2 Sightings

3.1.2.1 Dolphins

During the 2019 survey, including both on and off effort sightings, the research team sighted a total of 118 dolphin groups consisting of 584 individuals, including twelve mixed species groups (Table 3, Figure 8). 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 where relevant).

Table 3. Group characteristics of dolphins sighted during the 2019 survey.

Species	Total Groups	Total Individuals	On effort Groups	On effort Individuals	Mean group size	Minimum group size	Maximum group size
Humpback	75	271	43	166	3.6	1	20
Inshore bottlenose	20	106	7	38	5.3	1	14
Offshore bottlenose	1	3	1	3	3.0	3	3
Snubfin	6	32	3	15	5.3	2	10
Spinner	2	22	1	17	11.0	5	17
Unidentified dolphin	2	2	2	2	1.0	1	1
Mixed (Humpback/Inshore bottlenose)	6	57	5	48	9.5	5	17
Mixed (Humpback/Snubfin)	3	33	1	6	11.0	6	15
Mixed (Inshore bottlenose/Spinner)	1	20	0	0	20.0	20	20
Mixed (Snubfin/Inshore bottlenose)	2	38	0	0	19.0	13	25
Total	118	584	63	295			

Separating mixed species groups into their component species resulted in total dolphin sightings per species for the 2019 survey as follows: 297 humpback, 156 inshore bottlenose, 87 snubfin, 39 spinner, 3 offshore bottlenose and 2 unidentified dolphins. Further details of sightings of each species are provided in Appendix 1 (Table 30 - Table 34).

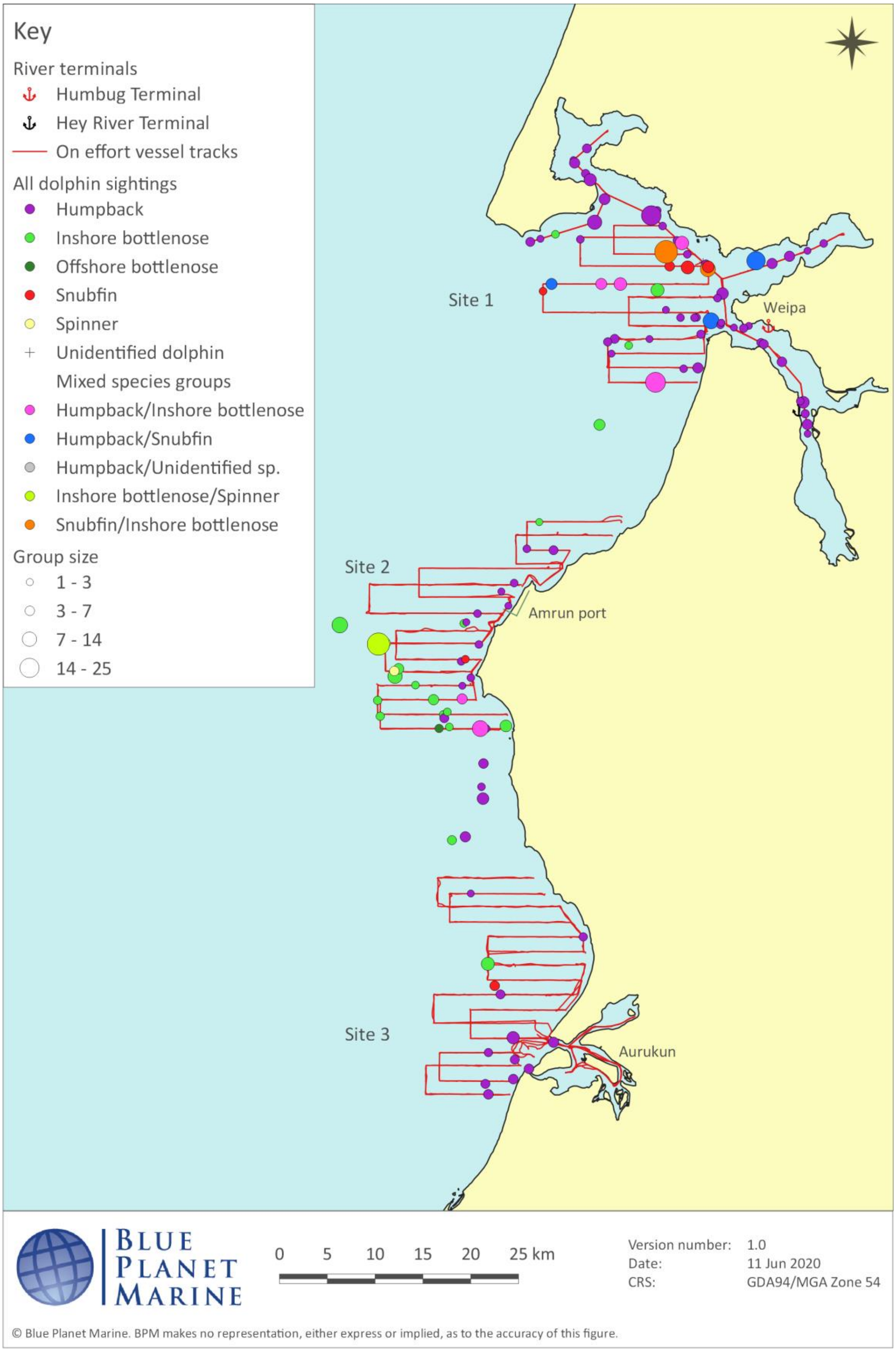

Figure 8. All on and off effort dolphin groups sighted during the 2019 Inshore Dolphin Survey.

3.1.2.2 Non-dolphins

During the 2019 survey, the observer team also sighted 352 individuals of other (i.e. non-dolphin) marine megafauna species (Figure 9). Of the non-dolphin species sighted, the most common were marine turtles (n=166, 47%), sea snakes (n=100, 28%), rays (n=42, 12%) and sharks (n=25, 7%).

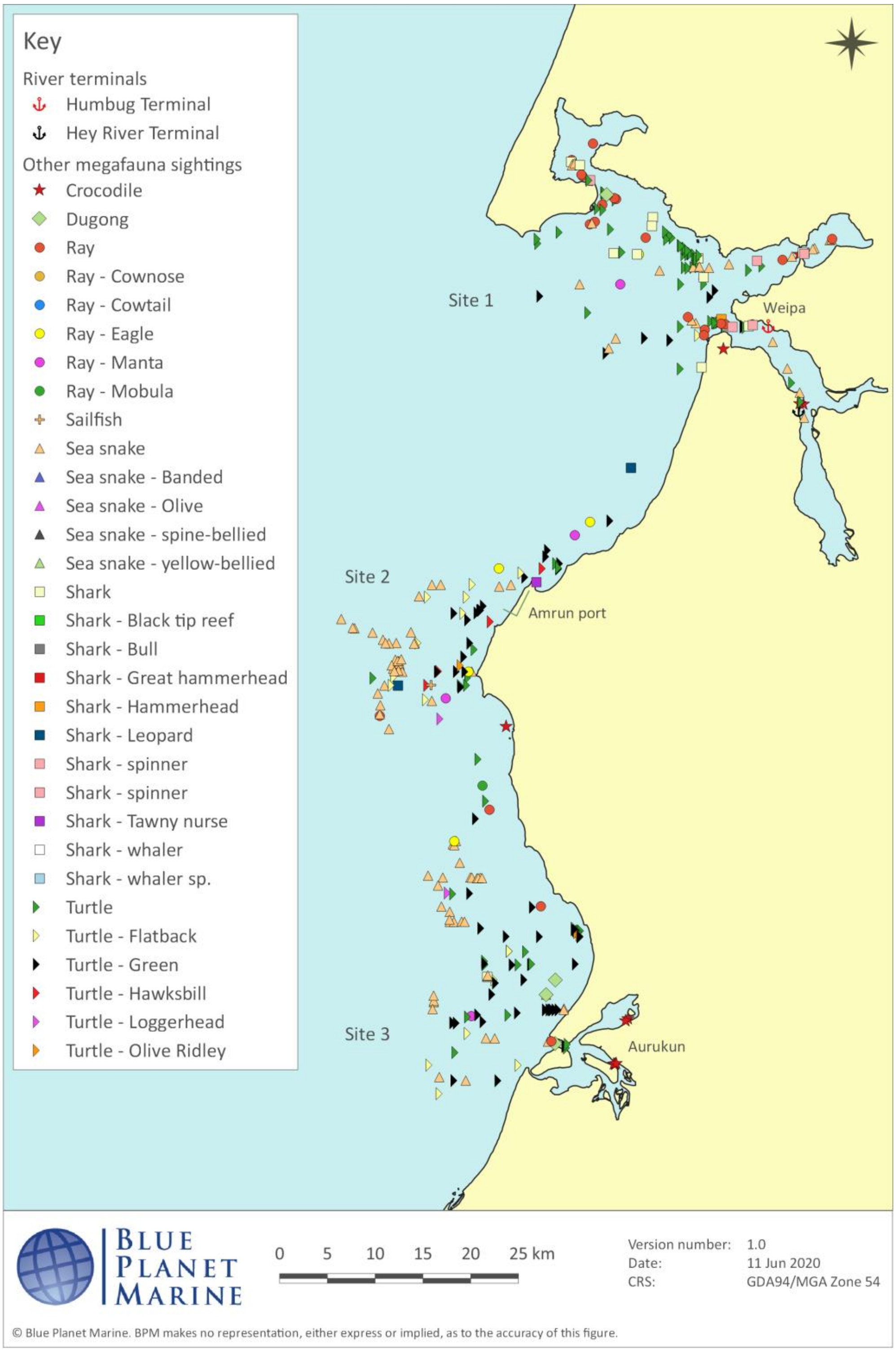

Figure 9. Location of other marine megafauna sightings during the 2019 dolphin survey.

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 (1,585 km) during the 2019 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 (LERs) and Survey Area Encounter Rates (SAERs) of dolphin species during the 2019 survey.

Species	Humpback	Inshore Bottlenose	Offshore Bottlenose	Snubfin	Spinner
Groups (individuals)	49 (185)	12 (70)	1 (3)	4 (18)	1 (17)
Mean LER (dolphins / km of transect)	0.12	0.04	0.002	0.01	0.01
Mean SAER (dolphins / km^2 of transect)	0.23	0.09	0.004	0.02	0.02

The overall LER for all dolphin species combined was 0.19 dolphins per km of transect for the 2019 survey. The overall SAER for all species was 0.37 dolphins per km^2 of effort. SAERs per grid cell are shown for humpback, bottlenose and snubfin dolphin species combined in Figure 10 (excludes spinner and offshore bottlenose), for humpback dolphins in Figure 11, for inshore bottlenose dolphins in Figure 12 and for snubfin dolphins in Figure 13. With only one on-effort sighting each of spinner dolphins and offshore bottlenose dolphins in 2019, SAERs were not mapped separately for these species.

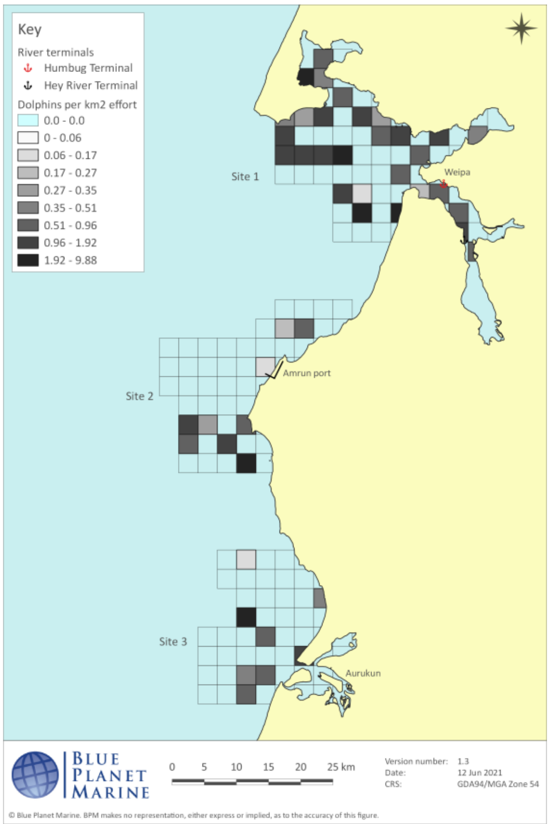

Figure 10. 2019 Survey Area Encounter Rates (dolphins per km^2 effort) for humpback, inshore bottlenose and snubfin dolphins combined.

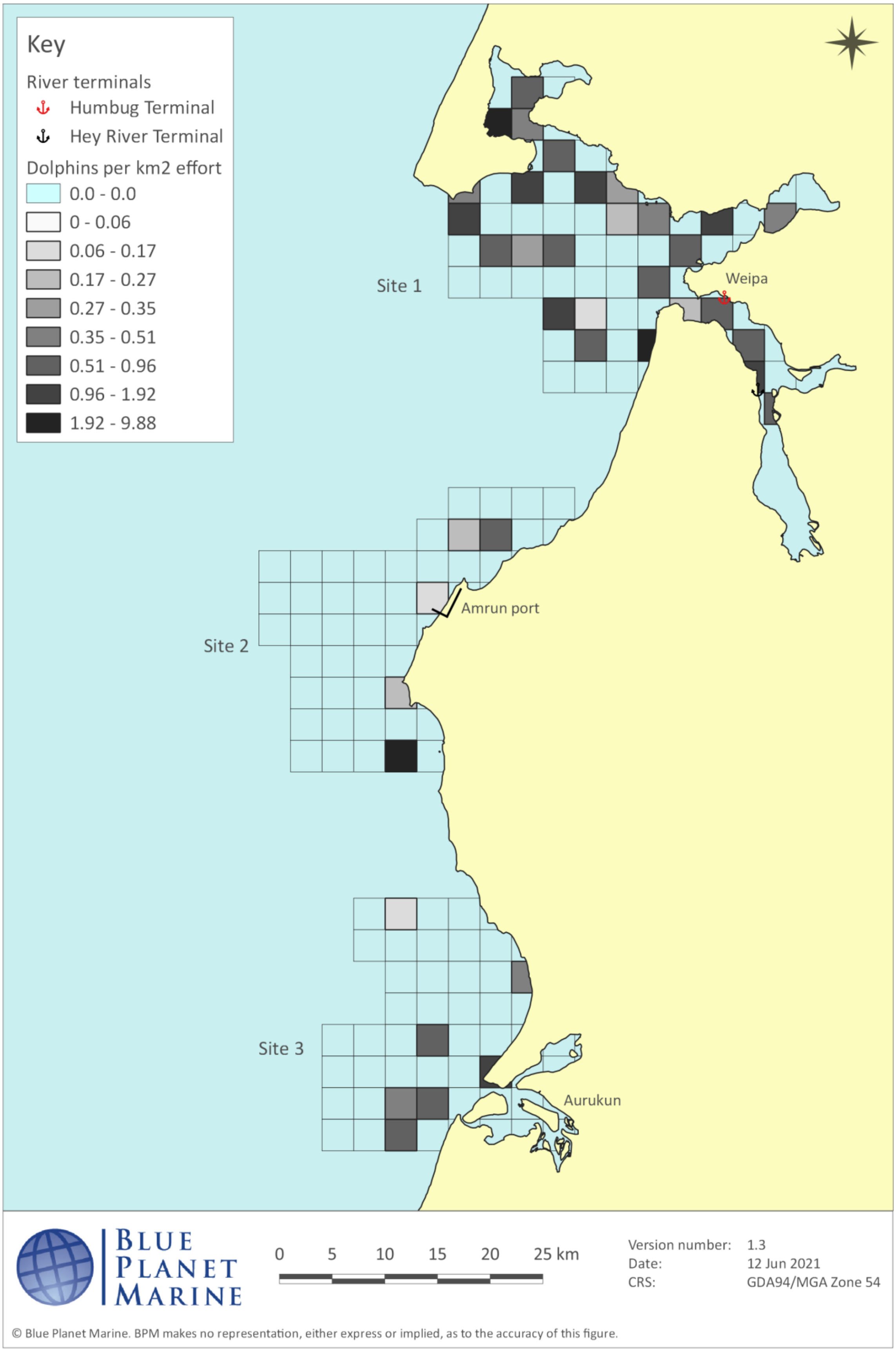

Figure 11. 2019 Survey Area Encounter Rates (dolphins per km^2 effort) for humpback dolphins.

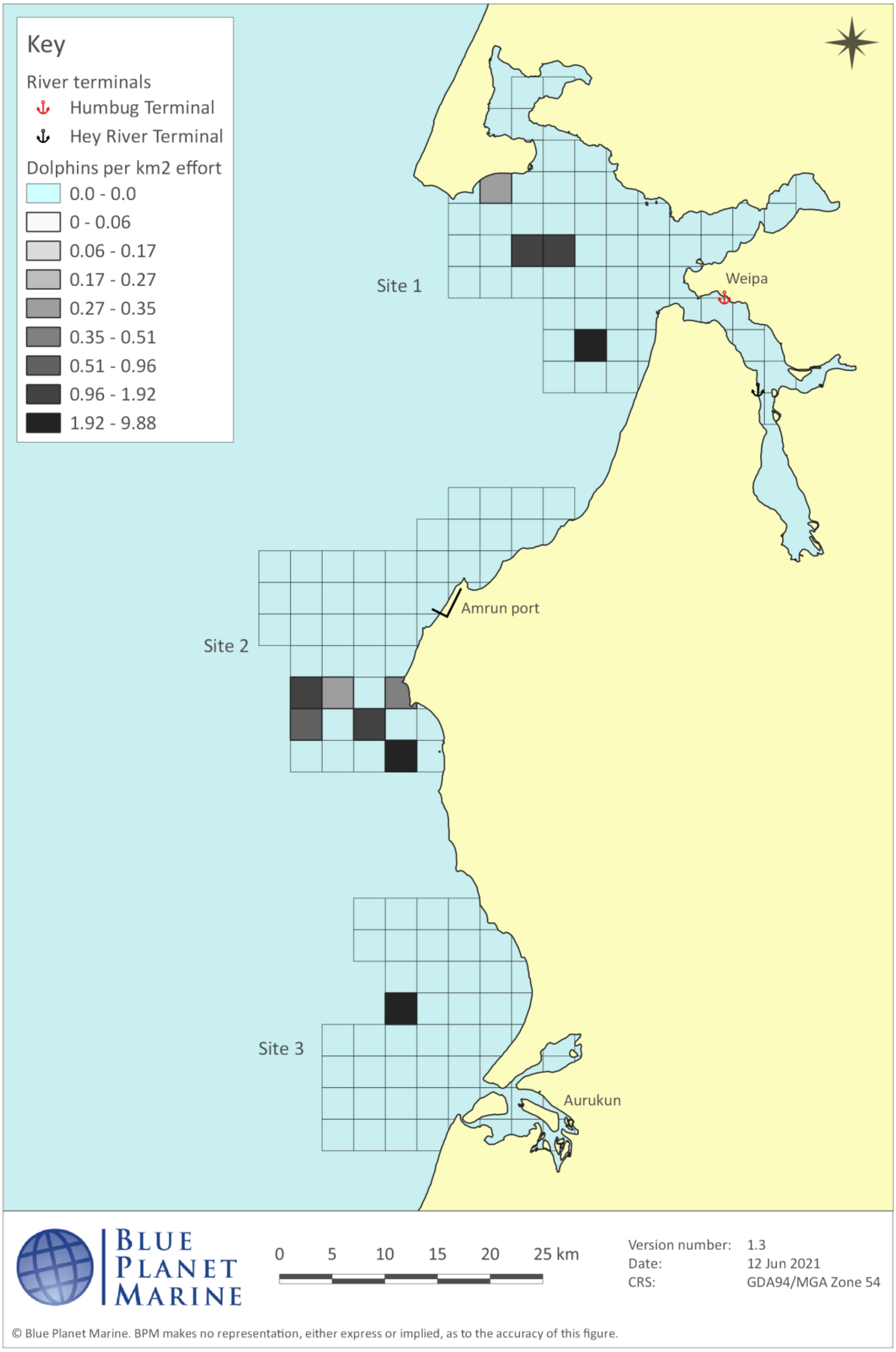

Figure 12. 2019 Survey Area Encounter Rates (dolphins per km^2 effort) for inshore bottlenose dolphins.

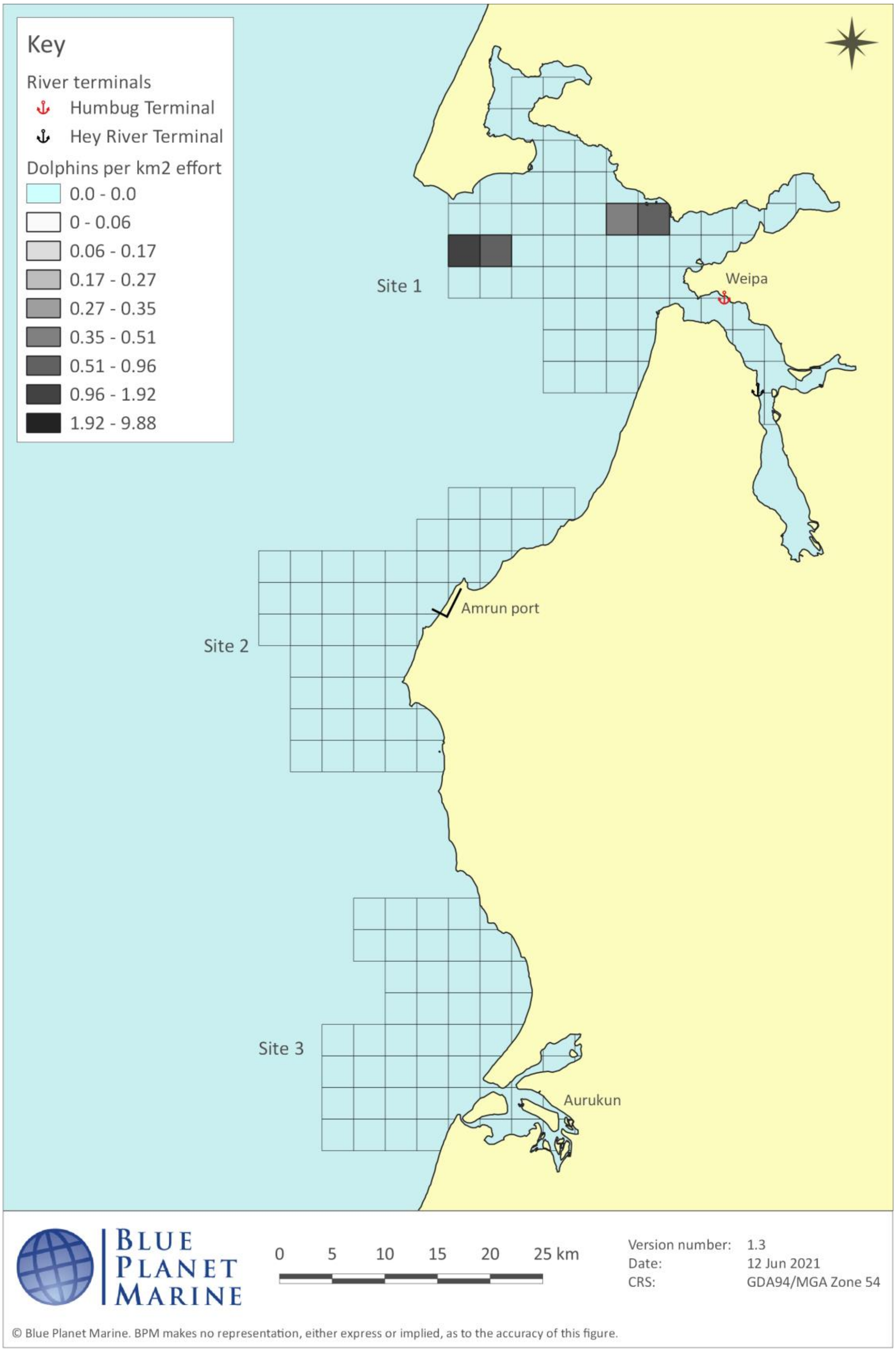

Figure 13. 2019 Survey Area Encounter Rates (dolphins per km^2 effort) for snubfin dolphins.

3.1.4 Identification and resight rates

At least one useable identification photograph (excluding unmarked individuals) was obtained from 87 (74%) of the 118 dolphin groups sighted in 2019. Identified individuals included:

- 124 humpback dolphins used in capture-recapture (CR) analyses, including:
  - 91 photographed in one secondary sample (SS), 29 in two SS, 4 in three SS and none photographed in all four SS;
- 67 bottlenose dolphins used in CR analyses, including:
  - 59 photographed in one SS, 6 photographed in two SS and 2 photographed in three SS.
- 36 snubfin dolphins used in CR analyses, including:
  - 20 photographed in one secondary sample (SS), 11 in two SS, 4 in three SS and 1 photographed in all four SS; and
- Six spinner dolphins:
  - All photographed on the same day (from two different groups).

The number of dolphins identified (IDs) per group ranged from 1 to 15 for humpback dolphins, 1 to 10 for bottlenose dolphins and 1 to 16 for snubfin dolphins. Example identification images are shown in Figure 14.

Figure 14. Identification images of dolphins photographed during the 2019 survey. Clockwise from top left: snubfin, humpback, bottlenose, spinner.

3.1.5 Abundance estimates

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

3.1.6 Individual dolphin movements

Sighting locations of humpback dolphins (n=41), bottlenose dolphins (n=12) and snubfin dolphins (n=19) photographed on more than one day during the 2019 survey are shown in Figure 15, Figure 16 and Figure 17 respectively. No dolphins were photographed at more than one site in 2019.

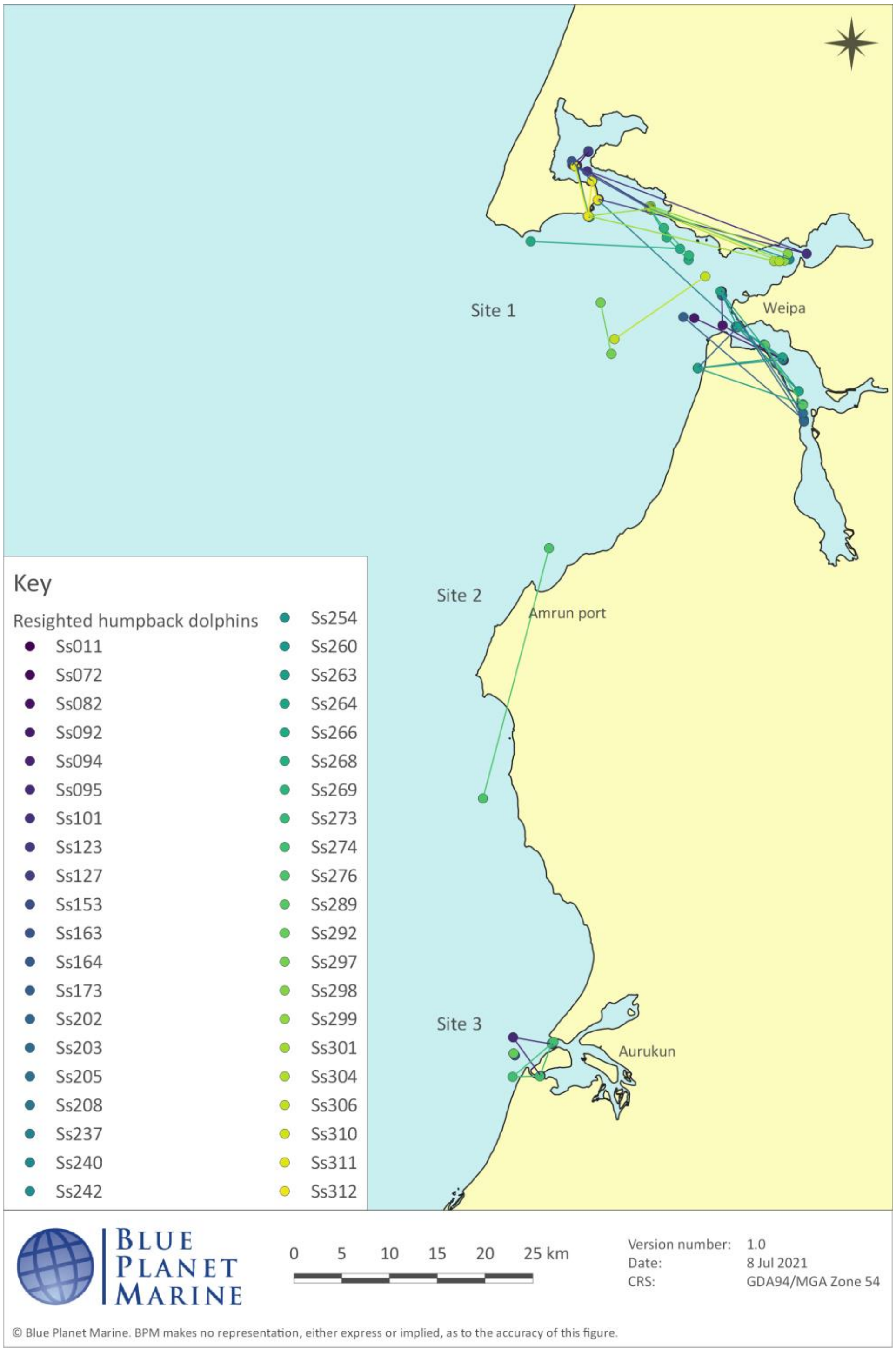

Figure 15. Sighting locations of 41 humpback dolphins photographed on more than one day during the 2019 survey. Interpolated lines drawn between sighting locations for each dolphin are "as the crow flies" and not intended to denote travel routes.

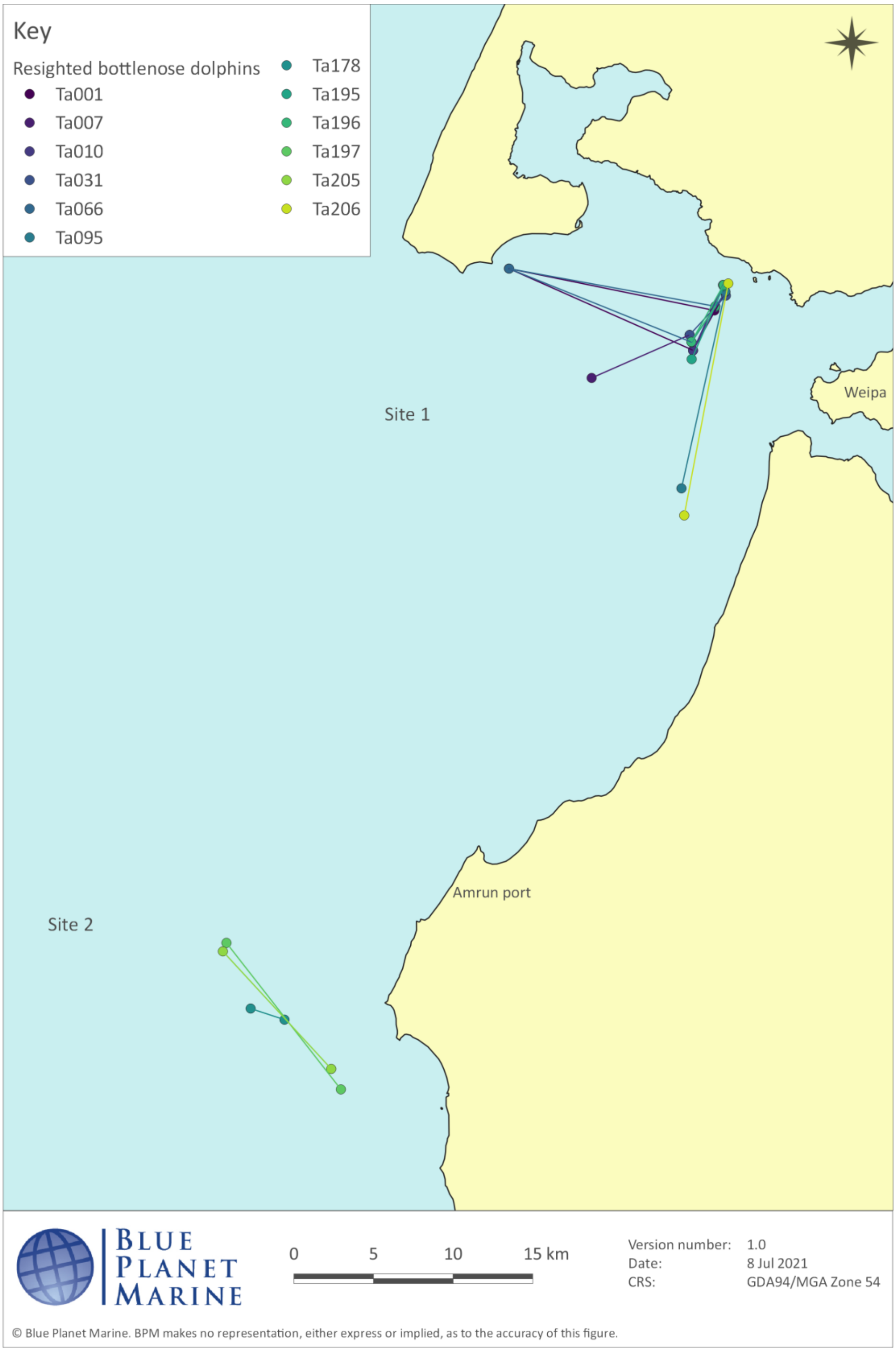

Figure 16. Sighting locations of 12 bottlenose dolphins photographed on more than one day during the 2019 survey. Interpolated lines drawn between sighting locations for each dolphin are "as the crow flies" and not intended to denote travel routes.

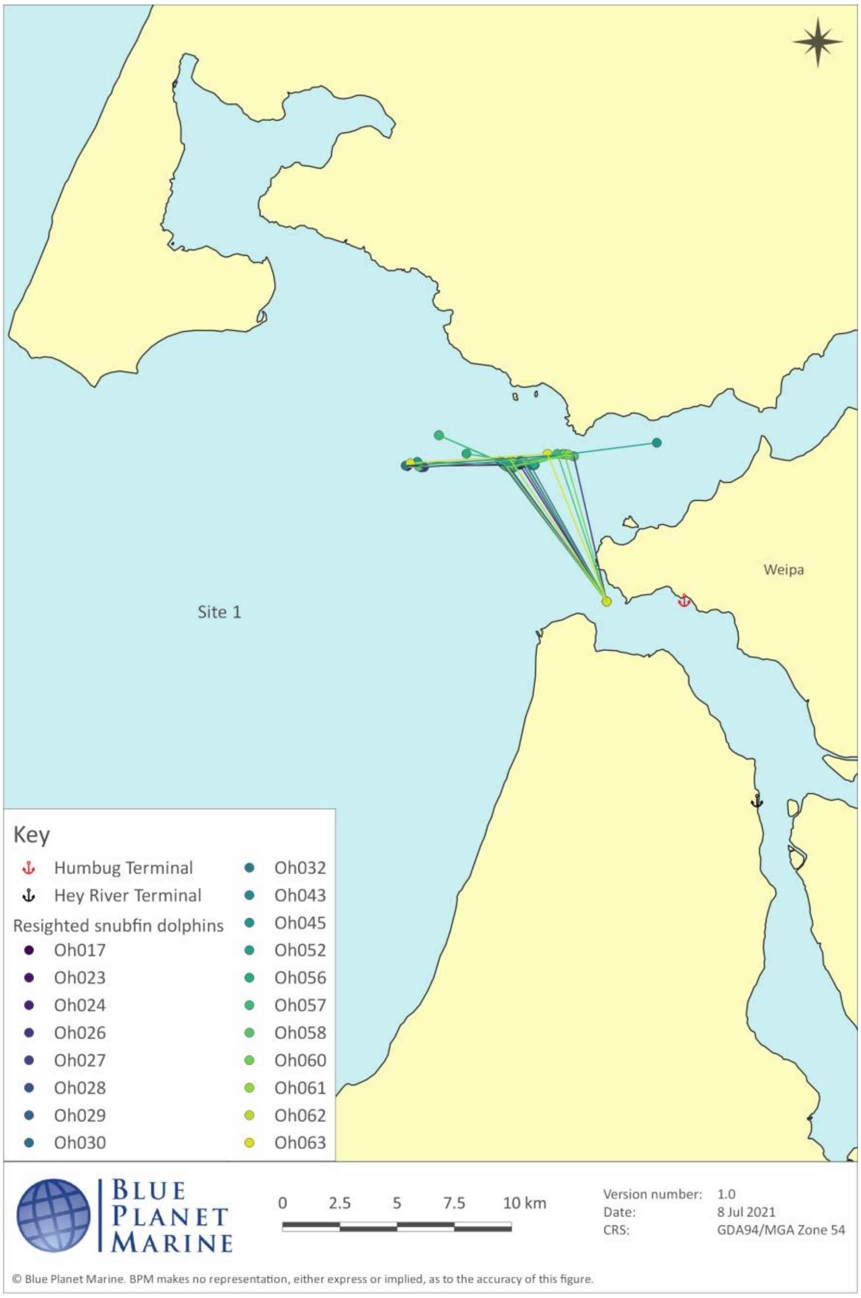

Figure 17. Sighting locations of 19 snubfin dolphins photographed on more than one day during the 2019 survey. Interpolated lines drawn between sighting locations for each dolphin are "as the crow flies" and not intended to denote travel routes.

3.1.7 Environmental parameters and habitat preferences

Dolphin sightings correlated closely with effort per moon and tide phase, with approximately 55.3% of the survey completed during spring tides and 58.5% of all sightings occurring during those tides. Conversely, ~44.7% of the survey was completed during neap tides and 41.5% of all sightings occurred during those tides.

Of the 118 groups sighted during the 2019 survey, 47.5% (n=56) occurred on a rising tide, with 41.5% on a falling tide (n=49), and 6.8% at low tide (n=8) and 4.2% (n=5) 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 5.

Table 5. Dolphin sightings and tidal states during the 2019 survey.

Site	Falling (%)	Low (%)	Rising (%)	High (%)
1	34 (28.8)	5 (4.2)	25 (21.2)	3 (2.5)
2	9 (7.6)	3 (2.5)	18 (15.3)	1 (0.8)
3	6 (5.1)	0	13 (11.0)	1 (0.8)
All sites	49 (41.5)	8 (6.8)	56 (47.5)	5 (4.2)

After separating mixed species groups into their component species, of all the humpback dolphin sightings in 2019 (n=84), 40 (47.6%) were on a falling tide, 36 (42.9%) on a rising tide, 5 (6.0%) at low tide and 3 (3.6%) at high tide. For bottlenose dolphins (n=29), 9 (31.0%) sightings were on a falling tide, 16 (55.2%) on a rising tide, 3 (10.3%) at low tide and 1 (3.4%) at high tide. For snubfin dolphins (n=11), 5 (45.5%) sightings were on a falling tide, 3 (27.3%) on a rising tide, 2 (18.2%) at low tide and 1 (9.1%) at high tide. Sightings of bottlenose, humpback and snubfin dolphins by tide state are shown in Appendix 1 (Figure 32, Figure 33 and Figure 34) respectively.

Sightings of snubfin dolphins (n=11) occurred at the shallowest mean depth of any species (7.1 m) during the 2019 survey, with humpback dolphins (n=84) sighted at a mean depth of 8.6 m and bottlenose dolphins (n=29) at 14.1 m. Summary statistics for depths at which dolphin sightings occurred during the 2019 survey are shown in Table 6. Summary statistics for other environmental parameters (temperature, salinity, turbidity and pH) recorded at dolphin sighting locations are shown in Table 7 for the 2019 survey. Temperature, salinity, pH and turbidity were not collected at sites 2 and 3 during the 2019 survey.

Table 6. Depth at sighting location of dolphin groups during the 2019 survey.

Species	Number of groups sighted	Depth at sighting location (m)		
		Mean (Std Dev)	Minimum	Maximum
Humpback	75	8.7 (±5.5)	1.0	26.8
Humpback/Inshore bottlenose	6	8.6 (±4.4)	3.7	16.1
Humpback/Snubfin	3	7.4 (±4.2)	4.0	12.1
Inshore bottlenose	20	16.3 (±7.0)	4.4	26.8
Inshore bottlenose/Spinner	1	23.7 (N/A)	23.7	23.7
Offshore bottlenose	1	18.6 (N/A)	18.6	18.6
Snubfin	6	7.9 (±3.0)	3.8	11.5
Snubfin/Inshore bottlenose	2	4.2 (±0.7)	3.7	4.7
Spinner	2	21.5 (±2.2)	19.9	23.0
Unidentified dolphin	2	10.8 (±5.6)	6.8	14.7
All dolphin species combined	118	10.3 (±6.5)	1.0	26.8

Table 7. Environmental parameters recorded at dolphin sighting locations for the 2019 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	75	28.1 (±0.7)	33.7 (±0.9)	3.3 (±2.9)	8.6 (±0.3)
Humpback/Inshore bottlenose	6	28.3 (±0.2)	32.5 (±0.3)	0.5 (±0.4)	8.6 (±0.1)
Humpback/Snubfin	3	27.6 (±0.1)	33.3 (±0.5)	3.1 (±3.2)	8.5 (±0.3)
Inshore bottlenose	20	27.5 (±1.1)	32.5 (±0.5)	0.7 (±0.1)	9.1 (±0.5)
Inshore bottlenose/Spinner	1	26.6 (N/A)	N/A	N/A	N/A
Offshore bottlenose	1	N/A	N/A	N/A	N/A
Snubfin	6	28.0 (±0.2)	33.3 (±0.2)	2.5 (±0.1)	8.6 (±0.3)
Snubfin/Inshore bottlenose	2	28.2 (±0.1)	33.0 (±0.2)	1.4 (±1.6)	8.5 (±0.1)
Spinner	2	N/A	N/A	N/A	N/A
Unidentified dolphin	2	27.9 (N/A)	33.2 (N/A)	4.4 (N/A)	8.3 (N/A)
All dolphin species combined	118	28.0 (±0.7)	33.5 (±0.9)	2.9 (±2.7)	8.6 (±0.3)

*Temperature, salinity, pH and turbidity were not collected at sites 2 and 3 during the 2019 survey

The primary behaviour of humpback dolphin groups observed during the 2019 survey is shown in Appendix 1 Figure 38, of bottlenose dolphin groups in Figure 39 and of snubfin dolphins in Figure 40.

3.2 2014-2019 Surveys combined

The survey dates for each of the 2014-2019 surveys are shown in Table 8. Over the five years of survey to date, a total of 1,617 hours and 30 minutes have been spent on the water by all vessels, including 671 hours and 58 minutes on effort. The total distance travelled by all vessels was 19,218 km, including 8,221 km on effort.

Table 8. 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
5	11 – 25 October 2019

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 2019 is shown in Table 9. 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, 72% in 2018 and 44% in 2019. The mean sea state conditions when sighting a dolphin group for each survey is shown in Table 10.

Table 9. Percentage of total on effort distance travelled at each Beaufort sea state during the 2014-2019 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%
2019	0	11%	33%	53%	4%
Mean	1%	17%	40%	38%	4%

Table 10. Mean sea state conditions at time of sighting of dolphin groups for each year of survey from 2014-2019.

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)
2019	118	2.32 (±0.92)
Total	467	2.06 (±0.93)

3.2.2 Sightings

3.2.2.1 Dolphins

An overview of all dolphin sightings (including both on and off effort sightings) from 2014-19 combined is shown in Figure 18. Sightings for 2019 are shown separately in Figure 8 and each year from 2014-2018 is shown separately in Appendix 1 (Figure 31). Details of sightings by species and year are shown in Table 11.

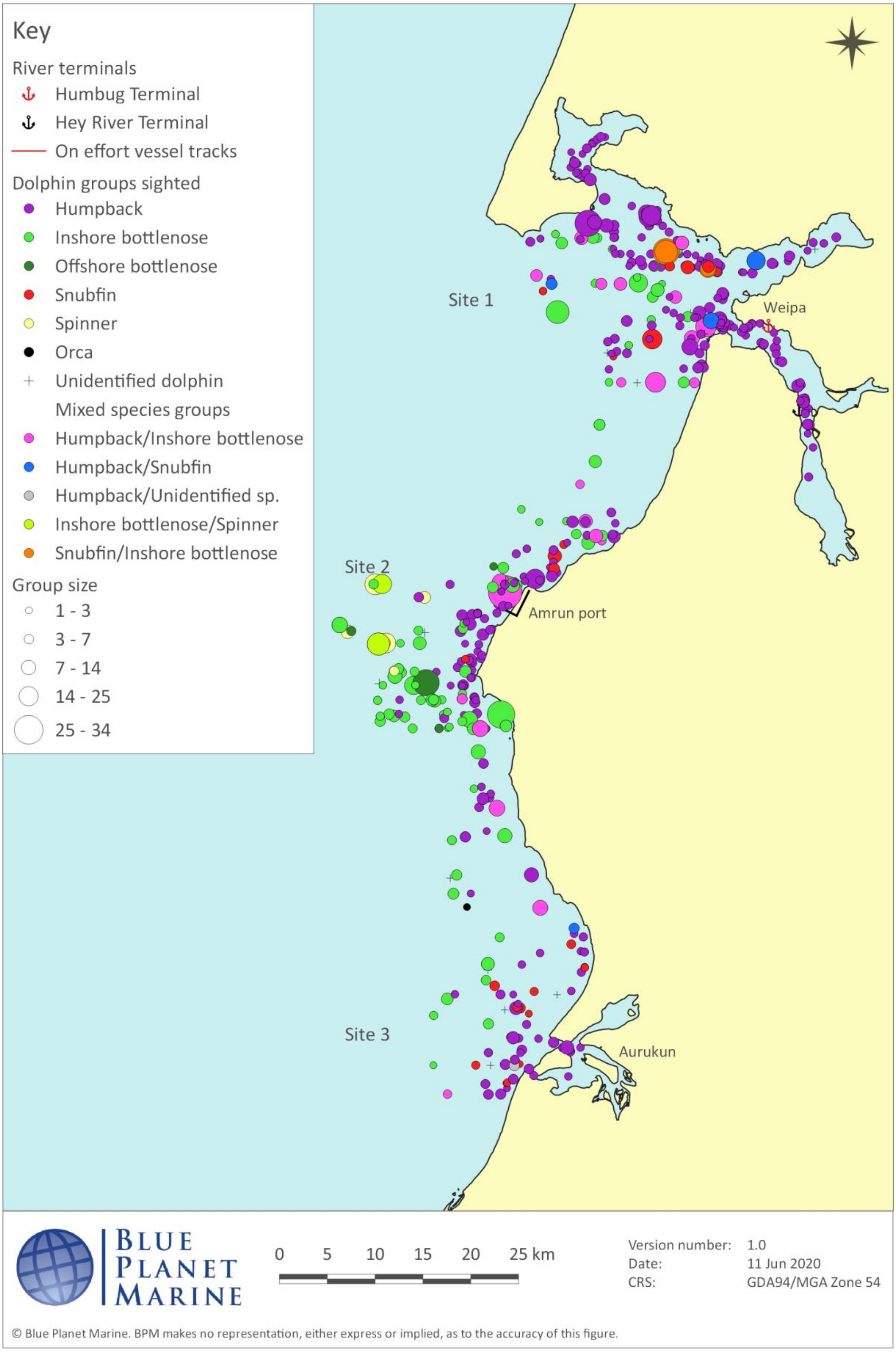

Figure 18. Overview of dolphin sightings and group sizes for the 2014-2019 surveys combined.

Table 11. Dolphin sightings by species during the 2014-2019 surveys. Mixed species groups are shown separately and have not been incorporated into the single species totals.

Species	2014		2016		2017		2018		2019		Total	
	Groups	Animals	Groups	Animals	Groups	Animals	Groups	Animals	Groups	Animals	Groups	Animals
Humpback	78	278	43	140	49	200	52	256	75	271	297	1,145
Inshore bottlenose	17	140	9	66	18	104	23	135	20	106	87	551
Offshore bottlenose	1	4	1	2	1	25	0	0	1	3	4	34
Orca	0	0	0	0	0	0	1	1	0	0	1	1
Snubfin	6	16	2	14	4	10	4	34	6	32	22	106
Spinner	1	9	0	0	3	29	0	0	2	22	6	60
Unidentified dolphin	5	7	4	7	3	3	3	6	2	2	17	25
Humpback / Inshore bottlenose	2	20	2	8	8	92	4	40	6	57	22	217
Humpback / Snubfin	1	5	0	0	1	5	1	5	3	33	6	48
Humpback / Unidentified dolphin	0	0	0	0	0	0	1	5	0	0	1	5
Inshore bottlenose / Spinner	0	0	0	0	0	0	1	16	1	20	2	36
Snubfin / Inshore bottlenose	0	0	0	0	0	0	0	0	2	38	2	38
Total	111	479	59	230	87	468	90	498	118	584	467	2,266

Further details of dolphin sightings from the 2014-2019 surveys are shown in Appendix I, including:

1) On and off effort sightings of each species after separating mixed groups into their component species (Table 30 - Table 34);
2) Sightings by species for each survey at each site (Tables 35-37);
3) A summary of age classes by species for 2014-2019 sightings combined (Table 38);
4) A summary of group sizes by species for 2014-2019 sightings combined (Table 39); and
5) Mean group size of humpback dolphins (Table 40), bottlenose dolphins (Table 41) and snubfin dolphins (Table 42) 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 12. Sighting locations of groups containing at least one humpback dolphin calf are shown in Figure 19, at least one bottlenose dolphin calf in Figure 20, and at least one snubfin dolphin calf in Figure 21.

Table 12. Summary of dolphin groups sighted with at least one humpback, bottlenose and snubfin dolphin calf present during the 2014-2019 surveys.

Target species	Year	Groups with target species present	Groups with target species calf present	Percentage with target species calf present
Humpback	2014	81	9	11.1
	2016	45	1	2.2
	2017	58	9	15.5
	2018	58	20	34.5
	2019	84	15	17.9
	Total	326	54	16.6
Inshore bottlenose	2014	19	2	10.5
	2016	11	2	18.2
	2017	26	8	30.8
	2018	28	15	53.6
	2019	29	9	31.0
	Total	113	36	31.9
Snubfin	2014	7	0	0
	2016	2	1	50.0
	2017	5	2	40.0
	2018	5	2	40.0
	2019	11	0	0
	Total	30	5	16.7

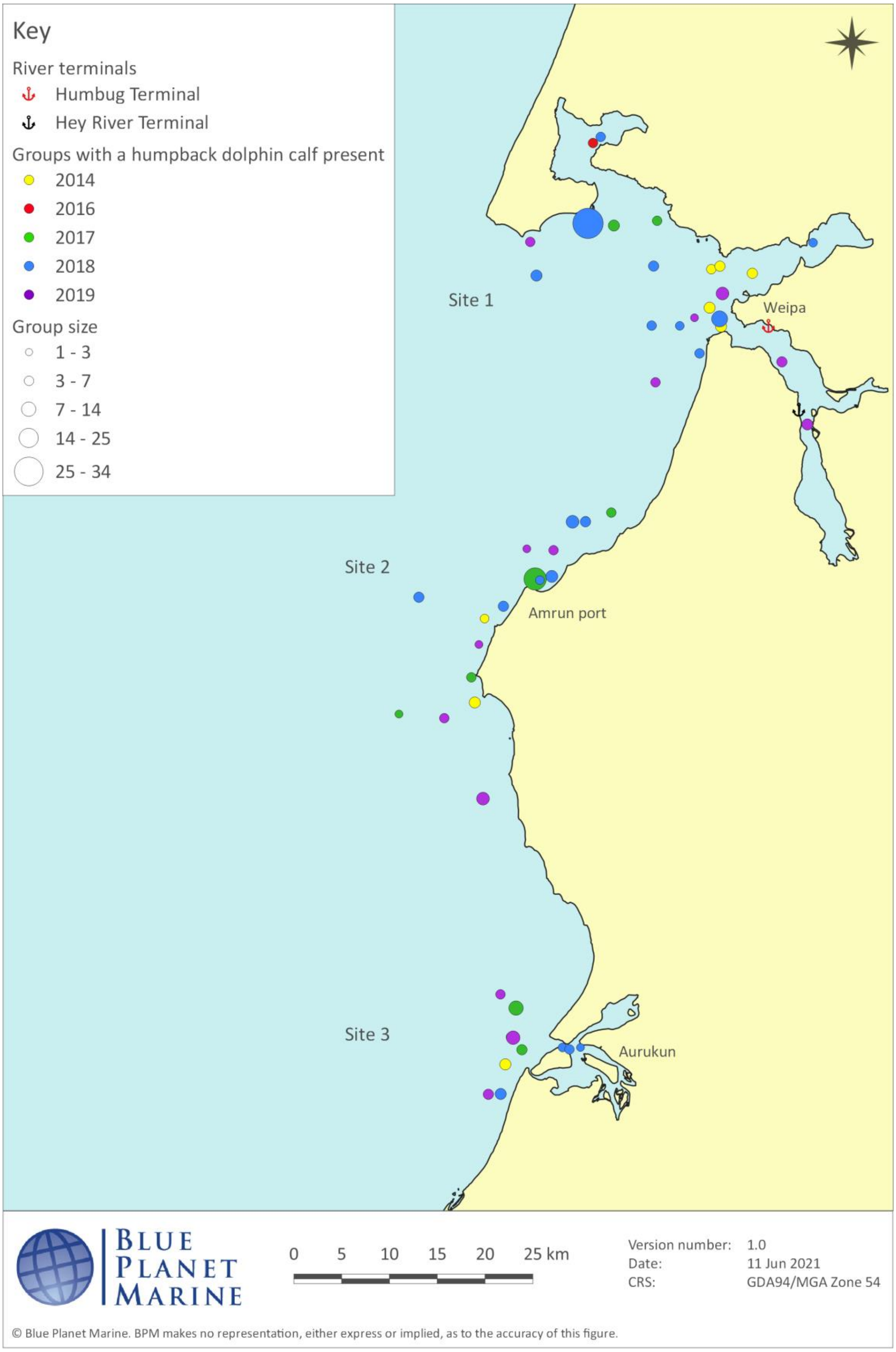

Figure 19. Sighting locations of groups with at least one humpback dolphin present during the 2014-2019 surveys.

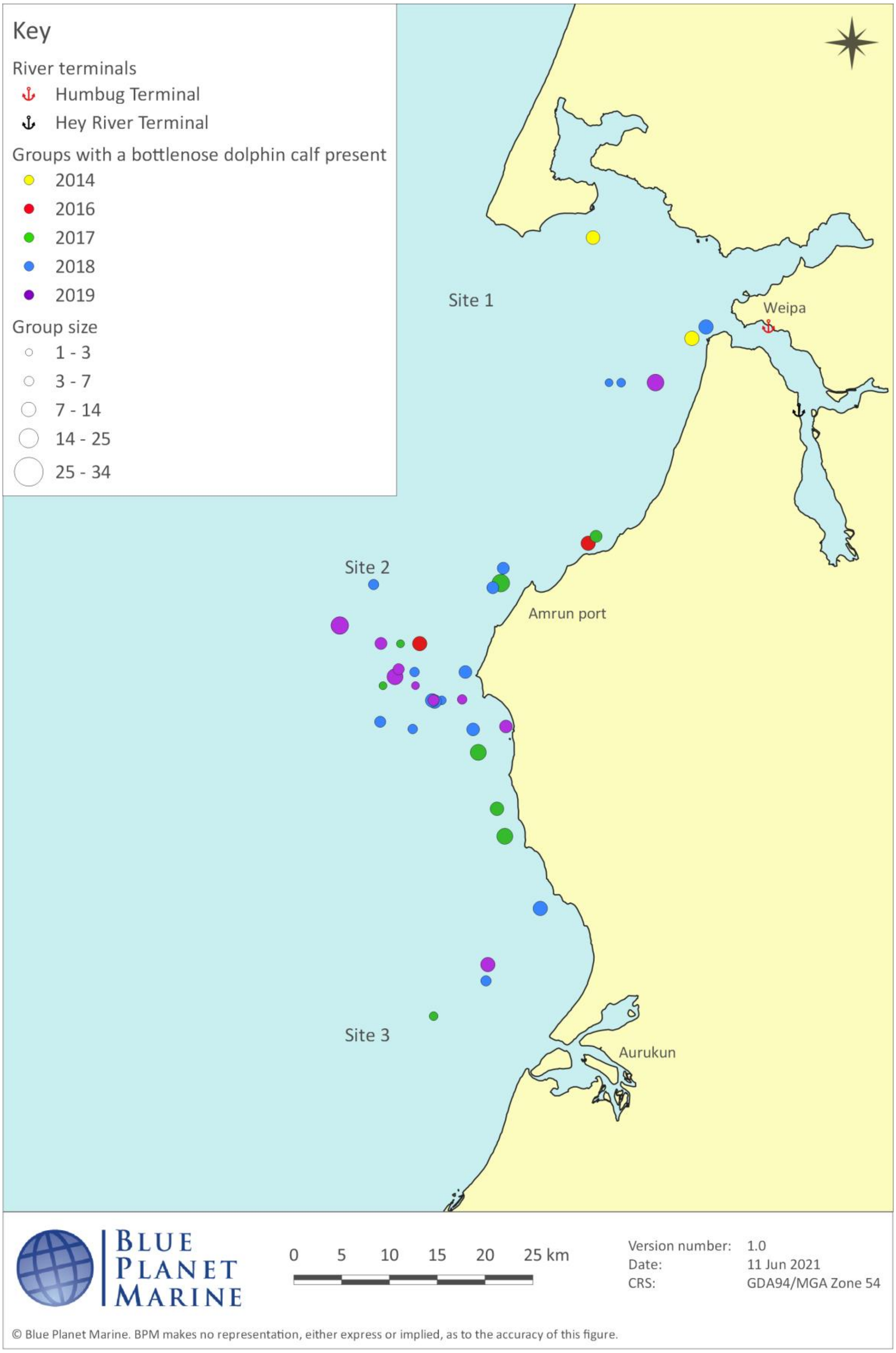

Figure 20. Sighting locations of groups with at least one bottlenose dolphin present during the 2014-2019 surveys.

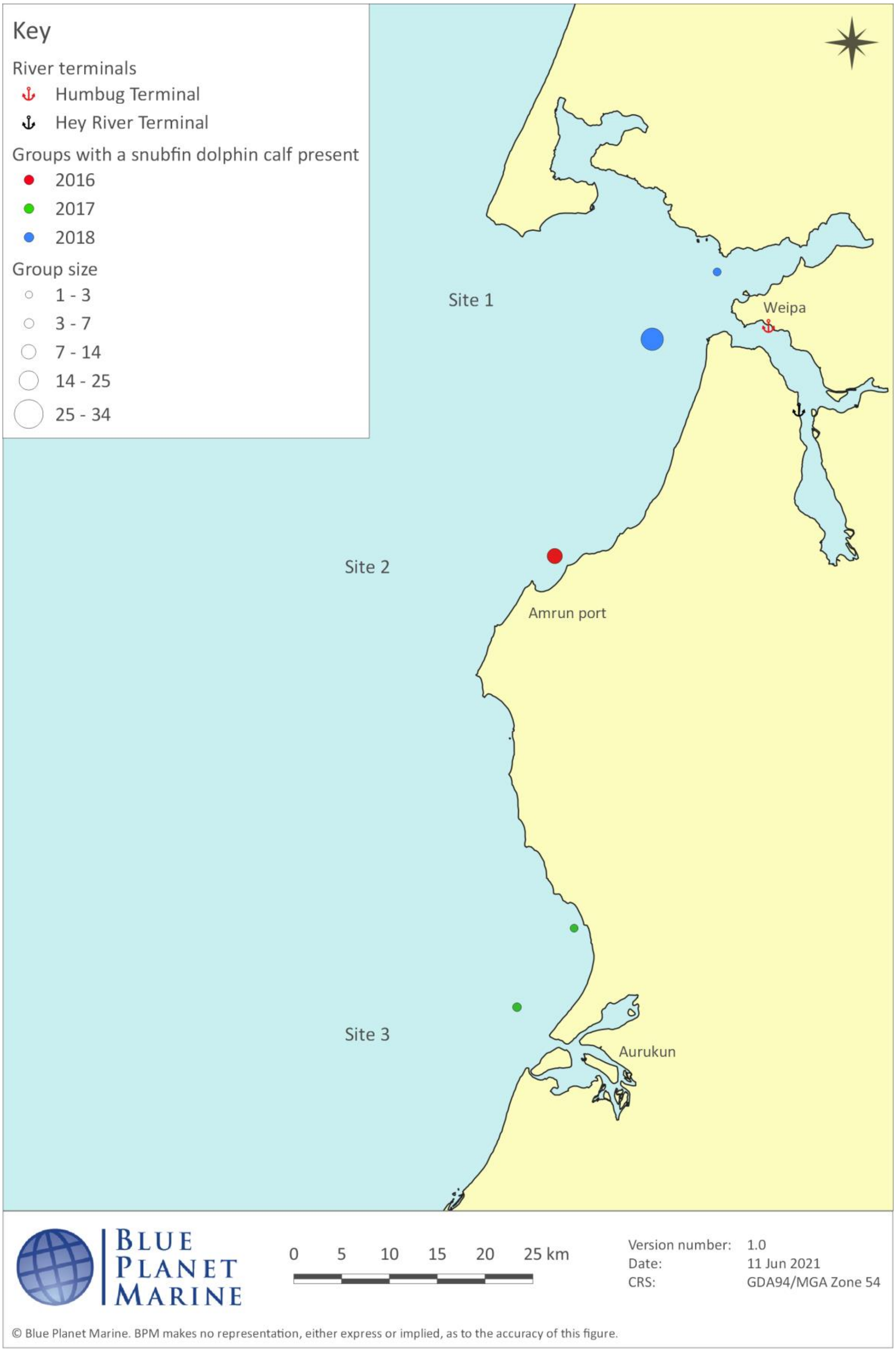

Figure 21. Sighting locations of groups with at least one snubfin dolphin present during the 2014-2019 surveys.

3.2.2.2 Non-dolphins

A summary of other marine megafauna sightings for each year of the survey is shown in Table 13.

Table 13. Summary of non-dolphin marine megafauna sightings during the 2014 to 2019 surveys.

Species	Site	2014	2016	2017	2018	2019	2014-2019 Total
Crocodile	1	2	0	0	1	4	7
	2	0	0	0	0	1	1
	3	1	2	1	0	7	11
	Transit	0	0	0	0	0	0
	Species total	3	2	1	1	12	19
Dugong	1	1	0	0	1	2	4
	2	4	0	0	2	0	6
	3	4	1	2	0	4	11
	Transit	0	0	0	0	0	0
	Species total	9	1	2	3	6	21
Ray	1	21	10	14	13	27	85
	2	3	3	0	4	6	16
	3	6	7	25	7	4	49
	Transit	1	0	0	0	5	6
	Species total	31	20	39	24	42	156
Sea snake	1	33	29	44	48	27	181
	2	44	18	29	54	36	181
	3	13	11	21	26	33	104
	Transit	1	0	0	0	4	5
	Species total	91	58	94	128	100	471
Shark	1	6	14	17	10	21	68
	2	2	2	8	15	2	29
	3	2	3	25	6	1	37
	Transit	1	0	1	0	1	3
	Species total	11	19	51	31	25	137
Turtle	1	72	27	32	48	64	243
	2	44	20	33	52	40	189
	3	39	70	54	47	59	269
	Transit	3	2	1	0	3	9
	Species total	158	119	120	147	166	700
Sailfish	2	0	0	1	0	0	1
	Species total	0	0	1	0	0	1
All species	Total	303	219	308	334	352	1516

3.2.3 Dolphin encounter rates

A comparison of overall encounter rates (LERs and SAERs) of humpback dolphins for the five years of the survey are shown in Table 14, and bottlenose dolphins in Table 15.

Table 14. Comparison of encounter rates of humpback dolphins from the 2014-2019 dolphin surveys. Note: 2014 rates were recalculated from GHD (2015) to include only ON effort sightings 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
2019	49	185	1585	0.12	793	0.23

Table 15. Comparison of encounter rates of bottlenose dolphins from the 2014-2019 dolphin surveys. Note: 2014 rates were recalculated from GHD (2015) to include only ON effort sightings 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
2019	12	70	1585	0.04	793	0.09

SAERs per grid cell for each year of survey from 2014-2019 are shown for humpback dolphins in Figure 22 and bottlenose dolphins in Figure 23. With only 14 on effort sightings of snubfin dolphins during the five surveys from 2014-2019, encounter rates for this species were not mapped separately for each year. SAERs for all five years of snubfin dolphin data combined are shown in Figure 24.

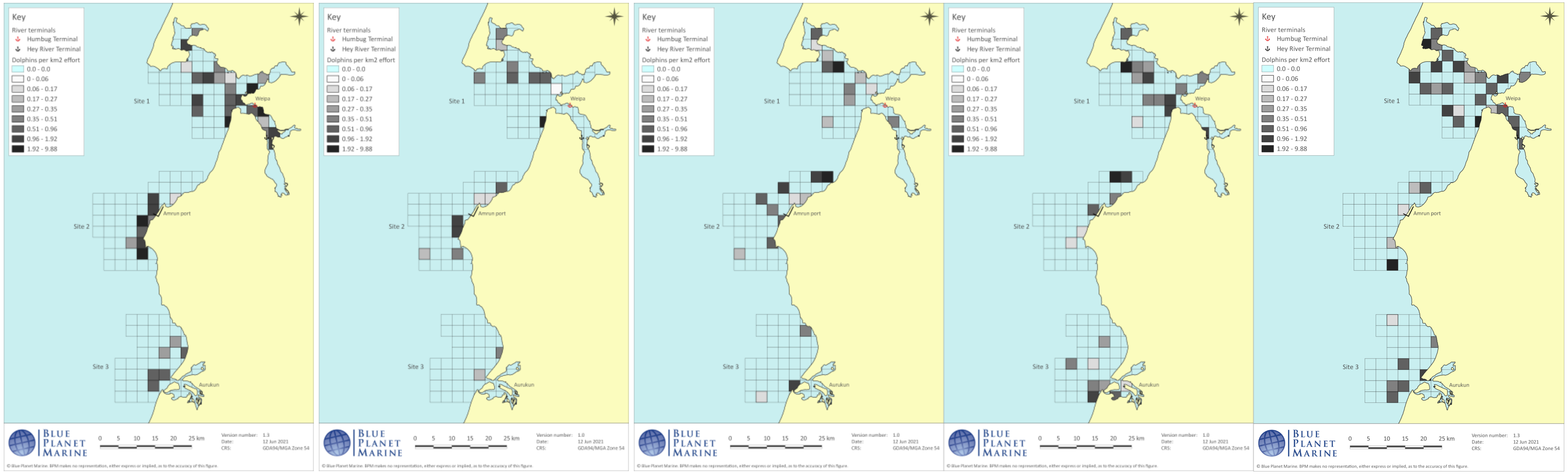

Figure 22. Survey Area Encounter Rates of humpback dolphins (per km^2 effort) for each year of survey (L to R: 2014, 2016, 2017, 2018, 2019).

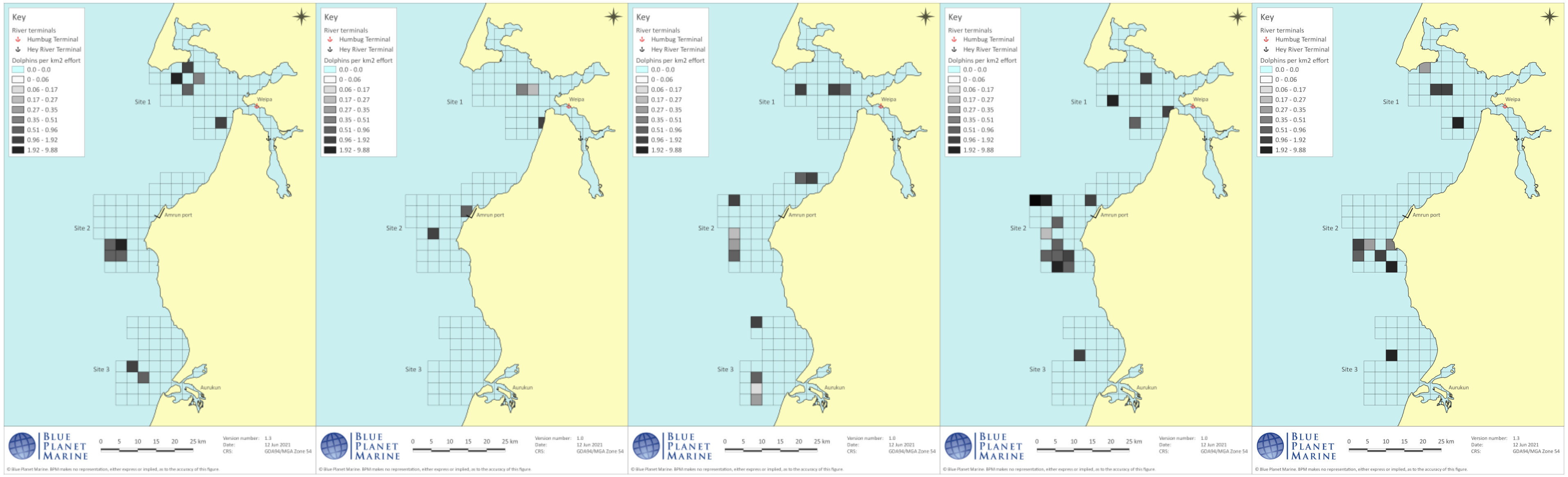

Figure 23. Survey Area Encounter Rates of inshore bottlenose dolphins (per km^2 effort) for each year of survey (L to R: 2014, 2016, 2017, 2018, 2019).

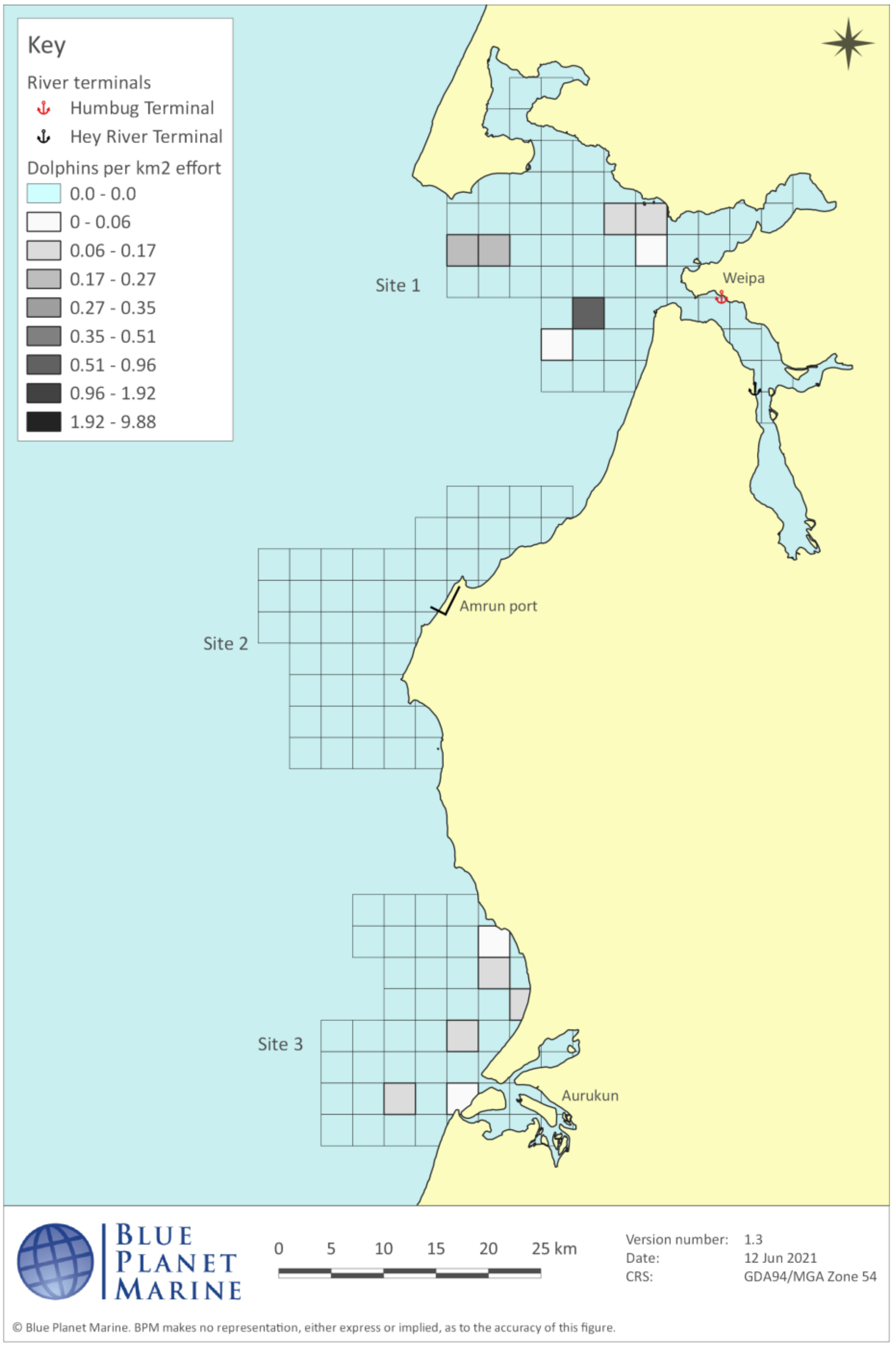

Figure 24. Survey Area Encounter Rates of snubfin dolphins (per km^2 effort) during the five surveys combined (2014, 2016, 2017, 2018 and 2019).

3.2.4 Individual identification and resight rates

Combining all photo-identification data from the five primary samples in 2014, 2016, 2017, 2018 and 2019, the number of new humpback, snubfin and bottlenose dolphins identified for each day of the survey is shown in Figure 25.

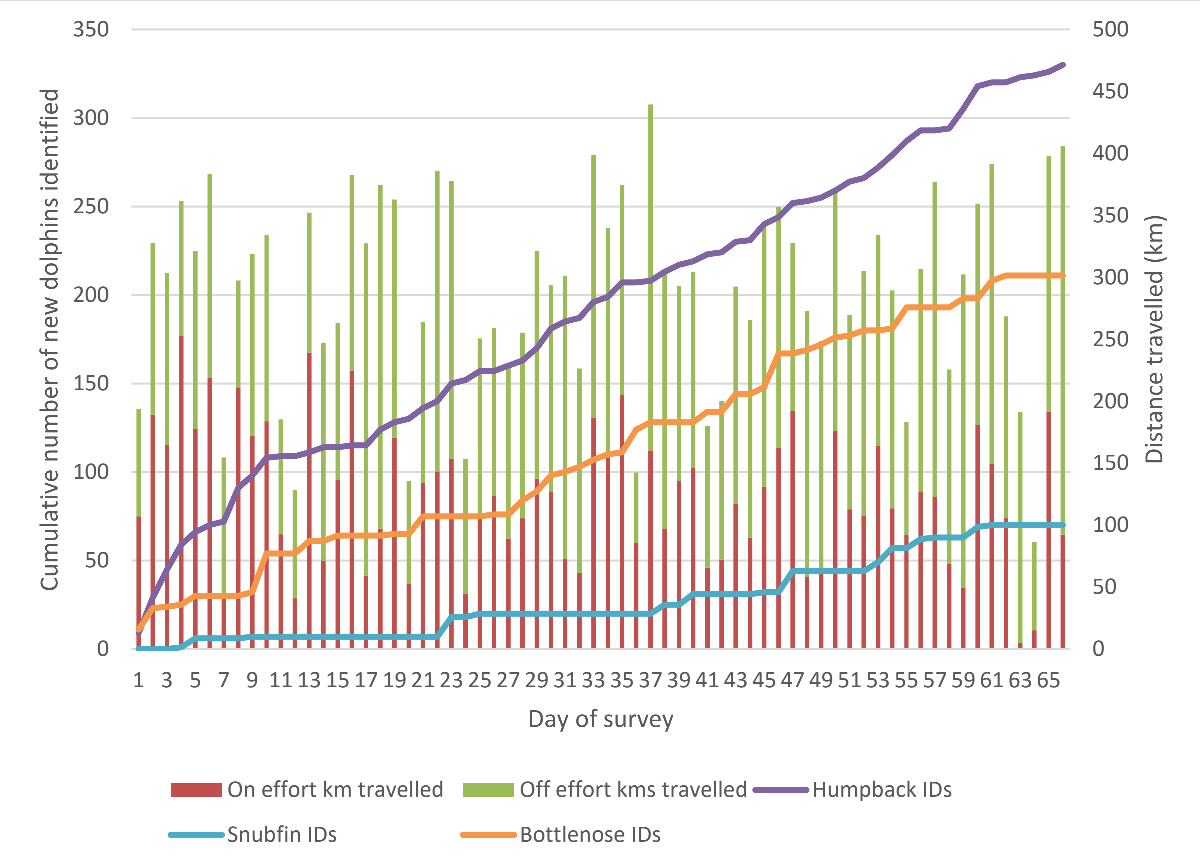

Figure 25. Cumulative number of new identifications (including on and off effort) of humpback, snubfin and bottlenose dolphins for each day of survey from 2014-2019 (2014: Days 1-11, 2016: Days 12-24, 2017: Days 25-37, 2018: Days 38-51 and 2019: Days 52-66).

Restricting the dataset to images of sufficient photo quality for Capture-Recapture (CR) analysis, the number of years individual humpback, bottlenose and snubfin dolphins were captured (i.e. photographed) is shown in Table 16. The highest number of secondary samples an individual dolphin was captured in was eight (out of the 20 secondary samples conducted over the four years) (Table 17).

Table 16. Number of years in which individual humpback, bottlenose and snubfin dolphins were captured from the five primary samples surveyed from 2014-2019.

Number of years captured	Individual humpback dolphins (%)	Individual bottlenose dolphins (%)	Individual snubfin dolphins (%)
1	226 (68%)	151 (72%)	36 (75%)
2	72 (22%)	41 (19%)	12 (25%)
3	26 (8%)	13 (6%)	0
4	6 (2%)	3 (1.4%)	0
5	0	3 (1.4%)	0
Total	330 (100%)	211 (100%)	48 (100%)

Table 17. Number of secondary samples in which individual humpback, bottlenose and snubfin dolphins were captured from the 20 secondary samples surveyed across 2014-2019.

Number of secondary samples captured	Individual humpback dolphins (%)	Individual bottlenose dolphins (%)	Individual snubfin dolphins (%)
1	179 (54%)	143 (68%)	28 (58%)
2	84 (25%)	41 (19%)	9 (19%)
3	36 (11%)	14 (7%)	7 (15%)
4	15 (5%)	5 (2%)	4 (8%)
5	10 (3%)	5 (2%)	0
6	5 (1.5%)	2 (1%)	0
7	0	0	0
8	1 (0.3%)	1 (0.5%)	0
Total	330 (100%)	211 (100%)	48 (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), 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 five years 2014, 2016, 2017, 2018 and 2019 in Table 18.

Table 18. Number of humpback dolphin individuals and captures for the 2014-2019 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
2019	84	14	26	124	115	15	31	161

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, 2018 and 2019 than for 2016 and 2017. Consequently, the 2014, 2018 and 2019 data contributed more information to the models than the 2016 and 2017 data.

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 0.428 for the overall test of lack of fit (overdispersion). None of the three component tests was significant (all p>0.166), 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 19. The estimated total population sizes are also shown based on an estimate of 0.88 (SE = 0.013) of the population being distinctively marked.

Table 19. 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	0.69	0.02	0.65	0.73
$\gamma'' = \gamma'$ All intervals	0.01	0.003	0.01	0.02
p 2014_1	0.24	0.02	0.21	0.29
p 2014_2	0.13	0.01	0.11	0.16
p 2014_3	0.23	0.02	0.19	0.27
p 2014_4	0.16	0.01	0.14	0.19
p 2016_1	0.01	0.00	0.01	0.02
p 2016_2	0.02	0.00	0.01	0.03
p 2016_3	0.12	0.01	0.10	0.15
p 2016_4	0.14	0.01	0.11	0.17
p 2017_1	0.08	0.01	0.06	0.12
p 2017_2	0.12	0.02	0.08	0.18
p 2017_3	0.18	0.03	0.13	0.26
p 2017_4	0.03	0.01	0.02	0.04
p 2018_1	0.16	0.02	0.13	0.20
p 2018_2	0.18	0.02	0.14	0.23
p 2018_3	0.28	0.03	0.23	0.33
p 2018_4	0.20	0.02	0.17	0.24
P 2019_1	0.16	0.02	0.13	0.20
P 2019_2	0.16	0.02	0.13	0.19
P 2019_3	0.24	0.02	0.19	0.28
P 2019_4	0.20	0.02	0.17	0.24
N Marked 2014	188	14	165	220
N Marked 2016	213	31	163	287
N Marked 2017	213	31	164	288
N Marked 2018	170	16	145	208
N Marked 2019	216	18	187	259
N Total 2014	214	16	184	248
N Total 2016	242	36	182	322

Parameter	Estimate	SE	LCI	UCI
N Total 2017	242	35	182	322
N Total 2018	193	18	161	231
N Total 2019	245	21	208	290

Coefficients of variation (CVs) of the total population estimates were 0.08, 0.15, 0.15, 0.09 and 0.09 for the years 2014, 2016, 2017, 2018 and 2019, respectively. All these estimates meet the 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, 2018 and 2019 in Figure 26.

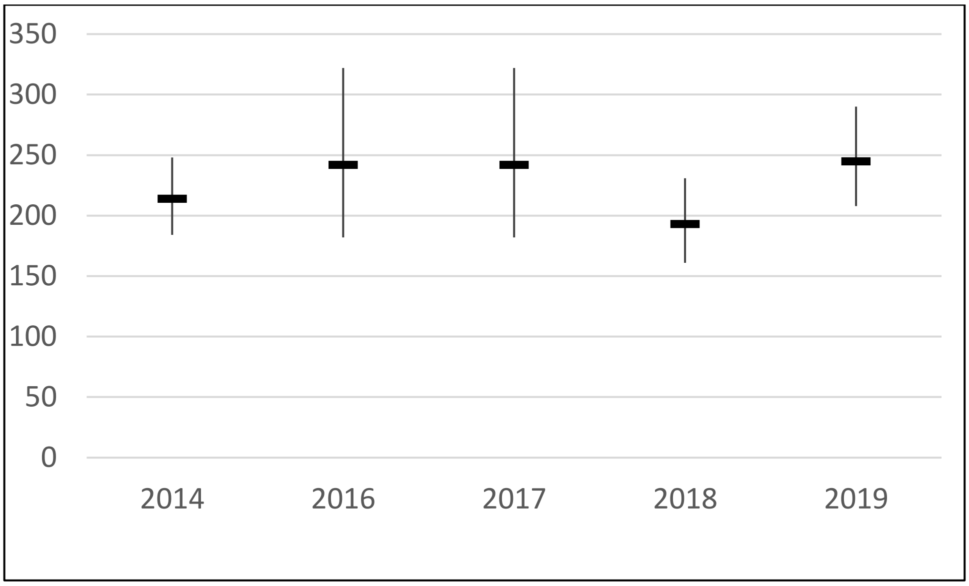

Figure 26. Estimated number of individual humpback dolphins present at all sites combined (Weipa, Boyd Point and Aurukun) during the 2014, 2016, 2017, 2018 and 2019 sampling periods with 95% confidence interval.

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 five years 2014, 2016, 2017, 2018 and 2019 in Table 20.

Considering the sites separately, relatively few individuals were captured and, with few exceptions, very few individuals were captured more than once. No individuals were captured more than once in at least one year at every site (i.e. for every site, there was at least one year with no recaptures). The data for all sites combined were used for the analysis. Although only one individual was captured more than once within-season in the years 2016 and 2018, with the 2019 data, there may now be sufficient data to obtain reasonably reliable estimates.

There were insufficient data to estimate apparent survival or temporary emigration separately for each year. A typical response would be to model these parameters as constant over all years. This was inconsistent with the pattern of abundance estimates over the five years however: abundance increased steadily from 2014 to 2018 but there was a sharp decline of more than 1/3rd from 2018 to 2019 suggesting a decline in apparent survival and increased emigration from the area after 2018. Consequently, some models were fitted with apparent survival constant between 2014 and 2018 and separately following 2018.

Table 20. 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
2019	25	38	4	67	33	40	4	77

The temporary emigration parameters, γ'' and γ', were initially fitted as equal and constant over years but the estimates were trivially small (zero to several decimal places), and models were refitted with these parameters fixed at zero.

Capture probabilities were fitted as varying over all primary and secondary samples.

The goodness of fit test from U-CARE indicated a poor fit of the data to the model with a significant p-value (p=0.032) for the overall test of lack of fit (overdispersion). An adjustment factor ($\hat{c}$) was calculated as $\hat{c} = \chi^2 / df = 16.82 / 8 = 2.103$ and applied to the fitted models. This means that model comparisons were made in terms of $QAIC_c$ rather than AIC_c.

Parameter estimates were interpreted only for the two models that had temporary emigration fixed at zero, one with constant apparent survival and one with a separate estimate following 2018. The $QAIC_c$ weights were 61% and 39% for these two models respectively so model averaging was used to derive parameter estimates from these models.

Model averaged parameter estimates, their standard errors and 95% confidence intervals are reported in Table 21. The estimated total population sizes are also shown based on an estimate of 0.89 (SE = 0.016) of the population being distinctively marked. Estimates of the total population in all three sites combined, with their 95% confidence intervals, are plotted for the years 2014, 2016, 2017, 2018 and 2019 in Figure 27.

The estimated rate of apparent survival between 2014 and 2018 was relatively high at 0.93 per annum, indicating a low rate of permanent emigration of 2.1% per annum during this period assuming a biological survival rate of 0.95 (Taylor *et al.* 2007 – see Brooks et al 2017). The estimate of apparent survival following 2018 was much lower at 0.77 per annum, indicating that the rate of permanent emigration had increased to 18.9% per annum.

Temporary emigration was fixed at zero in the interpreted models when it was discovered that estimates were trivially small.

Coefficients of variation (CVs) of the total population estimates were 0.17, 0.33, 0.22, 0.26 and 0.28 for the years 2014, 2016, 2017, 2018 and 2019, respectively. Only one these estimates (2014) meets the target of CV < 0.20 for abundance estimates from capture-recapture studies and the 95% confidence intervals are correspondingly quite wide.

Table 21. Bottlenose dolphin CRD model parameter estimates, standard errors (SE) and 95% confidence intervals (LCI and UCI). Parameters include apparent survival (S), temporary emigration ($\gamma''=\gamma'=0$), 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 2014-2018	0.93	0.02	0.88	0.96
S following 2018	0.77	0.20	0.27	0.97
$\gamma'' = \gamma'$ All intervals	Fixed = zero	NA	NA	NA
p 2014_1	0.23	0.04	0.16	0.32
p 2014_2	0.10	0.02	0.07	0.16
p 2014_3	0.10	0.02	0.06	0.15
p 2014_4	0.22	0.04	0.15	0.31
p 2016_1	0.10	0.03	0.05	0.18
p 2016_2	0.02	0.01	0.01	0.04
p 2016_3	0.12	0.03	0.07	0.20
p 2016_4	0.02	0.01	0.01	0.04
p 2017_1	0.06	0.01	0.04	0.09
p 2017_2	0.14	0.03	0.10	0.21
p 2017_3	0.03	0.01	0.02	0.05
p 2017_4	0.08	0.01	0.06	0.11
p 2018_1	0.02	0.00	0.01	0.03
p 2018_2	0.04	0.01	0.03	0.07
p 2018_3	0.09	0.02	0.05	0.14
p 2018_4	0.04	0.01	0.03	0.07
P 2019_1	0.14	0.05	0.07	0.26
P 2019_2	0.02	0.01	0.01	0.04
P 2019_3	0.15	0.05	0.08	0.27
P 2019_4	0.03	0.01	0.02	0.06
N Marked 2014	105	17.91	70	140
N Marked 2016	140	45.65	50	229
N Marked 2017	253	54.56	146	360
N Marked 2018	401	105.52	194	608
N Marked 2019	226	63.84	101	351
N Total 2014	118	20	84	165
N Total 2016	157	51	84	293
N Total 2017	284	62	187	432
N Total 2018	451	119	271	749
N Total 2019	254	72	147	438

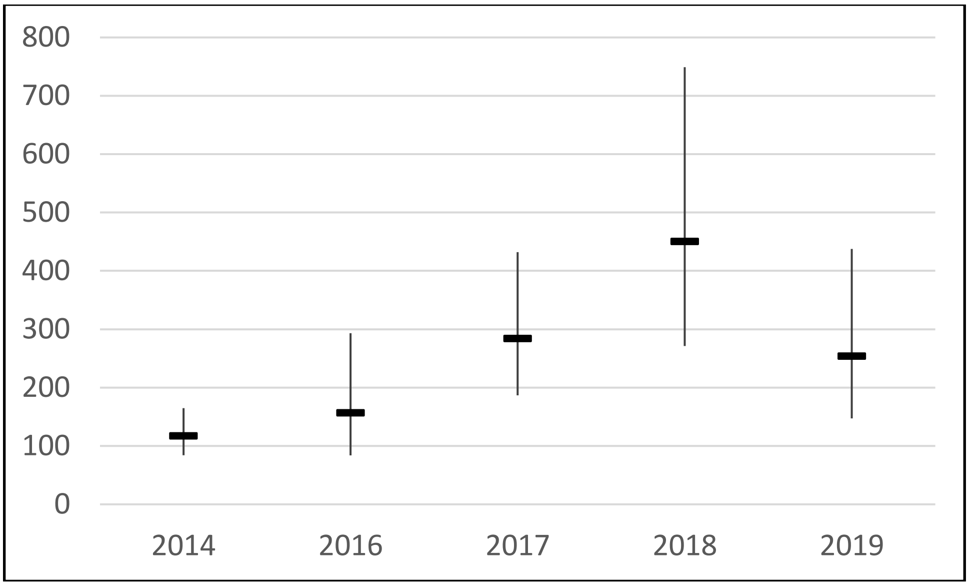

Figure 27. Estimated number of individual bottlenose dolphins present at all sites (Weipa, Boyd Point, and Aurukun) during the 2014, 2016, 2017, 2018 and 2019 sampling periods with 95% confidence interval.

3.2.5.3 Snubfin 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 years 2014, 2016, 2017, 2018 and 2019 in Table 22.

A total of 44 snubfin dolphins were photographed from 2014-2018, but only 24 of these were captured with 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 of the first four years of the study (2018), and only one individual was photographed in more than one of these years. Considering the low number of captures and recaptures, abundance estimates were not possible for this species for the years 2014-2018.

In 2019 however, a total of 36 individuals were captured a total of 58 times. With this number of recaptures, a closed population model could be fitted to estimate the abundance of snubfin dolphins in 2019.

Table 22. Number of snubfin dolphin individuals and captures for the 2014-2019 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	1	0	1	2	1	0	1	2
2016	0	7	0	7	0	7	0	7
2017	0	0	1	1	0	0	1	1
2018	8	6	0	14	9	6	0	15
2019	31	0	5	36	53	0	5	58

Program CAPTURE was invoked within program Mark to fit a closed population model to the 2019 data. The goodness of fit test in CAPTURE selected model Mt (time-varying capture probabilities, no strong evidence of behavioural response to first capture or individual heterogeneity of capture probabilities) as the appropriate model. The estimated capture probabilities varied between 0.16 (SE

= 0.06) and 0.47 (SE = 0.09) and the estimate of the size of the marked proportion of the population size was 44 dolphins (SE = 4.59, 95%CI = 39-59).

The estimated total population size was 52 (SE = 6.35, 95%CI = 41-66), based on an estimate of 0.85 (SE = 0.055) of the population being distinctively marked.

3.2.6 Individual dolphin movements

One hundred and four humpback dolphins were photographed in more than one year of the project from 2014-2019. Of these, 26 dolphins were photographed in three years and five were photographed in four years. No individual humpback dolphin was photographed in all five years of survey. Sighting locations for the 31 humpback dolphins photographed in at least three years of the project are shown in Figure 28 and all 104 individuals captured in more than one year in Appendix 1 (Figure 44).

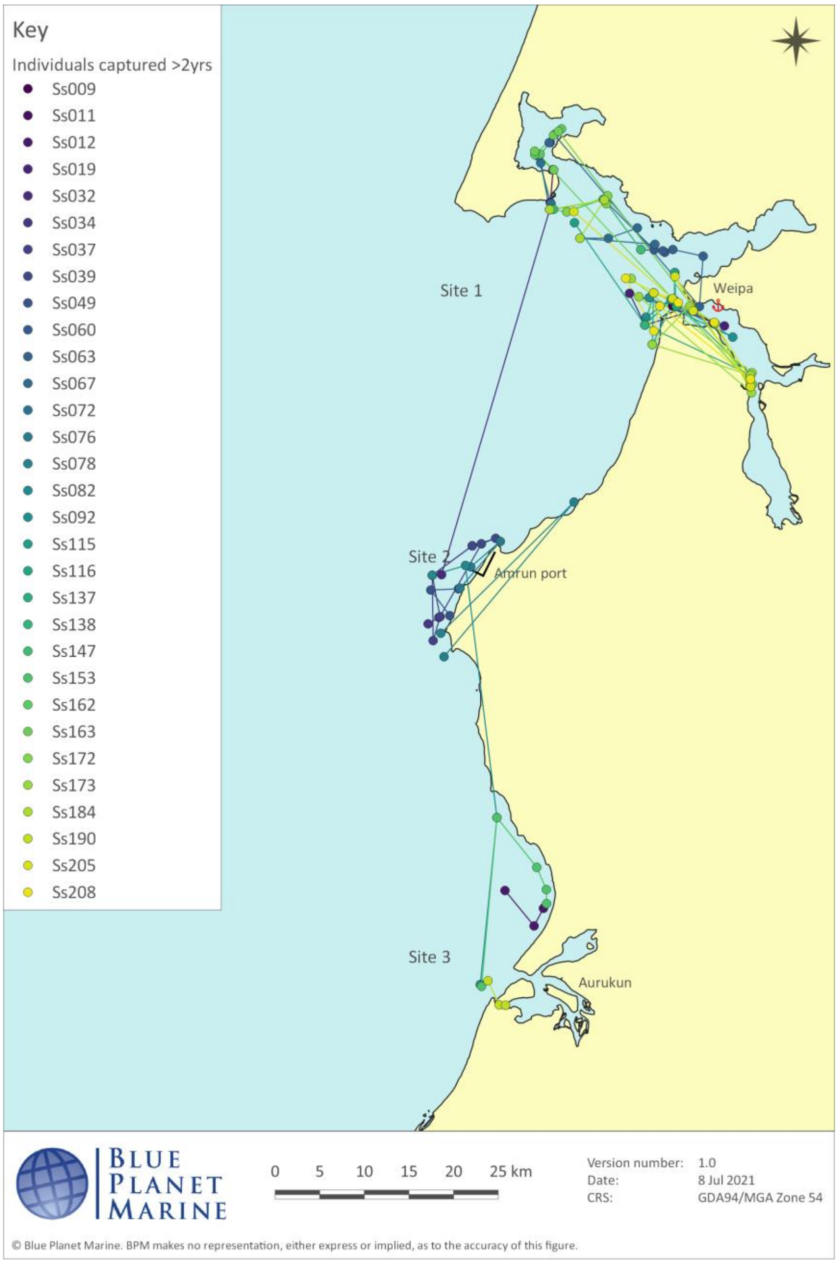

Figure 28. Sighting locations of 31 humpback dolphins photographed in at least three years of the project from 2014-2019, with interpolated lines drawn between sightings.

Sixty inshore bottlenose dolphins were photographed in more than one year of the project from 2014-2019, including thirteen photographed in three years, three photographed in four years and three photographed in all five years. Sighting locations for the 19 bottlenose dolphins photographed in at least three years of the project are shown in Figure 29.

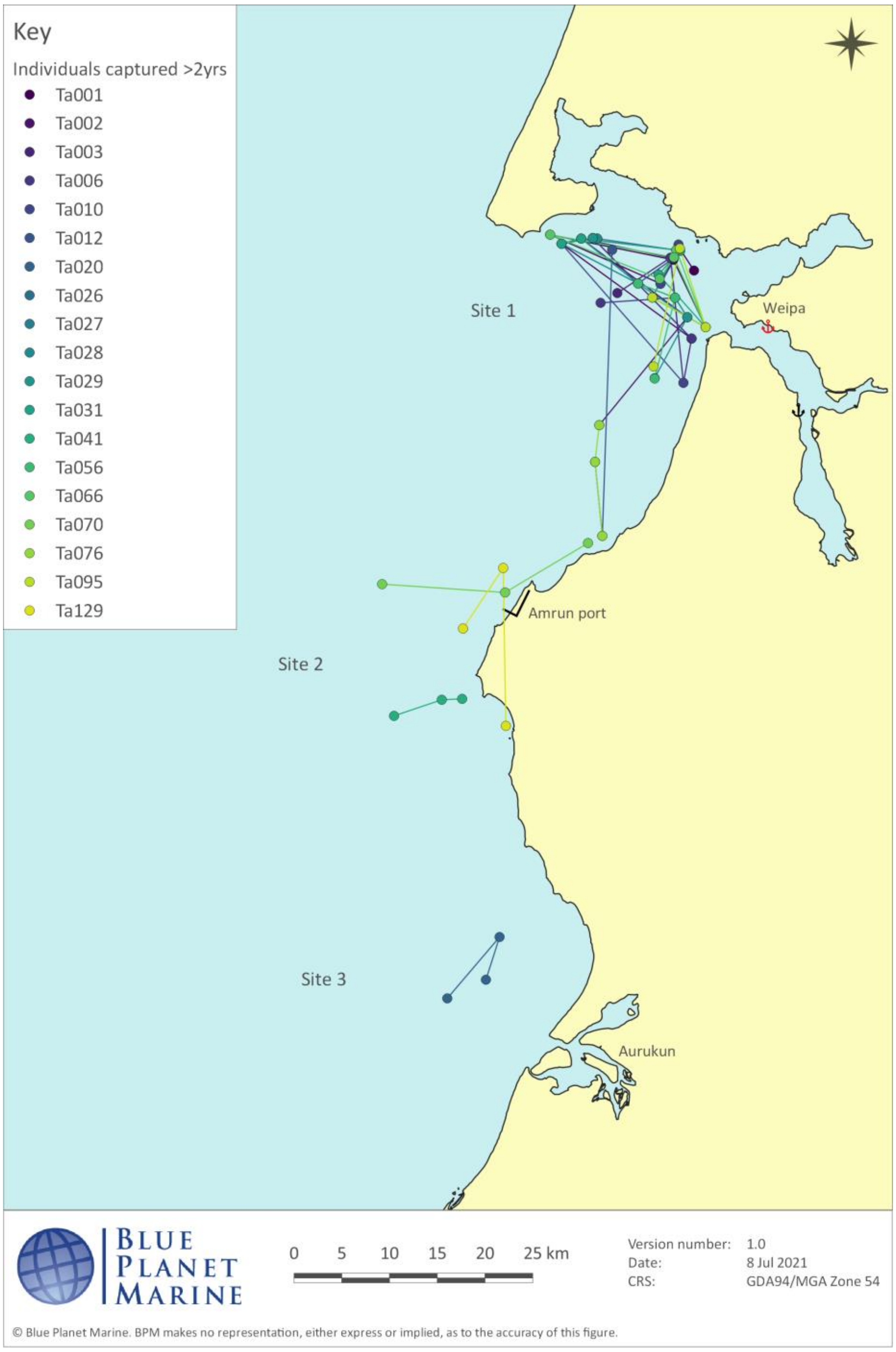

Figure 29. Sighting locations of 19 bottlenose dolphins photographed in at least three years of the project from 2014-2019, with interpolated lines drawn between sightings.

Twelve snubfin dolphins were photographed in more than one year of the project from 2014-2019 (Figure 30).

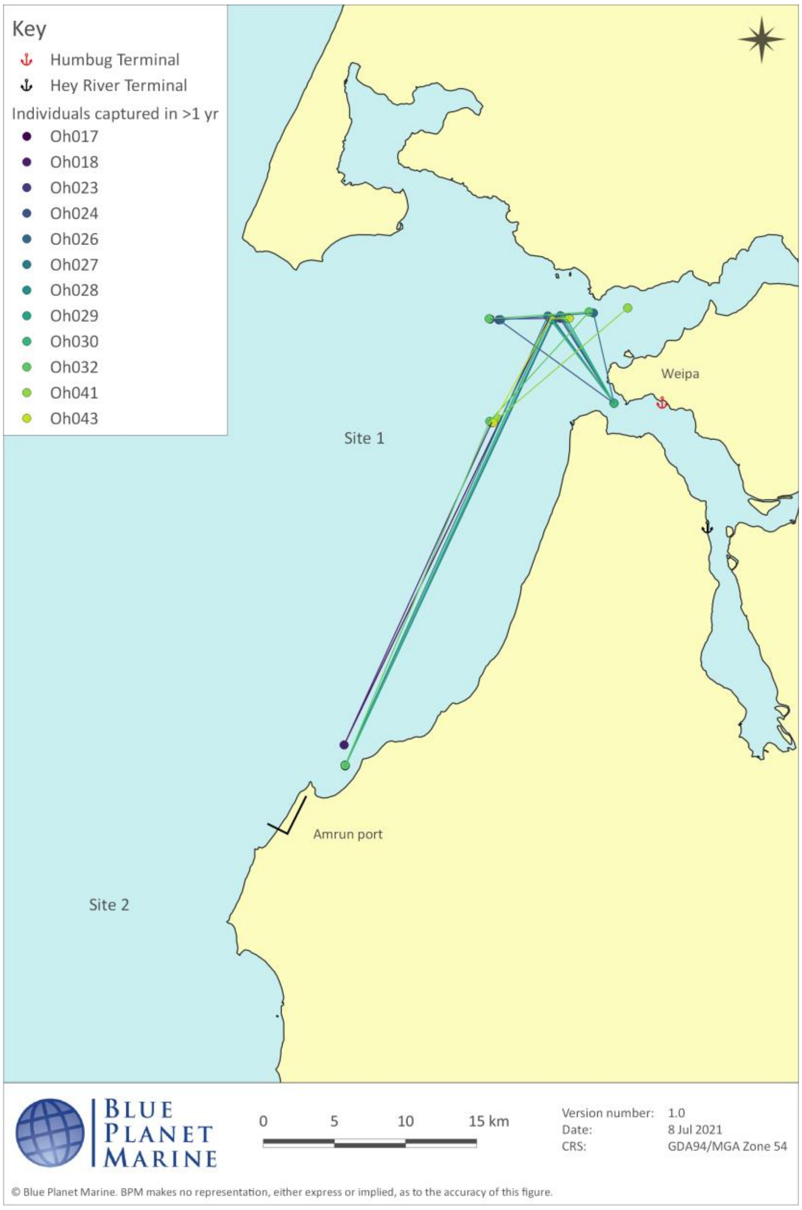

Figure 30. Sighting locations of twelve snubfin dolphins photographed in more than one year from 2014-2019, with interpolated lines between sightings.

3.2.7 Environmental parameters and habitat preferences

Combining sightings from all years (2014-2019), sightings by tidal state are shown in Appendix I for humpback dolphins (Figure 35), bottlenose dolphins (Figure 36), and snubfin dolphins (Figure 37). A summary of depths at which dolphin sightings occurred for all years combined (2014-2019) 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) and the post-construction survey (2019) 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 2014-2019 surveys combined. Mean values for each parameter across all sightings per species per year are shown in Table 26.

Table 23. Depth at sighting location of dolphin groups during the 2014-2019 surveys combined.

Species	Number of groups sighted	Depth at sighting location (m)		
		Mean (Std Dev)	Minimum	Maximum
Humpback	326	8.4 (5.3)	0.8	26.8
Inshore bottlenose	113	12.9 (6.6)	3.1	26.8
Offshore bottlenose	4	21.7 (2.7)	18.6	25.0
Snubfin	30	6.1 (2.7)	2.4	12.1
Spinner	8	22.9 (1.6)	19.9	25.0

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

Species	Phase	Sightings	Mean depth (Std Dev) (m)
Humpback	Pre-construction	81	9.0 (5.3)
	Construction	159	7.9 (5.2)
	Post-construction	84	8.6 (5.4)
Inshore bottlenose	Pre-construction	19	9.5 (6.0)
	Construction	65	13.3 (6.1)
	Post-construction	29	14.1 (7.6)
Snubfin	Pre-construction	7	5.3 (2.6)
	Construction	12	5.7 (2.3)
	Post-construction	11	7.1 (3.2)

Table 25. Environmental parameters recorded at dolphin sighting locations for the 2014-2019 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	326	30.0 (1.7)	34.9 (1.2)	3.8 (5.9)	8.1 (0.4)
Inshore bottlenose	113	29.5 (1.6)	34.6 (1.0)	1.4 (2.3)	8.1 (0.3)
Offshore bottlenose	4	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	30	29.7 (1.8)	34.6 (1.2)	4.6 (7.4)	8.2 (0.3)
Spinner	8	29.0 (1.9)	35.0 (0.4)	0.1 (0.2)	8.2 (0.4)

*N.B. Temperature, salinity, pH and turbidity were not collected at sites 2 and 3 during the 2019 survey.

Table 26. Mean values for environmental parameters per species per year of survey*.

Species	Year	Mean temperature (°C)	Mean salinity (ppt)	Mean turbidity (NTU)	Mean pH
Humpback	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
	2019	28.1	33.6	3.1	8.6
Inshore bottlenose	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
	2019	27.8	32.6	0.8	8.7
Snubfin	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
	2019	27.9	33.2	2.3	8.5

*N.B. Temperature, salinity, pH and turbidity were not collected at sites 2 and 3 during the 2019 survey.

3.2.8 Distance from shore and behaviours

A summary of the distance from the closest point of land for dolphin groups sighted from 2014-19 is shown in Table 27. Figures showing the primary behaviours of dolphin groups observed from 2014-2018 are shown for humpback dolphins in Appendix I - Figure 41, for bottlenose dolphins in Figure 42 and for all years combined (2014-2019) for snubfin dolphins in Figure 43.

Table 27. Distance from closest point of land for dolphin groups sighted during surveys, 2014-2019.

Dolphin species sighted	Number of groups	Mean distance to shore (km)	Minimum distance to shore (km)	Maximum distance to shore (km)
Humpback	297	2.07	0.001	10.74
Humpback/Inshore bottlenose	22	3.55	0.63	8.19
Humpback/Snubfin	6	2.15	1.05	5.66
Inshore bottlenose	87	6.03	0.82	15.14
Inshore bottlenose/Spinner	2	11.62	10.67	12.57
Offshore bottlenose	4	7.18	3.99	13.80
Snubfin	22	3.34	0.77	9.49
Snubfin/Inshore bottlenose	2	2.54	2.11	2.97
Spinner	6	9.88	5.54	14.12

4. Discussion

The 2019 inshore dolphin survey was the first post-construction phase survey and the fifth 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 2019 survey was successful in completing all transects during four secondary samples and in involving Wik Waya Traditional Owners (TOs) in the survey and project training days. Having successfully completed surveys to meet the Strategy objectives in 2014, 2016, 2017, 2018 and 2019, 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 to be made 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, Wik Waya Traditional Owners have participated in each year of the survey from 2014 to 2019. For the 2019 survey, TOs Jerry Wapau, Miles Kerindun, Darrus Wolmby, Mitchell Bandicootcha, Anthony Yunkaporta, Tianna Chevathen, Bridgette Bandicootcha, Anton Binjuda, Robert Adidi and Walter Convent 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, marine fauna observation and scientific data collection methods and equipment.

4.2 Sightings and encounter rates

The most frequently sighted dolphin species during the five surveys from 2014 to 2019 was the Australian humpback dolphin, with 326 (70%) of the 467 groups sighted including at least one member of this species. Inshore bottlenose dolphins were sighted in 24% of groups, with snubfin dolphins in only 6% of groups and spinner dolphins, offshore bottlenose dolphins and orca each seen in less than 2% of groups. Only humpback, inshore bottlenose and snubfin dolphins were sighted in every year of survey from 2014-2019.

The total number of dolphins sighted of each species each year varied between surveys. In general, fewer dolphins were sighted in 2016 and a higher number in 2019. The number of humpback dolphins sighted in 2014 (284), 2018 (279) and 2019 (297) were similar, with fewer in 2017 (222) and the lowest number recorded in 2016 (144). A similar pattern was observed for bottlenose dolphins, with 158 individuals sighted in 2014, 70 in 2016, 177 in 2017, 172 in 2018 and 156 in 2019. These patterns were also reflected in the encounter rates for these species (Table 14, Table 15). Furthermore, only a single humpback dolphin calf was observed in 2016, which was considerably lower than the numbers seen in 2014 (12), 2017 (13), 2018 (26) and 2019 (17). There are several possible explanations for the lower encounter rates and fewer sightings of dolphins during the 2016 survey compared with other years. These include:

- Potential seasonal differences between years, with the 2016 survey conducted during November (7-19), 2014 during December (7-19), and 2017, 2018 and 2019 during October (11-26). Although the surveys were all conducted within a 68-day window relative 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 2014-2018 (2014: 60%, 2017: 60%, 2018:72%), the lowest of all years was 2019 (44%), which generally had higher numbers of dolphins sighted. It appears unlikely that sea state conditions were a major factor in the substantially lower numbers of humpback and bottlenose dolphins sighted in 2016 compared with other years.
- 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 (piling for the Humbug and Hey River terminals was completed in August 2016, with the dolphin survey conducted from 7-19 November), 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 in 2016 (Figure 31). Potential displacement of bottlenose dolphins is less likely considering the differences in habitat 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 31). Bottlenose and snubfin dolphins were not sighted in the Hey River in any year of survey from 2014-2019;
- 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 permit conditions for the 2016 survey restricted the research to spending no more than 30 minutes within 50 m of encountered groups, whereas the limit was 60 minutes for all other 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 13), 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 relatively wide. These estimates are detailed in section 4.3.1.

In considering the results of the 2014-2019 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 and 2019) 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)	Total length surveyed (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
Onslow 2015-16 (WA)	890	0.01	Raudino et al. 2018a
Thevenard Island 2015-16 (WA)	287	0.04	Raudino et al. 2018a
Montebello Islands 2017 (WA)	244	0.08	Raudino et al. 2018b
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	BPM 2021 (this study) Recalculated from GHD 2015
Weipa-Aurukun 2016 (QLD)	1590	0.04	BPM 2021 (this study)
Weipa-Aurukun 2017 (QLD)	1617	0.06	BPM 2021 (this study)
Weipa-Aurukun 2018 (QLD)	1618	0.09	BPM 2021 (this study)
Weipa-Aurukun 2019 (QLD)	1585	0.12	BPM 2021 (this study)

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

While low numbers of snubfin dolphins were sighted in all years from 2014-2018 (range = 12-36), a significantly higher number was sighted during the 2019 survey (n= 87).

4.3 Abundance estimates, identification and resight rates

Sufficient numbers of identification photographs and resights were obtained for humpback, bottlenose and snubfin 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 2014-2019 showed a continual increase for each of humpback, bottlenose and snubfin dolphins (Figure 25), 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 214 in 2014, 242 in 2016, 242 in 2017, 193 in 2018 and 245 in 2019. Overall, abundances were consistent over time with a minimum (lower 95% CI) of 161 individual dolphins present during any primary sample. Typically, more than 200 dolphins use the sampling areas at Weipa, Boyd Point and Aurukun combined 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 studies 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	193 (161-231) - 245 (208-290)	BPM 2021 (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 0.01 – 0.28. 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 16 of the 20 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 69% per annum with a relatively small standard error. This is a low rate that 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 29.2%. The temporary emigration rate was, in contrast, small and estimated with a quite large standard error. 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. 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 21, the estimates of total population size show a steady increase from 2014 to 2018, with over 450 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. The rate of increase in the between-year estimates from 2014 to 2018 was 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 0.93 per annum, this indicated a relatively low rate of permanent emigration of 2.1% per annum assuming a biological survival rate of 0.95 (Taylor *et al.* 2007, see Brooks et al 2017). However, the estimate of total population size for 2019 was 254 (95% CI: 147-438) and apparent survival following 2018 was much lower at 0.77 per annum, indicating that the rate of permanent emigration had increased to 18.9% per annum. Not only was apparent survival high during the growth period 2014-2018, but the rate of growth was also too great to be accounted for by in situ births alone suggesting a relatively high rate of immigration from elsewhere. Similarly, but in contrast, the rate of decline following 2018 was too great to be accounted for by the reduction in apparent survival (increase in permanent emigration) alone, suggesting that the previous rate of immigration was not maintained.

4.3.3 Snubfin dolphins (*Orcaella heinsohni*)

An insufficient number of identification photographs and resights of snubfin dolphins were obtained during the first four years of survey for CR analysis and abundance estimation for 2014 to 2018, with only one dolphin photographed in more than one year and one photographed in two secondary samples within a year. However, in 2019, a total of 36 individuals were captured a total of 58 times. With this number of recaptures, a closed population model was able to be fitted to estimate the abundance of snubfin dolphins in 2019. Using an estimated proportion of the population being distinctively marked of 0.85, the total number of snubfin dolphins estimated to have used the sampling areas at Weipa, Boyd Point and Aurukun in October 2019 was 52 (95% CI: 41-66). 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 have also been received during the 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 more informative population modelling to be conducted in the future.

4.3.4 Summary

Considering the results of the CR analyses for all three species overall, the factors driving which dolphins come and which go is unknown, but it is clear that movements into and out of the sampling area are reasonably long term for humpback and bottlenose dolphins, with very low rates of temporary emigration suggesting when these dolphins leave the area, they stay away permanently or for an extended period of time. There was no evidence to suggest that the variation in abundance estimates was related to the timing of construction activities associated with the Amrun Project, other than the potential issues outlined for 2016. It is unclear why humpback dolphins permanently emigrated and immigrated at quite high rates in all intervals from 2014-2019; bottlenose dolphins immigrated at quite a high rate and emigrated at a low rate from 2014-2018 but then immigrated at a low rate and emigrated at a high rate after 2018; and snubfin dolphins were seen in low numbers from 2014-2018 but a larger number was encountered in 2019 and numerous dolphins remained in the study area for a longer period. The variation in capture probabilities and encounter rates for each of these species over years may be related to variation in the use of the sampling area and adjacent parts of western Cape York. Aerial or vessel-based surveys outside the study area could provide further insights into the dynamics for each species.

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 in all years, and the small number of snubfin dolphin groups sighted were spread across the three sites, but primarily at site 1 in 2018 and 2019. Of all dolphins observed in this study, snubfin dolphins were encountered at the shallowest mean depth (6.1 m) and at a mean distance of 3.1 km from the closest point of land, humpback dolphins at a mean depth of 8.4 m and distance of 2.2 km from land, inshore bottlenose dolphins at 12.9 m deep and 5.6 km from land, offshore bottlenose dolphins at 21.7 m and 7.2 km from land and spinner dolphins at 22.9 m deep and 10.3 km from land. These depths and distances from shore 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). That humpback and snubfin dolphins were encountered more often at Site 1, which includes three river systems (Pine, Mission and Hey Rivers) opening into an embayment, is also consistent with known habitat preferences. No major differences were found between pre-construction, construction and post-construction phase mean depths or distances from land 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=30) 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 41). 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, although pH was generally higher at Site 1 in 2019 than in other years (Table 25, Table 26). In contrast, mean temperature and turbidity values recorded at dolphin sighting locations in 2014 were higher than in other years (Table 25, Table 26). It should be noted that different brands of water quality meters were used for the 2014 survey compared with the 2016-2019 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 in the operational phase, it is important to consider how potential impacts on the inshore dolphins in the region are 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 and encounter rates recorded for Australian humpback dolphins at any location in Australia to date, it is clear that the study 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 2014-2019, including in proximity to the river and port facilities. However, the very low number of humpback dolphins sighted in the Hey River in 2016 (1 group consisting of 2 individuals) 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 five years of survey prevent strong conclusions from being drawn about the causes. Nevertheless, increasing sightings of humpback dolphins in the Hey River in 2017, 2018 and 2019 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 (3 groups, 9 dolphins), 2018 (4 groups, 17 dolphins) and 2019 (11 groups, 37 dolphins) than in 2014 (15 groups, 54 dolphins), this should be monitored in future.

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 (150 m caution zone and 50 m exclusion zone) 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 operational phase surveys.

The presence of humpback dolphin calves (Figure 19), and to a lesser extent bottlenose (Figure 20) and snubfin (Figure 21) calves, in the vicinity of the port facility requires consideration. Although numbers were low, more than 12.5% of humpback dolphin calves encountered from 2014-2019 (n=8/63) were sighted within 3 km of the port facility. Calf presence close to the port should be closely monitored in future. 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. Measures in the Amrun Project Operations Marine and Shipping Management Plan (RTW 2021) include ensuring vessels are maintained to a high standard to reduce noise emissions; ensuring engines, thrusters and auxiliary plant is not left in stand-by or running mode unnecessarily; and other measures consistent with the IMO Guidelines for the reduction of underwater noise from ships (IMO 2014). At current levels, approximately 260 shipments (520 movements) are expected from the Port each year. Should shipping levels increase or a large number of calves be observed in close proximity to the port in future, additional mitigation measures may be required. Lastly, any maintenance dredging for the Project is required to 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, bottlenose and snubfin dolphins after combining five years of data (2014, 2016, 2017, 2018, 2019), there were considerable limitations to the modelling. This was reflected by very wide Coefficients of variation (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 humpback, bottlenose or snubfin dolphins, and both on and off effort captures were included in analyses to increase sample sizes. CVs of the total population estimates for humpback dolphins were 0.08, 0.15, 0.15, 0.09 and 0.09 for the years 2014, 2016, 2017, 2018 and 2019, respectively. All of these estimates meet the 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 20 samples for bottlenose dolphins, and 6 of 20 for humpbacks. Capture probabilities of ≥0.1 were achieved in 9 of 20 samples for bottlenose dolphins and 16 of 20 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 any future operational phase surveys.

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6. References

Beasley, I.L., Pollock, K., Jefferson, T.A., Arnold, P., Saksang, Y., San, L.K. and Marsh, H. (2013) Likely future extirpation of another Asian river dolphin: The critically endangered population of the Irrawaddy dolphin in the Mekong River is small and declining. *Marine Mammal Science*. 29 (3): E226-E252

Beasley, I.L. Golding, M. and Girringun Rangers. (2013b) Looking for Palangal (dolphins) and Balangal (dugongs) in Girringun Sea Country. School of Earth and Environmental Sciences, James Cook University. Unpublished report 37pp. Available from: http://www.nerptropical.edu.au/sites/default/files/publications/files/Girringun%20Survey%20Report_March%202013_0.pdf.

Beasley, I.L. Golding, M. and Girringun Rangers. (2014) Looking for Palangal (dolphins) and Balangal (dugongs) in Girringun Sea Country. School of Earth and Environmental Sciences, James Cook University. Unpublished report 50pp.

BPM (2018) Amrun Project Inshore Dolphin Survey 2016 Report. 43pp.

BPM (2019) Amrun Project Inshore Dolphin Survey 2017 Report. 30pp.

BPM (2019) Amrun Project Inshore Dolphin Survey 2018 Report. 87pp.

Braulik, G. & Reeves, R. (2018) *Stenella longirostris*. The IUCN Red List of Threatened Species 2018: e.T20733A50375784.

Brooks, L., Carroll, E. and Pollock, K. H. (2014) Methods for assessment of the conservation status of Australian inshore dolphins. Final report to the Department of Environment. 44pp.

Brooks L, Palmer C, Griffiths AD and Pollock KH (2017) Monitoring Variation in Small Coastal Dolphin Populations: An Example from Darwin, Northern Territory, Australia. *Front. Mar. Sci.* 4:94.

Brown, A. M., Bejder, L., Pollock, K. H. and Allen, S. J. (2014) Abundance of coastal dolphins in Roebuck Bay, Western Australia. Report to WWF-Australia. Murdoch University Cetacean Research Unit, Murdoch University, Western Australia. 25pp.

Brown, A.M., Bejder, L., Pollock, K.H. and Allen, S.J. (2016) Site-Specific Assessments of the Abundance of Three Inshore Dolphin Species to Inform Conservation and Management. *Frontiers in Marine Science* 3:4.

Buckland, S. T., Burnham, K. P. and Augustin, N. H. (1997). Model selection: an integral part of inference. *Biometrics **53**:603-618.*

Burnham, K. P. and Anderson, D. R. (2002). Model selection and multi-model inference: a practical information-theoretic approach. Springer.

Cagnazzi, D. (2013) Review of Coastal Dolphins in central Queensland, particularly Port Curtis and Port Alma regions. Gladstone Port Corporation. Queensland, Australia.

Cagnazzi, D. (2017) Increase understanding of the status of the Australian snubfin and Australian humpback dolphins within Port Curtis and Port Alma Final Project Report (CA14000085). Report produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of the Gladstone Ports Corporation Ecosystem Research and Monitoring Program. pp. 124.

Cagnazzi, D.D.B., Harrison, P.L., Ross, G.J.B., Lynch, P. (2011) Abundance and site fidelity of Indo-Pacific Humpback dolphins in the Great Sandy Strait, Queensland, Australia. *Marine Mammal Science* 27: 255-281.

Choquet, R., Reboulet, A. M., Lebreton, J. D., Giminez, O., and Pradel, R. (2005) U-Care 2.2 User's Manual. Montpellier: CEFE. Available online: http://www.cefe.cnrs.fr/fr/recherche/bc/bbp/264-logiciels.

Corkeron, P., Morissette, N. M., Porter, L. and Marsh, H. (1997) Distribution and status and of humpbacked dolphins, *Sousa chinensis*, in Australian waters. *Asian Marine Biology* 14: 49-59.

GHD (2014) SOE Inshore Dolphin Survey Protocols.

GHD (2015) Rio Tinto Alcan South of Embley Inshore Dolphin Project December 2014 Baseline Survey. 99pp.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K.A., Karkzmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S. & Wilson, B. 2012. *Tursiops aduncus*. The IUCN Red List of Threatened Species (2012a): e.T41714A17600466.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K.A., Karkzmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S. & Wilson, B. (2012b) Tursiops truncatus. The IUCN Red List of Threatened Species 2012: e.T22563A17347397.

Huang, S. L., Karczmarski, L., Chen, J., Zhou, R., Lin, W., Zhang, H., et al. (2012) Demography and population trends of the largest population of Indo-Pacific humpback dolphins. *Biol. Conserv.* 147, 234–242. doi: 10.1016/j.biocon.2012.01.004

Hunt T.N., Bejder L., Allen S.J., Rankin R.W., Hanf D., Parra G.J. (2017) Demographic characteristics of Australian humpback dolphins reveal important habitat toward the southwestern limit of their range. *Endanger Species Res*. 32:71–88.

IMO (2014). Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life. *MEPC.1/Circ.833*, April 2014.

Kendall, W. L., and Nichols, J. D. (1995). On the use of secondary capture-recapture samples to estimate temporary emigration and breeding proportions. *J. Appl. Stat.* 22, 751–762. doi: 10.1080/02664769524595

Kendall, W. L., Nichols, J. D., and Hines, J. E. (1997). Estimating temporary emigration and breeding proportions using capture-recapture data with Pollock's robust design. *Ecology* 78, 563–578.

Link, W.A., Yoshizaki, J., Bailey, L.L., and Pollock, K.H. (2010) Uncovering a Latent Multinomial: Analysis of Mark–Recapture Data with Misidentification. *Biometrics* 66(1): 178-185.

Meager, J.J. and Hawkins, E. (2017) Moreton Bay Dolphin Project: Long-term monitoring of iconic tropical dolphins at a key index site. Final report to James Cook University. 79 pages.

Meager J.J., Hawkins E.R., Ansmann I., Parra G.J. (2018) Long-term trends in habitat use and site fidelity by Australian humpback dolphins *Sousa sahulensis* in a near-urban embayment. *Marine Ecology Progress Series* 603:227-242.

Morrison, T.A., Yoshizaki, J., Nichols, J.D., and Bolger, D.T. (2011) Estimating survival in photographic capture–recapture studies: overcoming misidentification error. *Methods in Ecology and Evolution* 2(5): 454-463.

Palmer, C., Brooks, L., Parra, G. J., Rogers, T., Glasgow, D., and Woinarski, J. (2014) Estimates of abundance and apparent survival of coastal dolphins in Port Essington harbour, Northern Territory, Australia. *Wildl. Res.* 41, 35–35.

Parra, G. J., Corkeron, P. J., and Marsh, H. (2006) Population sizes, site fidelity and residence patterns of Australian snubfin and Indo-Pacific humpback dolphins: implications for conservation. *Biol. Conserv.* 129, 167–180.

Parra, G., Cagnazzi, D., Perrin, W. & Braulik, G.T. (2017) *Sousa sahulensis*. The IUCN Red List of Threatened Species 2017: e.T82031667A82031671. http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T82031667A82031671.en

Parra, G., Cagnazzi, D. & Beasley, I. (2017) *Orcaella heinsohni* (errata version published in 2018). The IUCN Red List of Threatened Species 2017: e.T136315A123793740. http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T136315A50385982.en

QGIS Development Team (2018) QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

Raudino H.C., Douglas C.R., Waples K.A. (2018a) How many dolphins live near a coastal development? *Regional Studies in Marine Science* 19:25–32.

Raudino H.C., Hunt T.N., Waples K.A. (2018b) Records of Australian humpback dolphins (*Sousa sahulensis*) from an offshore island group in Western Australia. *Marine Biodiversity Records* 11:14.

RTA Weipa (2014) Inshore dolphin offset strategy: South of Embley Project, January 2015.

RTA Weipa (2021) South of Embley Project – Operations Marine and Shipping Management Plan, April 2021.

Taylor, B. L., Chivers, S. J., Larese, J., and Perrin, W. F. (2007) Generation Length and Percent Mature Estimates for IUCN Assessments of Cetaceans. Administrative Report LJ-07-01, Southwest Fisheries Science Center, 8604 La Jolla Shores Blvd., La Jolla, CA 92038.

Urian, K. W., Hohn, A. A., and Hansen, L. J. (1999). Status of the Photo-Identification Catalog of Coastal Bottlenose Dolphins of the Western North Atlantic. Report of a Workshop of Catalog Contributors. NOAA Technical Memorandum NMFS-SEFSC-425.

White, G.C. and K. P. Burnham. (1999) Program MARK: Survival estimation from populations of marked animals. *Bird Study 46 Supplement*, 120-138.

White G.C., Anderson D.R., Burnham K.P. and Otis D.L. (1982) Capture–recapture and removal methods for sampling closed populations. Los Alamos National Laboratory Publication LA-8787-NERP, Los Alamos, New Mexico.

Yoshizaki, J., Pollock, K.H., Brownie, C., and Webster, R.A. (2009) Modeling misidentification errors in capture–recapture studies using photographic identification of evolving marks. *Ecology* 90(1): 3-9.

Appendix I

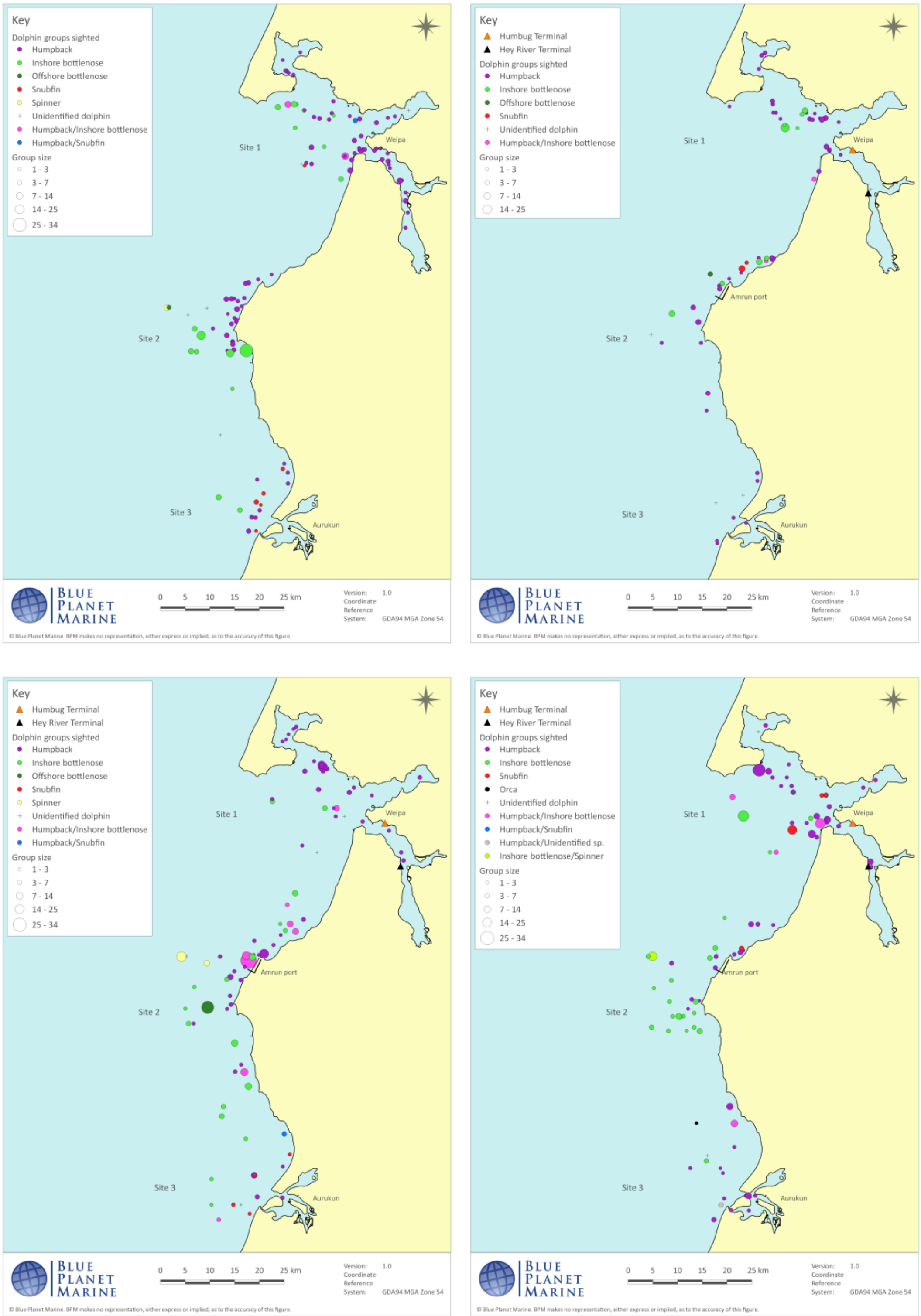

Figure 31. Dolphin groups sighted during surveys in 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right).

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

Humpback	All sightings (ON + OFF effort)		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
2019	84	297	49	185
Total	326	1,226	192	707

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	All sightings (ON + OFF effort)		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
2019	29	156	12	70
Total	113	735	62	359

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	All sightings (ON + OFF effort)		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
2019	1	3	1	3
Total	4	34	4	34

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

Snubfin	All sightings (ON + OFF effort)		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
2019	11	87	4	18
Total	30	166	14	56

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

	All sightings (ON + OFF effort)		ON effort sightings	
Spinner	Groups	Individuals	Groups	Individuals
2014	1	9	1	9
2016	0	0	0	0
2017	3	29	3	29
2018	1	3	1	3
2019	3	39	1	17
Total	8	80	6	58

Table 35. Sightings of humpback dolphins by site during the 2014-2019 surveys.

Humpback	Site 1		Site 2		Site 3		TRANSIT		Total Groups	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
2019	55	195	14	41	15	61	0	0	84	297
Total	186	723	85	293	54	208	1	2	326	1226
% of total	57.1	59.0	26.1	23.9	16.6	17.0	0.3	0.2	100	100

Table 36. Sightings of inshore bottlenose dolphins by site during the 2014-2019 surveys.

Inshore bottlenose	Site 1		Site 2		Site 3		TRANSIT		Total Groups	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
2019	10	59	16	81	3	16	0	0	29	156
Total	36	223	58	399	16	101	3	12	113	735
% of total	31.9	30.3	51.3	54.3	14.2	13.7	2.7	1.6	100	100

Table 37. Sightings of snubfin dolphins by site during the 2014-2019 surveys.

Snubfin	Site 1		Site 2		Site 3		TRANSIT		Total Groups	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
2019	9	80	0	0	2	7	0	0	11	87
Total	15	111	3	21	12	34	0	0	30	166
% of total	50.0	66.9	10.0	12.7	40.0	20.5	0.0	0.0	100	100

Table 38. Number of individual dolphins observed from each age class for each species during surveys from 2014-2019.

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	222	192	32	13	0	10
	2018	58	279	218	15	26	0	20
	2019	84	297	242	28	17	2	8
	Total	326	1226	983	146	69	2	38
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
	2019	29	156	127	12	22	1	1
	Total	113	735	565	84	70	2	14
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
	2019	1	3	3	0	0	0	0
	Total	4	34	30	4	0	0	0
Snubfin	2014	7	17	15	2	0	0	0
	2016	2	14	13	0	1	0	0
	2017	5	12	8	1	2	0	1
	2018	5	36	33	1	2	0	0
	2019	11	87	86	0	0	0	1
	Total	30	166	155	4	5	0	2
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
	2019	3	39	39	0	0	0	0
	Total	8	80	73	7	0	0	0

Table 39. Group size of dolphins sighted during the 2014-2019 surveys combined.

Species	Groups	Mean group size (Std Dev)	Min. group size	Max. group size
Snubfin	22	4.8 (4.4)	1	20
Humpback	297	3.9 (3.4)	1	30
Humpback/Snubfin	6	8.0 (4.4)	5	15
Humpback/Inshore bottlenose	22	9.9 (6.8)	3	34
Inshore bottlenose	87	6.3 (5.1)	1	32
Inshore bottlenose/Spinner	2	18.0 (2.8)	16	20
Offshore bottlenose	4	8.5 (11.0)	2	25
Spinner	6	10.0 (6.1)	4	18

Table 40. Group sizes of humpback dolphins sighted each year from 2014-2019 after separating mixed species groups into their component species (only conspecifics included 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	45	3.2 (2.3)	1	9
2017	58	3.8 (3.9)	1	20
2018	58	4.8 (4.7)	1	30
2019	84	3.5 (2.9)	1	20
Total	326	3.8 (3.3)	1	30

Table 41. Group sizes of bottlenose dolphins sighted each year from 2014-2019 after separating mixed species groups into their component species (only conspecifics included 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	6.9 (6.1)	1	31
2018	28	6.1 (4.8)	1	25
2019	29	5.4 (3.6)	1	14
Total	113	6.5 (5.3)	1	32

Table 42. Group sizes of snubfin dolphins sighted each year from 2014-2019 after separating mixed species groups into their component species (only conspecifics included in group size calculations).

Year	Number of groups	Mean group size (Std Dev)	Min. group size	Max. group size
2014	7	2.4 (2.0)	1	6
2016	2	7.0 (5.7)	3	11
2017	5	2.4 (0.5)	2	3
2018	5	7.2 (7.4)	2	20
2019	11	7.9 (5.4)	2	20
Total	30	5.5 (5.1)	1	20

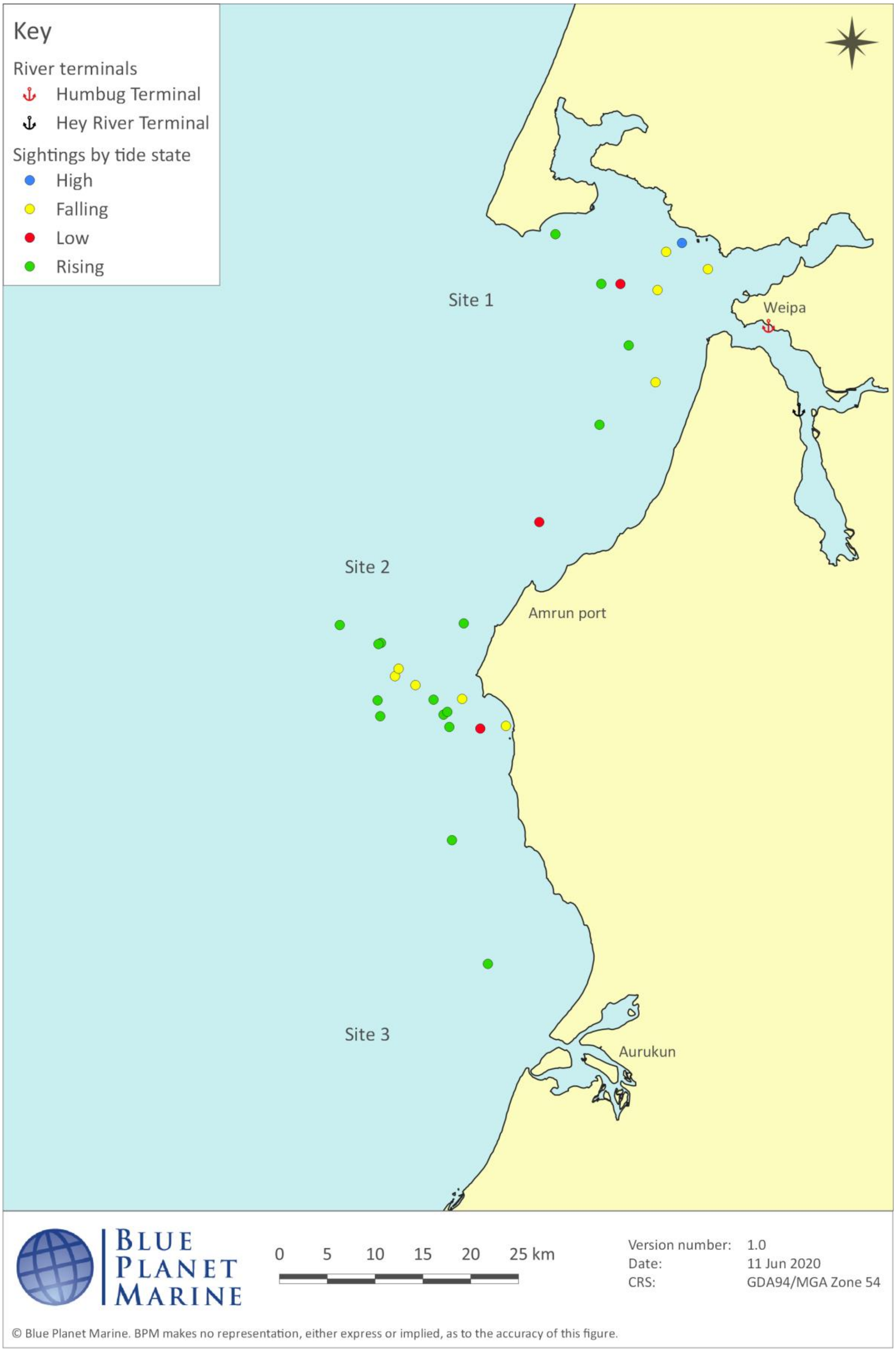

Figure 32. Bottlenose dolphin sightings by tidal state during the 2019 survey.

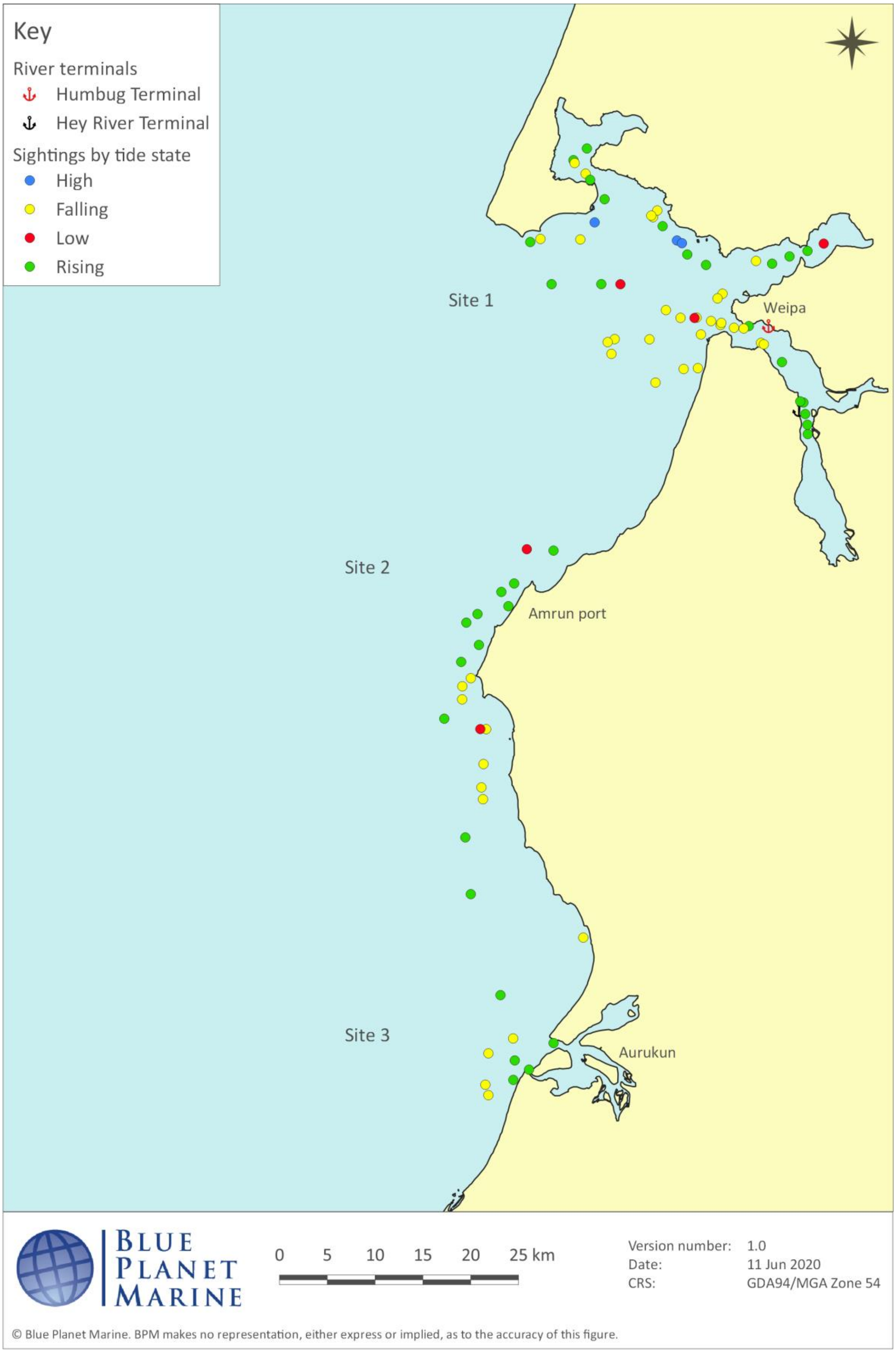

Figure 33. Humpback dolphin sightings by tidal state during the 2019 survey.

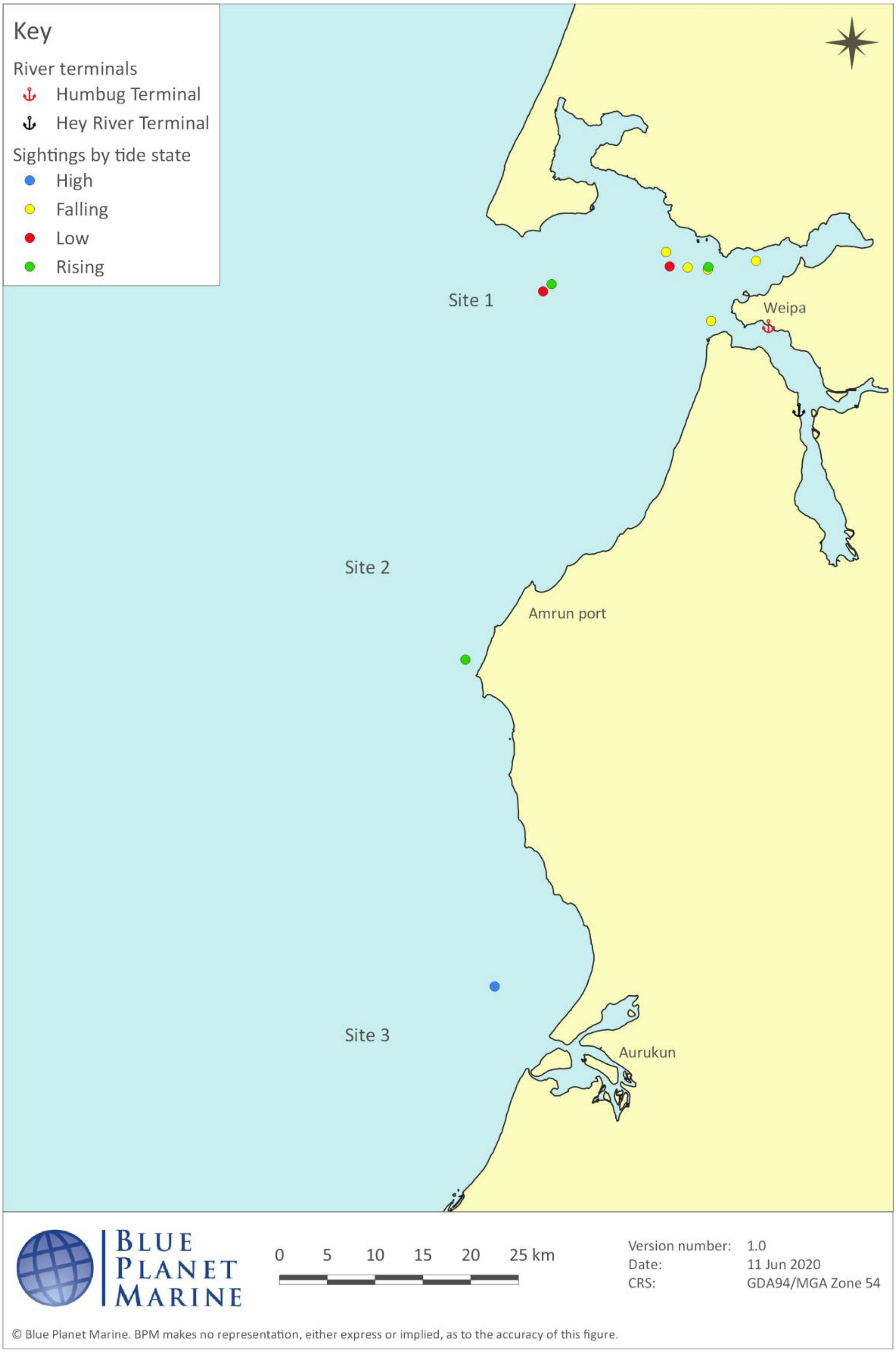

Figure 34. Snubfin dolphin sightings by tidal state during the 2019 survey.

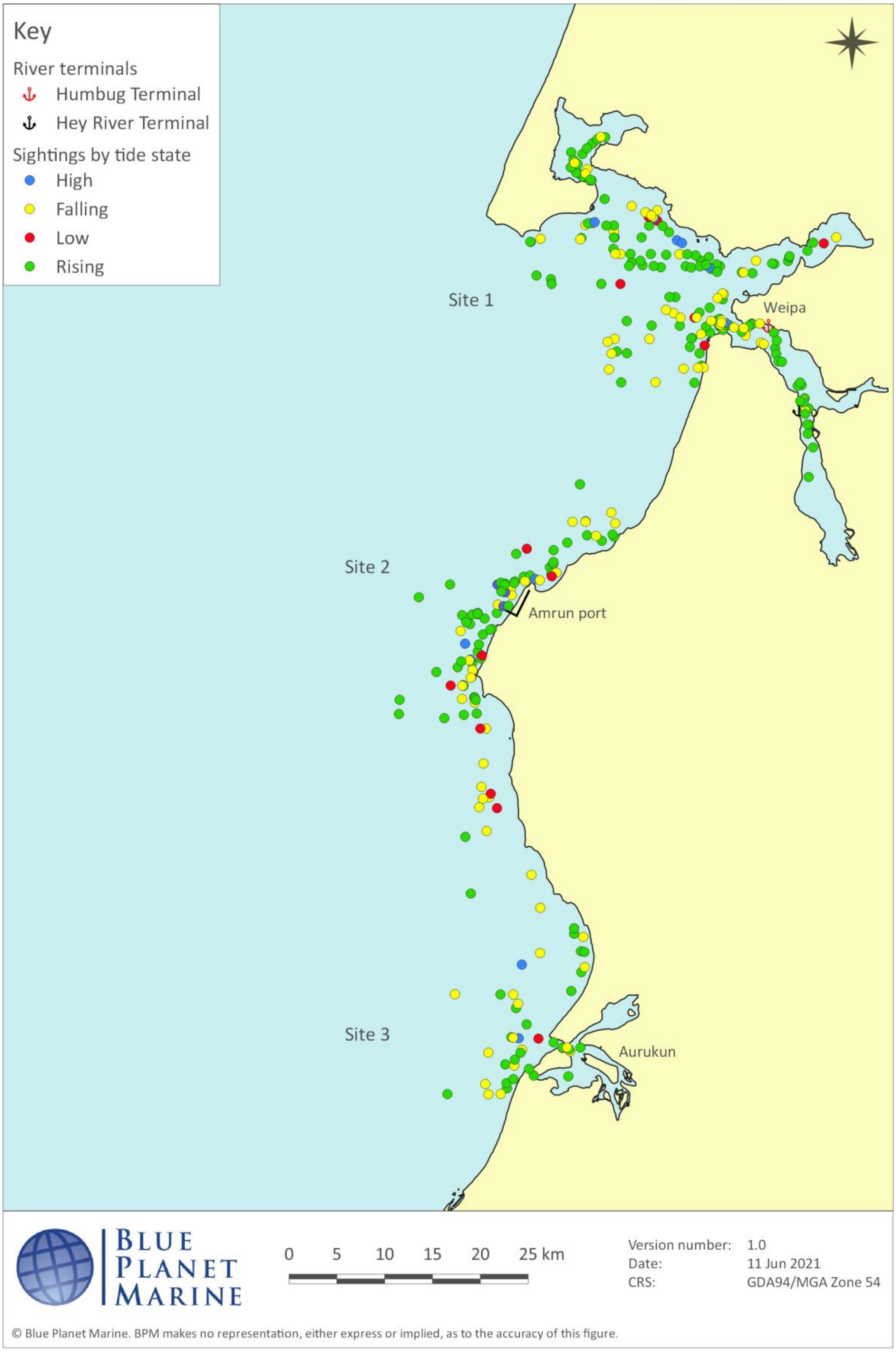

Figure 35. Humpback dolphin sightings by tidal state during the 2014-2019 surveys.

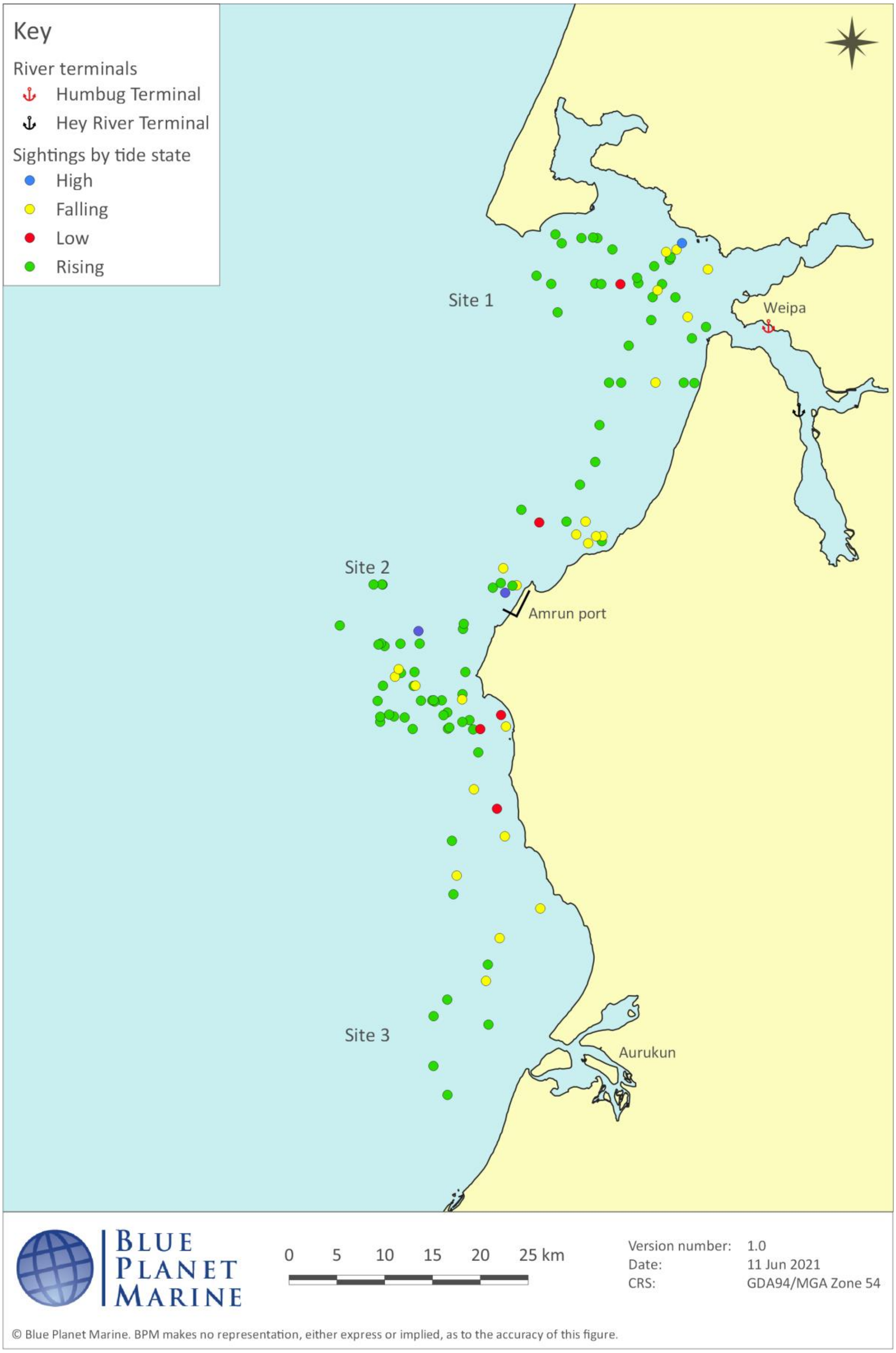

Figure 36. Bottlenose dolphin sightings by tidal state during the 2014-2019 surveys.

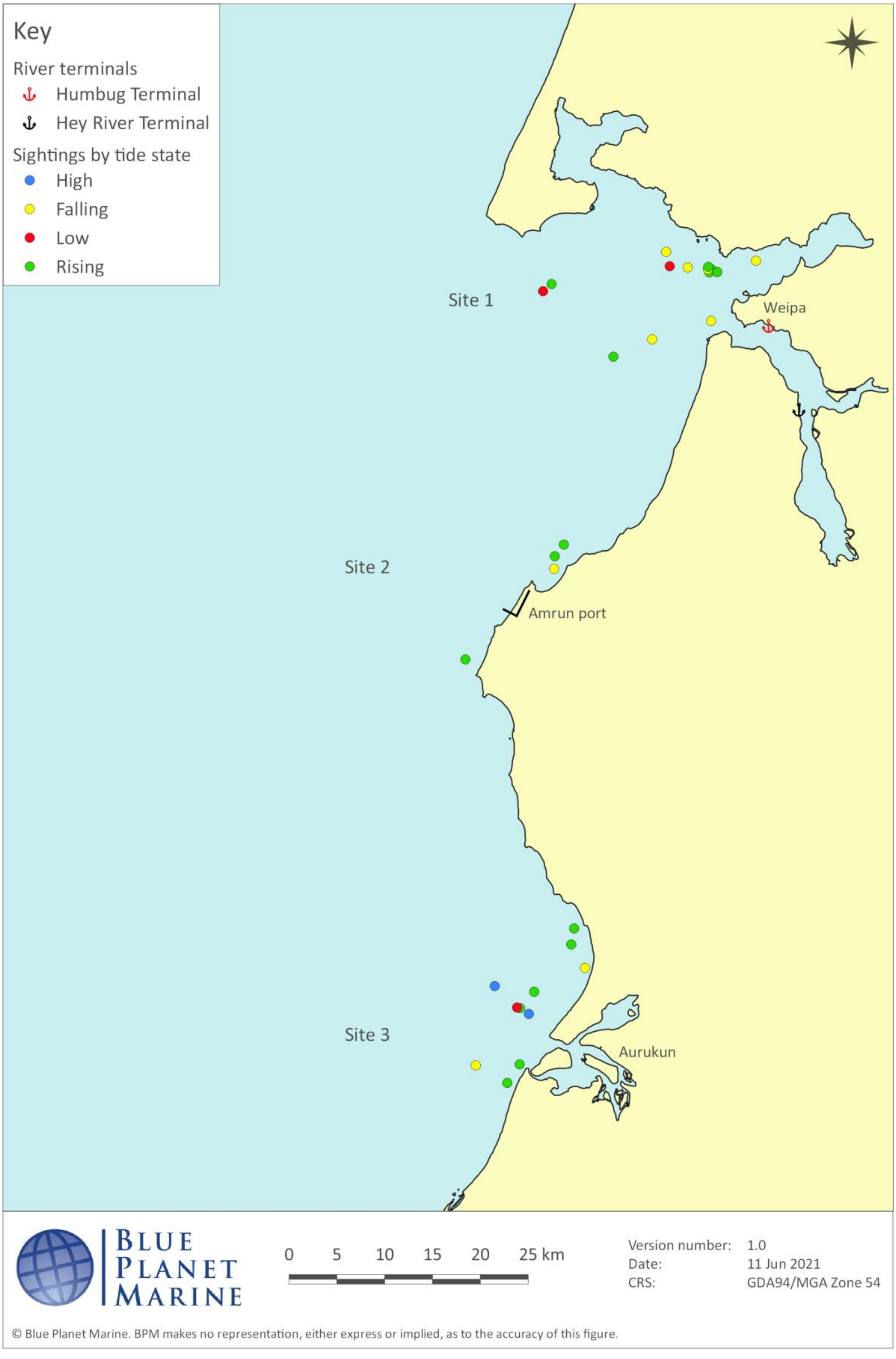

Figure 37. Snubfin dolphin sightings by tidal state during the 2014-2019 surveys.

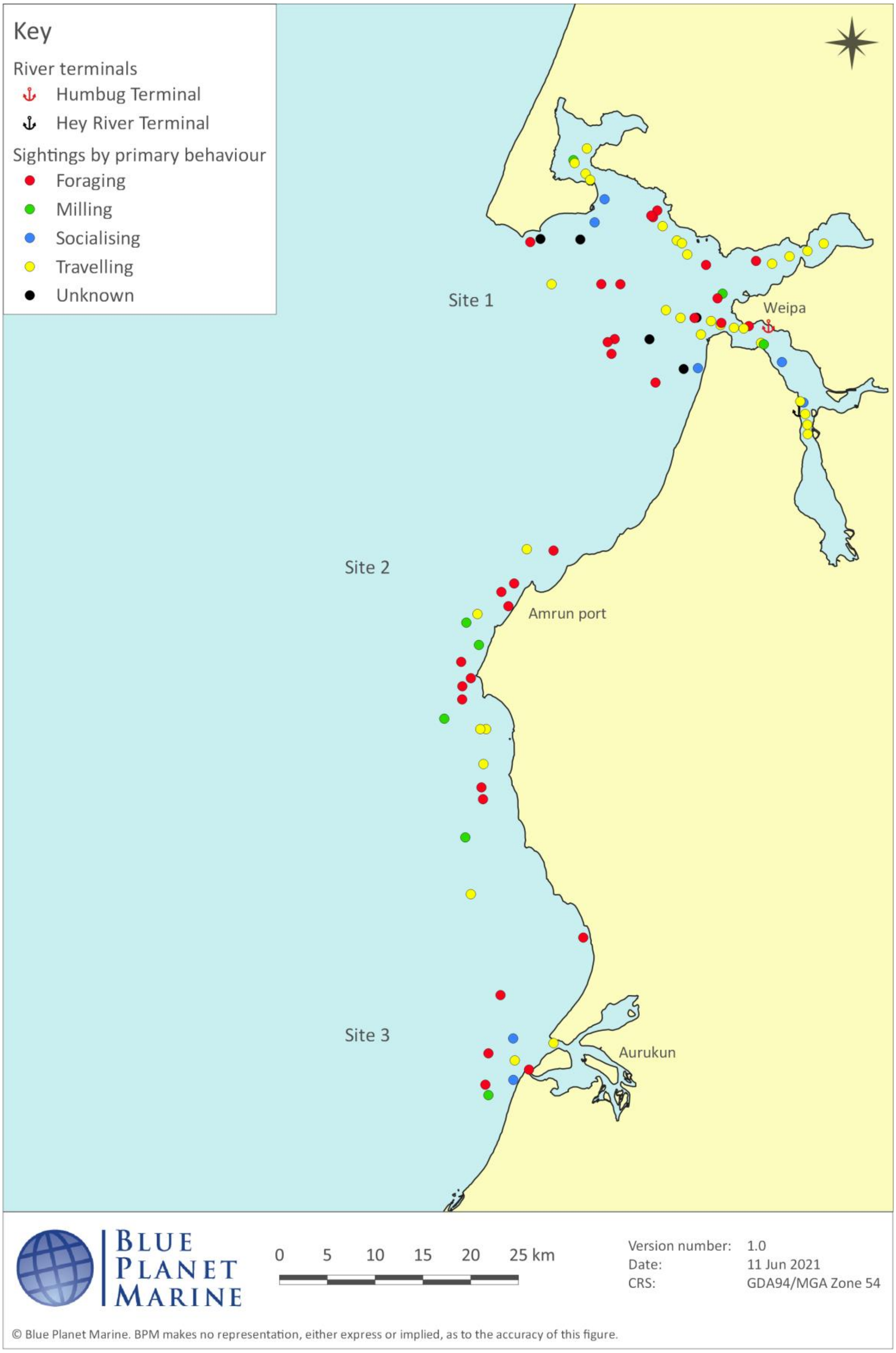

Figure 38. Sighting locations and primary behaviours of humpback dolphin groups observed during the 2019 survey.

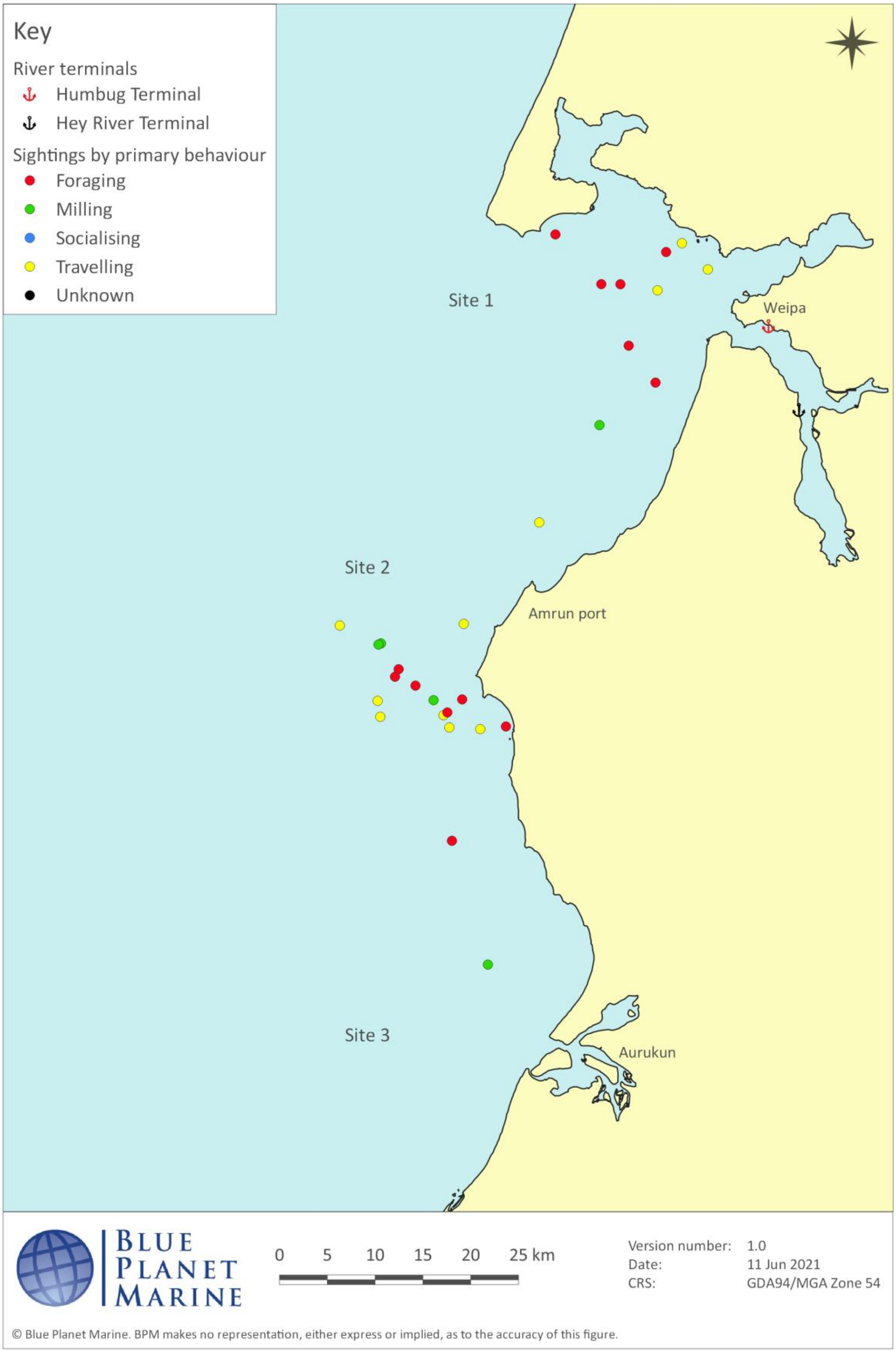

Figure 39. Sighting locations and primary behaviours of bottlenose dolphin groups observed during the 2019 survey.

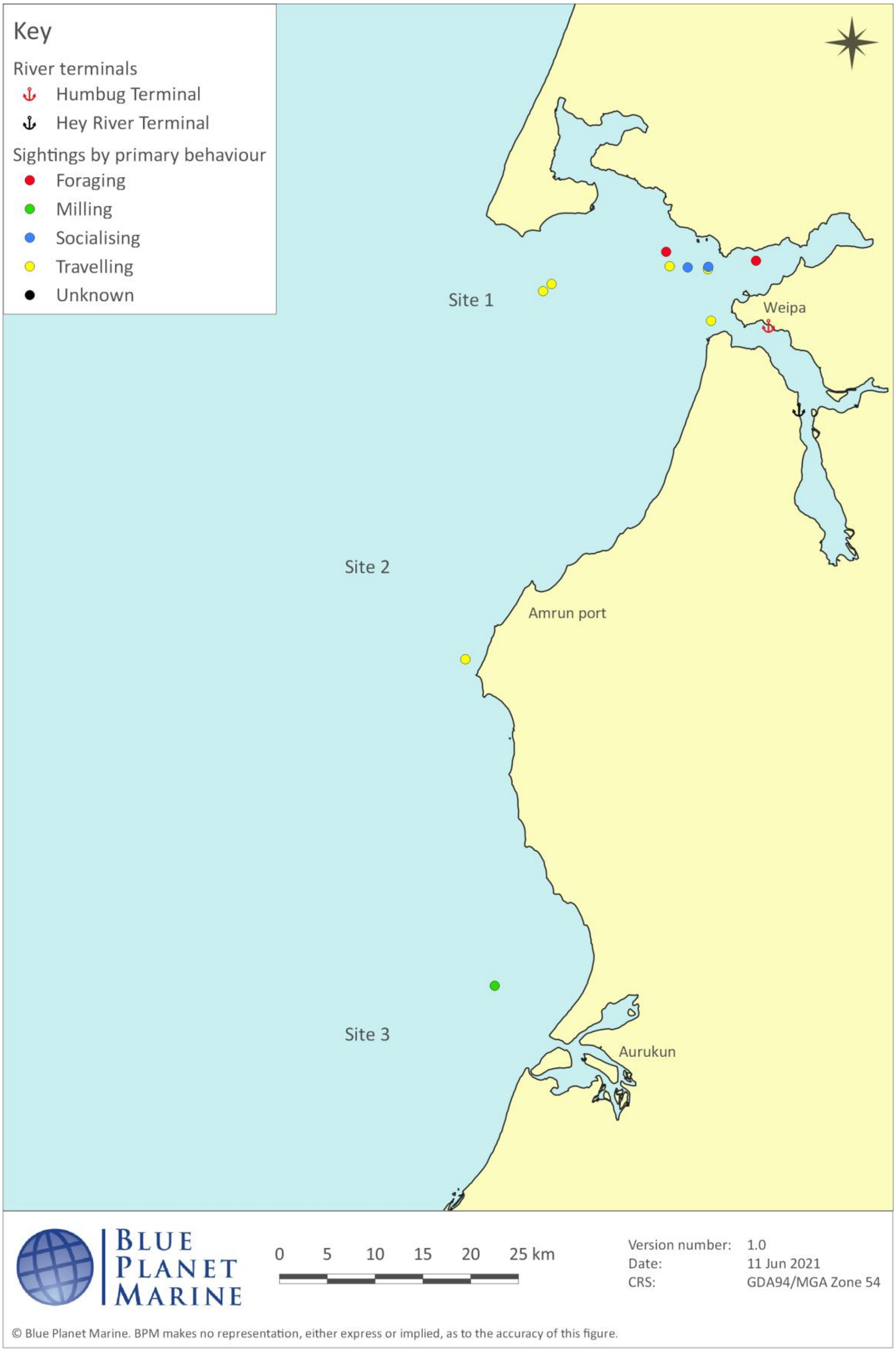

Figure 40. Sighting locations and primary behaviours of snubfin dolphin groups observed during the 2019 survey.

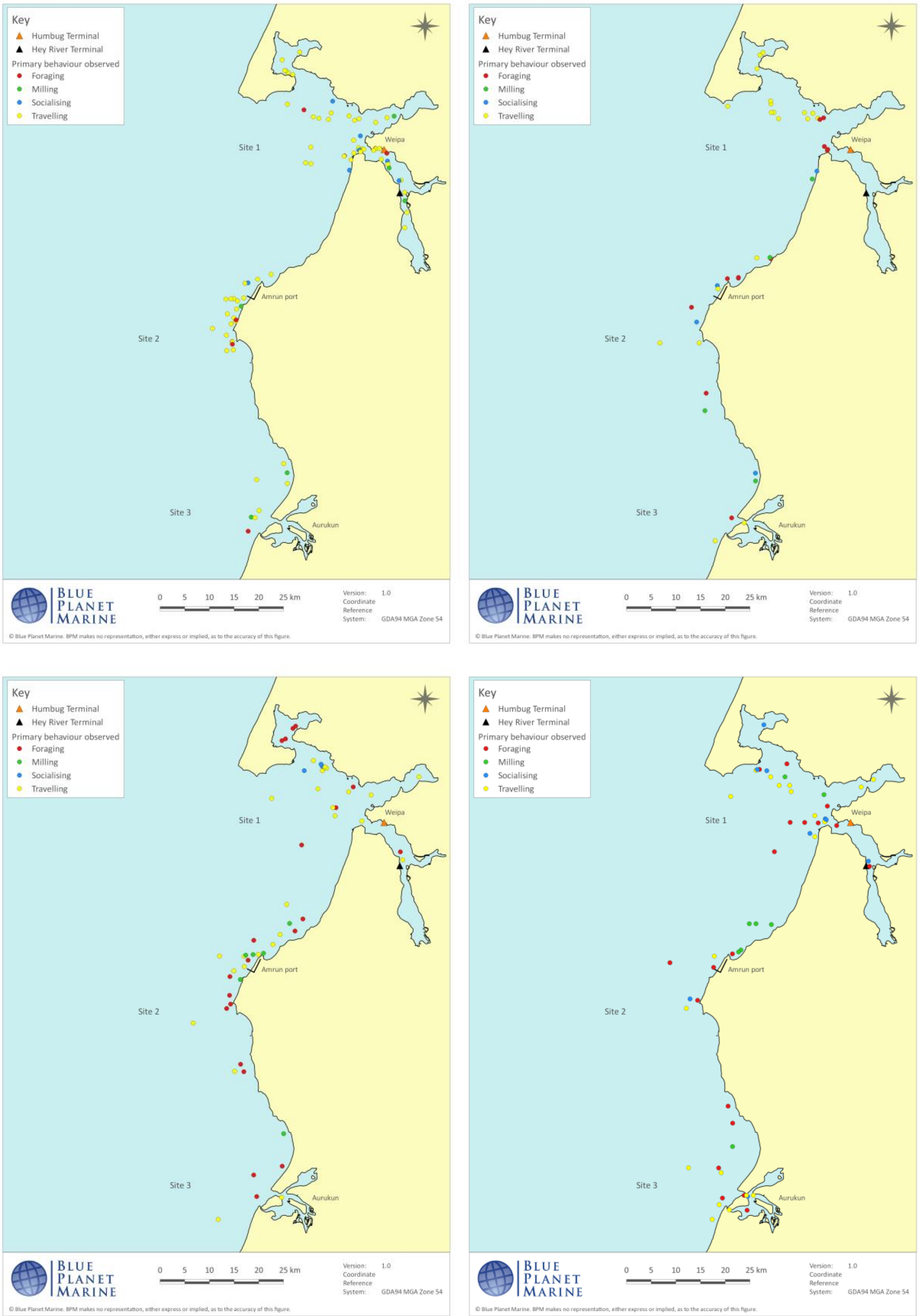

Figure 41. Sighting locations and primary behaviours of humpback dolphin groups observed during the 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right) surveys.

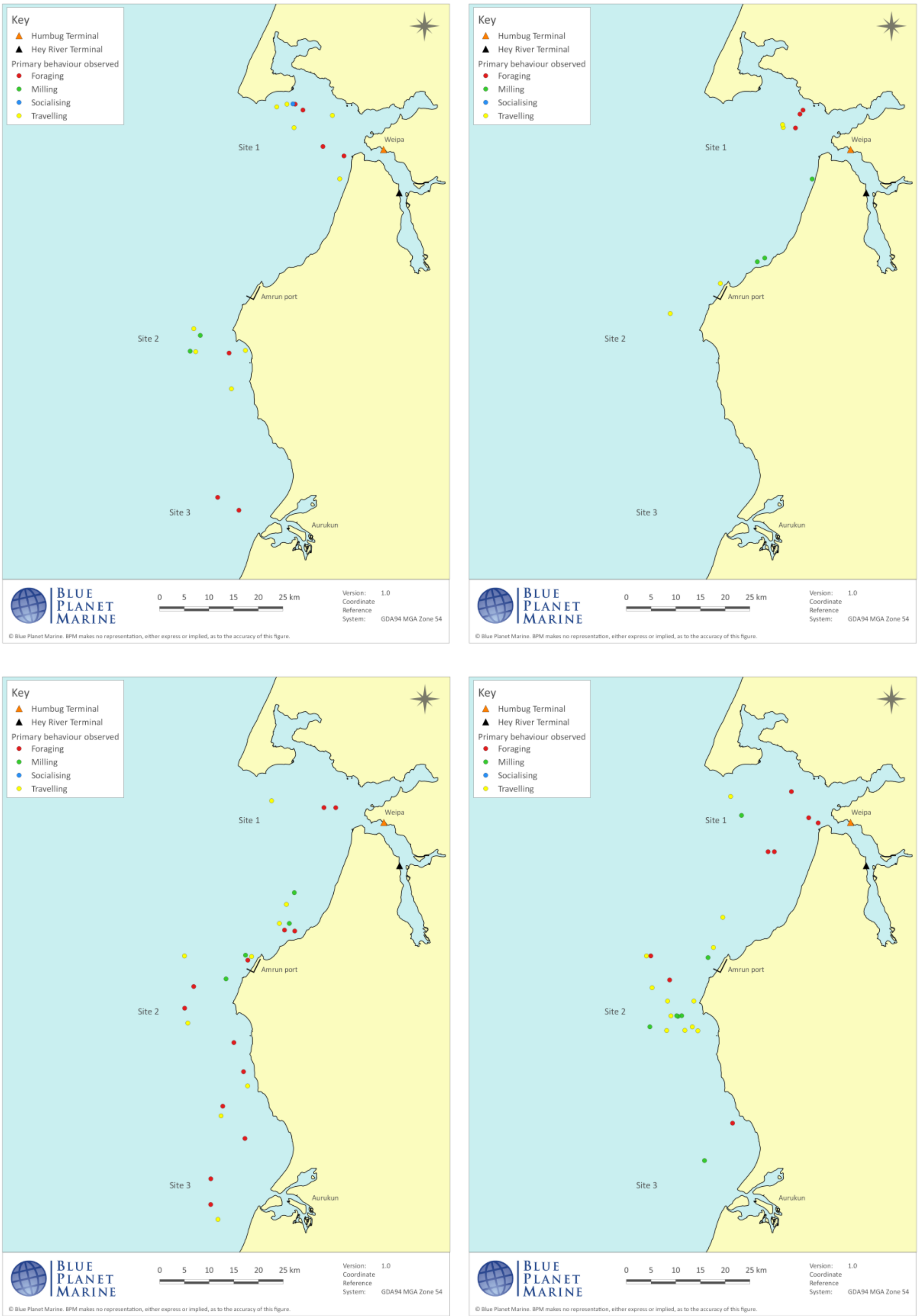

Figure 42. Sighting locations and primary behaviours of bottlenose dolphin groups observed during the 2014 (top left), 2016 (top right), 2017 (bottom left) and 2018 (bottom right) surveys.

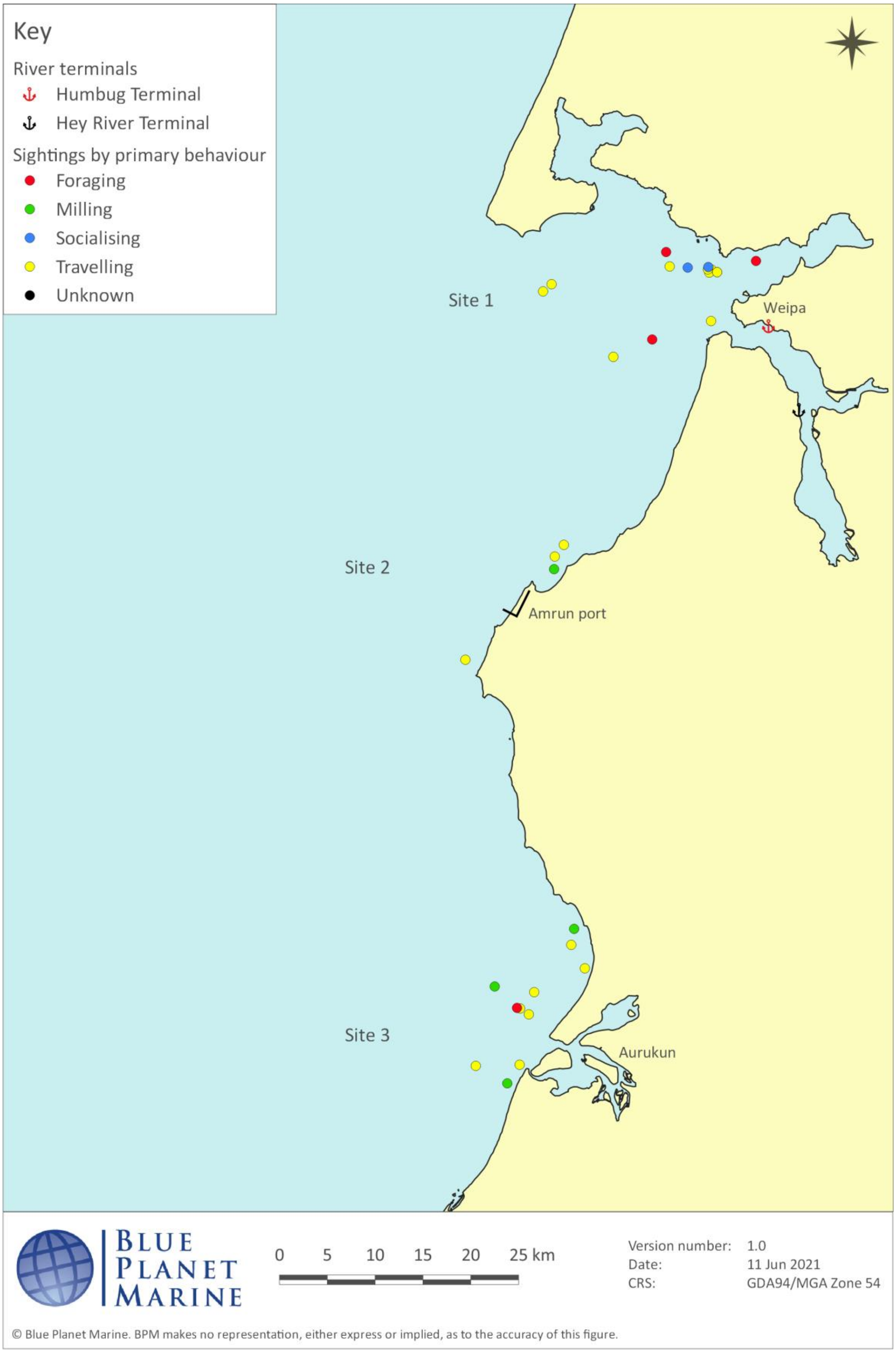

Figure 43. Sighting locations and primary behaviours of snubfin dolphin groups observed during the 2014 - 2019 surveys.

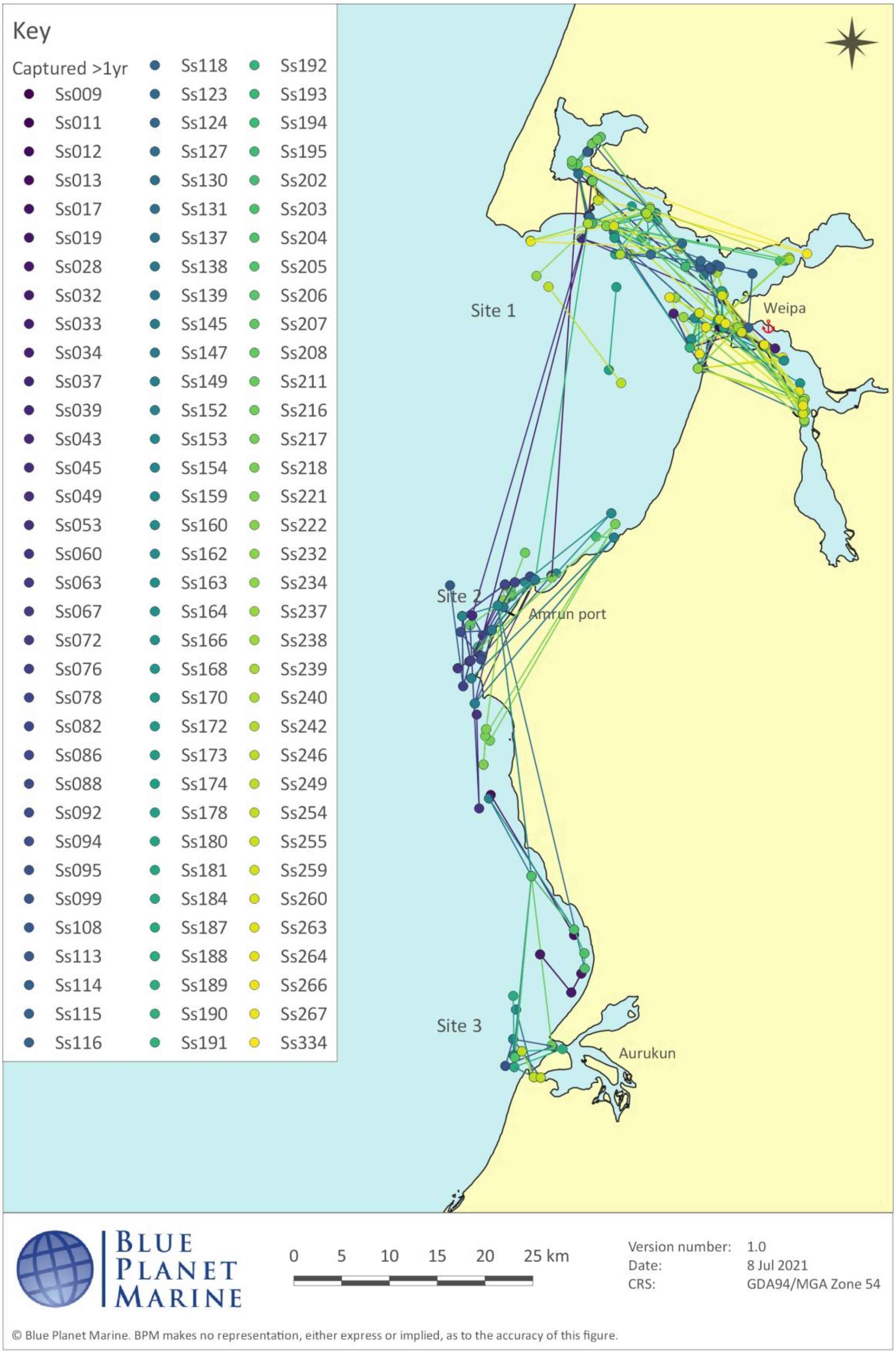

Figure 44. Sighting locations of 104 humpback dolphins photographed in at least two years of the project from 2014-2019, with interpolated lines drawn between sightings.