Dolphin Research Australia

Knowledge, Awareness, Action – Conserving Our Seas

Healthy Waterways-Healthy Dolphins

Project Report 2019

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Acknowledgements

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Contents

Summary

This report provides a summary of the Healthy Waterways-Healthy Dolphins Project from its commencement in 2018 to June 2019. It provides an outline of the preliminary results from the project over this period from the Tweed River, Richmond River and the Gold Coast-Broadwater estuaries. Comparisons to historical baseline data obtained from these sites are also made.

Dolphin Ambassador Citizen Science teams completed 51 surveys (190 hours) and observed 36 groups across all sites. The majority of groups observed were female Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) with dependent calves engaged in foraging behaviours. Long-term site fidelity was evident with some individuals resighted multiple times across the 2018/19 sampling period and in historic surveys.

Linear encounter rates (LER), number of dolphins per hour (DPH) and average group sizes in the Tweed River were 50% less in 2018/19 compared to 2010/11. Similarly, group sizes were also 50% smaller in the Gold Coast-Broadwater 2018/19 compared to 2010/11, however, LER and DPH remained comparable at this site over the same time periods. These differences are possibly related to large differences in environmental conditions caused by heavy rainfall in 2010/11 and below average rainfall in 2018/19, however further investigation is required to confirm this.

Fourteen dolphin stranding events were recorded in the Northern Rivers and Gold Coast region in 2018 to June 2019. Detailed assessments were made of 12 animals with the majority of individuals being immature male Indo-Pacific bottlenose dolphins.

Ongoing efforts will focus on continuing surveys at each site to determine the health, status and abundance of communities of dolphins that utilise the Tweed River, Richmond River and Gold Coast-Broadwater estuaries.

1. Project Introduction

Regional dolphin populations that utilise coastal and estuarine habitats are economically, socially, culturally and environmentally valuable. As apex predators, dolphins are bioindicators of environmental health and as such, can provide important insight into the condition of the habitats upon which they rely (Wells et al. 2004). Yet coastal dolphins are among the most vulnerable animals due to their exposure to human activities and habitat degradation, which makes them more susceptible to injury, disease and mortality (Bossley et al. 2016; Bossley and Woolfall 2008; Chabanne et al. 2012; Chabanne et al. 2017; Moreno and Mathews 2018). In recent years, concerns have increased regarding the impacts of threatening processes on dolphin populations inhabiting estuarine areas (Chabanne et al. 2012; Chabanne et al. 2017).

Estuarine communities of bottlenose dolphins are particularly vulnerable to decline due to elevated exposures to anthropogenic activities and habitat degradation that are concentrated along coastal fringes and more precisely around estuarine areas where the majority of urbanized and industrial activities occur (Chabanne et al. 2012). Pressure from habitat loss from land reclamation, lower water quality levels due to industrial and residential source pollutants, sewage and sediment run-off in addition to, exposure to dredging, port, boating and fishing activities, for example, have been linked to declines in the health and abundance of estuarine communities (Bossley et al. 2016; Chabanne et al. 2012).

There is some evidence that suggests resident dolphin communities occupy and rely on the major estuarine systems of South East Queensland and Northern New South Wales (Fury and Harrison 2008; Peterson 2012). Concerns for the health of dolphin populations in this region have recently escalated following the detection of viruses in stranded animals as well as the key threats including shark nets and degradation of coastal habitats from coastal development and agricultural practices, pollution, vessel activities, fishing interactions, and decreased prey (Cockcroft 1992; Krogh and Reid 1996; Ryder et al. 2015; Stone et al. 2012; Woinarski et al. 2014).

Despite these concerns and the economic, social, cultural and environmental value of dolphin communities in Northern New South Wales and South East Queensland region, we know little about their health and survival. Are their numbers stable? Do their calves survive to maturity? Do they have the capacity to withstand the existing threats - particularly if they use degraded estuarine habitats every day?

The Healthy Waterways-Healthy Dolphins Project is a long-term research and monitoring program that will integrate non-invasive scientific research and education to provide for environmentally positive outcomes. The project will help fill these critical knowledge gaps and determine the status and health of dolphin communities in estuaries of South East Queensland and Northern New South Wales. Citizen science teams will investigate the abundance, status and health of dolphin communities that utilise a number of different estuaries including the Gold Coast-Broadwater. Participants will gain skills in recording dolphin behaviour and identification along with testing water quality. This project will raise awareness and encourage stewardship of local environments,

particularly rivers and coastal habitats through citizen science participation and community engagement. Furthermore, this project will contribute to the long-term protection of coastal dolphins to aid in effective management and conservation planning by providing better scientific understanding of the status, health and relationships between higher order predators and environmental quality.

1.1 Project Aims

The Healthy Waterways-Healthy Dolphins Project aims to investigate the relationships between the utilisation and status of coastal dolphin populations and the health of estuaries. To achieve this, key estuarine systems in South East Queensland and Northern New South Wales have been selected as study sites; Gold Coast-Broadwater, QLD, Tweed River, NSW and Richmond River, NSW. Each of these estuaries have different levels of disturbance and are suitable for comparison. The following project objectives are to:

- Assess the abundance, trends and residency patterns of dolphin communities in these major estuarine systems;
- Identify habitats and prey species of critical importance to resident dolphin populations;
- Examine the health of resident populations of dolphins utilizing major estuaries using assessments of external features from photographs and samples from stranded animals;
- Investigate the relationships between estuarine condition from water quality monitoring data and the status of dolphin communities;
- Provide opportunities for public engagement and participation to encourage environmental stewardship;
- Provide for more informed management plans and ensure more effective conservation initiatives.

2.0 Study Sites

The Gold Coast-Broadwater, Tweed River and Richmond River estuaries are the primary study sites. Table 1 outlines the size of the study sites and the length of each survey route. Each estuary features main and branched channels with mangrove, seagrass, sandy and muddy substrates. Habitats supported by these dynamic estuaries have a high conservation value being vital supports for the reproduction and feeding of many aquatic fauna species (Dunn et al. 2014). They are a nursery ground for commercial and recreationally important fish species (Dunn et al. 2014), which are also known prey of Indo-Pacific bottlenose dolphins, e.g. yellow fin bream (*Acanthopagrus australis*), sand whiting (*Sillago ciliata*) and mullet (*Mugil cephalus*) (Cockcroft and Ross 1990; Dunn et al. 2014; Fury and Harrison 2011b).

Limited baseline information is available on the dolphin communities from each of these sites providing a rare opportunity to draw comparisons over relatively long timeframes.

Table 1: Catchment and estuary area for each study site along with the total survey route length.

Site	Catchment Area (km^2)	Estuary Length (km	Survey Route (km)
Tweed River, NSW[1]	1126	37	41
Richmond River[1] Estuary, NSW	6878	42	44
Gold Coast-Broadwater, QLD[2]	>5872	-	105

[1]Information sourced from http://www.ozcoasts.gov.au

[2]Total catchment area includes the Coomera, Nerang and Pimpama Rivers and the Broadwater catchments combined. Information sourced from https://www.goldcoast.qld.gov.au/

2.1 Tweed River Estuary

The Tweed River system is a wave dominated estuary with a catchment area of 1126km^2 and an estuarine area of 22.7km^2 with one constricted entrance via the river bar to the open ocean (http://www.ozcoasts.gov.au). The Tweed estuary includes important habitats for fish species, with 149 species identified in the lower catchment (Pratt et al. 2017). Seagrasses, saltmarshes and mangroves are also key habitats of the Tweed estuary.

A previous baseline study estimated a community of around 55 Indo-Pacific bottlenose dolphins (95% CI = 51.56-57.76) regularly used the Tweed River estuary (Author's unpublished data). This community appears to consist of resident individuals and primarily mother-calf groups that have been observed up to 30km upstream (Peterson 2012).

A key management action outlined in the Coastal Management Program for the Tweed River Estuary, is to '*support the maintenance of populations of higher order predators in the estuary (such as resident Indo-Pacific bottlenose dolphins and eastern osprey) through:*

- *Implementing actions that improve compliance with water quality objectives;*
- *Limiting impacts associated with dredging;*
- *Minimising conflict between resident populations, boating and fishing activities;*
- *Engaging the community re conservation of higher order predators; and*
- *Continuing support of population monitoring of higher order predators in the estuary* (Pratt et al. 2017).

This project seeks to inform and assist to implement these management actions.

Estuary Health

The Tweed River catchment has been largely modified and disturbed. The Tweed region experiences increasing pressures from a growing coastal population. Between 2009-2016, the Tweed region (Local Government Area) increased by 6.84% reaching a density of 70 people/km^2 (Pratt et al. 2017). Extensive urban areas line the edges of the lower Tweed catchment. Urbanised areas also feature in the upper catchment with the major township of Murwillumbah. The extent of urban areas is expected to increase in the near future with further developments zoned to cater for the increasing population. Land-use practices in the middle and upper catchment are dominated by agricultural activities including grazing (e.g. cattle) and cropping (e.g. sugar cane). The estuary is also utilised by aquaculture (i.e. oyster farming) and tourism ventures in addition to being popular for recreational boating, fishing and other aquatic activities (e.g. swimming, snorkelling and diving). Numerous conservation areas have also been designated within the boundaries of the Tweed River catchment including the Stotts Island Nature Reserve situated along the mid-estuary and the Mooball National Park and Mount Nullum Nature Reserve in the upper catchment (Pratt et al. 2017).

Land use practices along with the extensive clearing of riparian vegetation have contributed to the estuary experiencing elevated levels of sedimentation, nutrients, acid sulphate soils and pollutants largely from stormwater, agricultural and urban run-off (Pratt et al. 2017). Extensive reductions (approximately 80%) in seagrass coverage and density have occurred between 1930 and 2015 in the lower reaches of the estuary (Pratt et al. 2017). This decline has been partially attributed to increased nutrient loads and, in some areas, poor tidal flushing and low abundance of macro/microinvertebrate epiphytic grazers.

New South Wales Fisheries recently classified the status of the Tweed River estuary to be in 'fair condition' following an extensive assessment (Riches 2016). The broad classifications of very poor, poor, fair, good, and very good were based on extensive analysis of fish community data using a number of variables including; nativeness, expectedness and recruitment (Riches 2016).

The recent environmental health report card for the Tweed River (as part of the Tweed River Estuary Coastal Management Program) scores the water quality from 'A' (good) primarily in the

lower estuary to C in the upper-middle estuary and D in the Cobaki, Terranora and Rous tributaries (TSC 2019).

2.2 Richmond River Estuary

The Richmond River stretches from Ballina, Northern New South Wales, to over 600km inland with a total catchment area of 6861km^2. The estuary is a wave dominated estuary that supports a number of threatened communities (Campbell et al. 2011). Indo-Pacific bottlenose dolphins utilise the Richmond River estuary throughout the year (Fury and Harrison 2008). Previous research estimated the community to consist of 34 (95% CI 19-49) dolphins that exhibited high levels of site fidelity and residency (Fury and Harrison 2008; Fury and Harrison 2011b). Dolphins were more likely to enter the estuary 1-2 hours prior to the high tide with higher numbers occurring during the Austral months of spring. Dolphins were less likely to use the estuary during flood events during periods with decreased salinity, pH and dissolved oxygen and increased turbidity (Fury and Harrison 2011a). Fury and Reif (2012) reported that an increase in the poxvirus within the Richmond River dolphin community correlated to flood events.

Estuary Health

Major modifications have occurred over time within the Richmond River catchment and the estuary continues to experience intensive pressures from human land-use practices. Changes in the floodplain and drainage systems have caused considerable alterations in the natural systems. Agricultural practices are the most prominent land-uses including horticulture (e.g. macadamia, tea tree and sugar cane farming), cattle grazing and forestry (Dawson 2002). Urbanised centres around the major townships of Ballina and Lismore dominate the lower and upper catchment boundaries (respectively). These practices have led to extensive land-clearing and clearing of riparian vegetation which has led to bank erosion, sedimentation and estuarine habitat loss (Dawson 2002). Additionally, increased stormwater, urban and agricultural runoff increase pollutant loads adding to the reduced water quality of the river system. Designated natural reserves and protected areas compose the minority of the land-use within the catchment. The river is also used for recreational and commercial fishing (including aquaculture and oyster farming) and is popular for boating and tourism activities (Dawson 2002).

During periods of heavy rainfall, the estuary is prone to acid sulphate influxes and flooding. Several major fish kills in recent decades have also occurred in 2001, 2008 and 2017. The 2001 fish kill was one of the largest recorded in Australia and left the river ‘devoid of oxygen and life’ (Dawson 2002). These fish kills were attributed to low levels of oxygen, increased blackwater, combined with flood, drainage issues and sediment loads (Dawson 2002).

In 2016, the health of the fish communities in the Richmond River estuary were reported to be in good condition in the main arm and lower reaches with communities in the numerous middle and upper tributaries being of fair to poor condition (Riches 2016). However, a recent comprehensive assessment on the health of the estuary reported the overall state of the Richmond catchment to be in poor condition (Ryder et al. 2015). This Ecohealth program assessment uses a standardised approach to determining the health of catchments based on a number of physical, chemical and

biological indicators in marine, estuarine and freshwater waterways (Ryder 2012). The assessment uses standardised condition grades from A (excellent) to E (very poor) to report on the overall health by combining measures of indicators measured across the catchment (Ryder 2012). Under this grading system, the Richmond River catchment's overall grade was a D, with upper estuarine areas having consistently poor conditions due to high nutrients, turbidity and algal blooms. The headwater streams were in slightly better condition with a grade of C.

2.3 Gold Coast-Broadwater

The Gold Coast-Broadwater system is fed by four principal rivers; the Albert-Logan, Coomera, Pimpama and Nerang and is framed by two barrier islands in the east (North and South Stradbroke Islands) and a sand spit. Two constricted entrances between the barrier islands create the main access to the open ocean in the east with access in the north available through the wider Moreton Bay, a large sheltered coastal embayment. The Gold Coast-Broadwater estuary is a dynamic tidally dominated delta system with a catchment area of 5872 km^2 and water area of 98.85 km^2 (Ozcoasts, 2015; www.ozcoasts.gov.au accessed 3rd December 2015). The Gold Coast-Broadwater survey site encompasses the southern limits of the Moreton Bay Marine Park.

There is little known about the dolphin communities that utilise the Gold Coast-Broadwater region. However, an early study completed between 2010-2011 provides some limited baseline information (Author's unpublished data). The study findings indicated that the Gold Coast-Broadwater estuary supports a small resident community of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). This community of dolphins was estimated to consist of 27 adults (95% CI 22.3-31.4) (Author's unpublished data) that have a core habitat at the entrance to the Coomera River (Peterson 2012) with some individuals having long-term residency (Walters 2015).

Estuary Health

The Gold Coast-Broadwater region is experiencing increasing pressure from anthropogenic activities and population growth. Recreational boating and fishing are popular activities throughout the waterways in addition to tourism operations. Land-use practices are typified by agriculture in the upper-middle catchment and highly urbanised areas in the lower catchment. Urban areas consist of extensive canal developments and areas of reclamation. The effects of urban development have resulted in increased sedimentation, nutrient and stormwater runoff contributing to declines in water quality (Waltham et al. 2011).

Recent assessments from the Ecosystem Health Monitoring Program led by Healthy Land and Water, report the environmental conditions within the study site range from excellent to fair. The Monitoring Program is a comprehensive program that undertakes regional assessments on catchment, river and estuary health. The program provides a grade of the condition of regions based on multiple indicators including; pollutant loads (sediment, nitrogen, chlorophyll a and phosphorus), habitat extent (wetland, seagrass, coral and mud etc.), riparian extent (freshwater wetland, estuarine wetland, riparian), aquatic invertebrates and fish (Water 2018). Condition grades range from A (Excellent) to F (Fail).

Grades from 2019 reported by the Program that correspond to the regions that encompass the Gold Coast-Broadwater study area are outlined in Table 2.

Table 2: 2019 Health Monitoring Program Report Card Grades for the Gold Coast-Broadwater study site subdivided by catchment and sites defined by the program. Information sourced from https://reportcard.hlw.org.au.

Site	Grade
Nerang	C
Pimpama-Coomera	B-
Broadwater	A
Albert	B-
Logan	C
Southern Bay	B+

3.0. Methods

3.1 Information Collected

To achieve the project objectives, four datasets were used; i) monthly vessel-based surveys, ii) historical data from vessel surveys, iii) opportunistic dolphin sighting information from the public from Dolphin Research Australia's Dolphin Watch initiative, and iv) samples from deceased dolphins (Figure 1).

Trained observers were positioned on the vessel such that the entire circumference of the vessel could be scanned for dolphins. When dolphins were detected, the vessel would approach to no closer than 30m (as per NSW Animal Care & Ethics permits). The group would then be followed for a minimum of 20mins and a maximum of 60mins. If the group displayed any avoidance behaviours towards the research vessel or exited the estuary to the open coast, the group follow was terminated. Animals were considered to be in the same group if they were engaged in the same activity and within an approximate radius of 100m (Mann 2000; Martin and Bateson 1993).

i) Dedicated vessel-based surveys were completed once per month at all sites to achieve a minimum of 12 surveys per site per year. Vessels travelled along pre-defined survey routes in each estuary at a speed of no more than 12knots (22km/h). Figures 5, 6 and 7 show the survey boundaries and routes at each site.

Figure 1: Sources of data collated for the Healthy Waterways-Healthy Dolphins Project.

During surveys, information on the behaviour, composition and location of dolphin groups were recorded manually onto datasheets. Behavioural observations were noted every two minutes using a combination of continuous and time-scan sampling (Martin and Bateson 1993). Behaviours were defined as states; feeding, travelling, travel-foraging, milling or resting and socialising (see Appendix A for definitions). The occurrence of behaviour events such as leaps and tail slaps were also noted (Appendix A). The composition of groups was defined according to age-class; the number of adults (full-grown individuals), subadults or juveniles (individuals approximately ¾ the size of an adult), calves (less than ¾ the size of an adult and spending the majority of the time in infant position (see Appendix A for definition)) and unknown (individuals whose age class could not be confirmed) (Chabanne et al. 2017).

Photographs were taken using a Canon 5D Mark III digital SLR camera with 100-400mm lens of each individual dolphin's dorsal fin for identification. Identification of individuals was determined by the unique pattern of nicks and notches along the leading and trailing edges of the dorsal fin (Defran et al. 1990; Hammond et al. 1990; Wursig and Jefferson 1990). Based on Hawkins and Gartside (2008), each image was graded from 1 (poor) -10 (excellent) according to quality, contrast and clarity of the fin. Those images rated as poor (equated to grades 1-2) were considered too low for the purposes of photographic identification and discarded. Images of ≥ 4 were considered of sufficient quality to be included in photo-id assessments.

Photographs of each individual dolphin identified will also be used to assess the animal's health. Using visual observation techniques, epidermal assessment of each individual from each estuary will be assessed for the type and extent of skin lesions and injury. Different types of skin lesions will be identified and categorised (e.g. the presence of poxvirus, black spot etc.) and compared between age-class and estuarine community. Similarly, the extent and type of injury present will also be assessed and categorised (e.g. the presence and extent of shark bite wounds, fishing line entanglement and boat-strike).

To gain an understanding of the habitat preferences and the influence of environmental parameters, water quality measures were taken where dolphins were present and absent. Where possible, water quality measures were recorded at each site using a multimeter probe. At all sites, temperature, conductivity, dissolved oxygen, turbidity, salinity and pH were recorded (with the exception of Tweed River where turbidity could not be measured due to the limitations of the equipment at this site). Water quality measures were taken at the end of the group follow (dolphin 'present' measure). A minimum of three 'dolphin absent' recordings were also taken at random *ad hoc* locations throughout the survey.

ii) Data obtained during recent surveys (2018-2019) were then compared with historical baseline data sets (Author's unpublished data) that have been collected between 2010-2011 in the Gold Coast and Tweed River; and periodically between 2014-2006 and 2016 in the Richmond River. These historical data provide a unique opportunity to obtain a long-term assessment on these dolphin communities. These historical data sets were obtained from vessel-based surveys using comparable behavioural and photographic identification techniques. Sampling of the sites was completed over intensive survey blocks during the Austral summer and/or winter at each site. The same survey routes were used to complete both historic and present data collection periods. The exception to this were surveys completed during 2004-2006 in the Richmond River region which focused on sampling the coastal region (Hawkins 2008). Individuals identified during this period were compared to the present sampling in the Richmond River. No other comparisons were possible with the 2004-2006 dataset.

iii) The Dolphin Watch citizen science initiative encourages members of the public to submit their dolphin sightings (including date, time, location, group size, behaviour and photographs) through the Dolphin Research Australia website. These opportunistic data provide useful information that can contribute to the understanding of residency, habitat use and health of dolphins in the regional communities.

iv) Additional data were acquired opportunistically from deceased and stranded beach-cast cetaceans. Necropsies were performed where possible and samples obtained to perform virology, histopathology and toxicology.

3.2 Data Analysis

Preliminary data collected from each site between January 2018 and June 2019 are summarised descriptively in the following sections. These observations are briefly compared with historic data

sets where possible. It should be emphasised that these results are preliminary only and present the progress of the Healthy Waterways-Healthy Dolphins Project.

Using 2018/19 boat-based data, a summary of the number of groups, individuals, dolphins per hour of survey effort (DPH) and the linear encounter rate (i.e. the number of dolphins encountered per km of survey effort, LER) were calculated for each site and compared to historical data. Mean group sizes were also calculated and compared between sites and sampling periods.

The survey routes, location of groups encountered during 2018/19 and historic sampling periods from each site were plotted in ArcGIS 10.5 (Esri Corp.). For Tweed and Richmond River sites, these locations were mapped with major estuarine habitat spatial layers (Creese et al. 2009).

The occurrence of different behaviour states for groups observed at each site were summarised to provide an indication of overall usage patterns. The occurrence of behaviours were compared between sites and sampling periods. Average environmental measures were then calculated where dolphins were present and absent for each site. At this stage of the project, environmental measures were only summarised for 2018/19 Richmond and Tweed River data.

The number of ‘marked’ individuals (i.e. dolphins with long-lasting natural marks such as scars, nicks and notches on the dorsal fin) were tallied for each site. The percentage of individuals that were newly identified and resighted between time periods for each site was then determined and compared between sampling periods.

Stranding records for Northern Rivers New South Wales were tallied using data from the NSW Office of Environment and Heritage Elements database and Sea World Research and Rescue Foundation along with incidents reported directly to Dolphin Research Australia. At the time of writing, similar records were unavailable from the Queensland Department of Environment, Science and the Arts. Where possible, external and internal assessments were made of deceased dolphins. External examinations included morphological measurements and recording of any injuries. Minimum samples acquired for histopathology, virology and toxicology included skin, blubber and teeth. Internal assessments from necropsy procedures included sampling of major organs e.g. kidney, lung, heart, and muscle.

4.0 Preliminary Results

4.1 Survey Effort 2018-June 2019

Between 2018 and June 2019, 51 vessel-based surveys (190 hours) were completed across all three sites (Table 3). Dolphins were observed on 51% of all surveys with the Gold Coast-Broadwater site having the highest percentage (88.9%) of encounters per survey and the Tweed River the lowest.

Table 3: Survey effort and the number of surveys dolphins were observed at each site from the commencement of the Project in 2018 to June 2019.

Site	Date Range	# Surveys	# Hours	# Surveys dolphins seen	% Surveys dolphins seen
Tweed River	February 2018-June 2019*	17	73	9	53
Richmond River	January 2018-June 2019**	14	48	9	64
Gold Coast Broadwater	May 2018-June 2019***	9	69	8	89
Total	**January 2018-June 2019**	**51**	**190**	**26**	**51**

*Note: *Monthly surveys commence in February 2018. **Monthly surveys commenced in July 2018. ***Monthly surveys commenced in November 2018.*

4.2 Historic Survey Effort

Historic data sets were acquired from each site prior to 2018 and provide a baseline for each estuarine community of dolphins. Table 4 outlines the sampling periods and effort from these surveys.

Table 4: Survey effort and the number of surveys dolphins were observed at each site from historic surveys prior to 2018.

Site	Date Range	# Surveys	# Hours	# Surveys dolphins seen	% Surveys dolphins seen
Tweed River	December 2010-August 2011	22	81	14	64
Richmond River	January - February 2016	11	43	7	64
Gold Coast Broadwater	December 2010-August 2011	38	245	17	45
Total	Historic surveys	71	369	38	54

The percentage of surveys dolphins were encountered in the Gold Coast has increased from 45% in 2010/11 to 89% in 2018/19. Despite the low sample size to date, this difference is notable. Comparably, in the Tweed a decrease in the number of surveys dolphins were encountered occurred from 64% in 2010/11 to 53% in 2018/19. The percentage of surveys where dolphins were encountered were the same between datasets in the Richmond River.

4.3 Dolphin Group Sightings

A total of 38 groups were observed in the 2018/2019 survey period with the majority of sightings recorded in the Richmond River (Table 5). Almost all groups observed at all sites were of Indo-Pacific bottlenose dolphins, with the exception of one group of Australian humpback dolphins (3 adults and 1 calf) in the Gold Coast-Broadwater.

Group sizes ranged between 1 and 28 individuals. Richmond River had the largest mean group size of 5.6 (SD = 6.0) in 2018/19 compared to the Tweed and Gold Coast-Broadwater that had comparably smaller group sizes (mean 2.5 SD = 1.1; 2.8, SD = 1.7 respectively). The majority (63%; N = 24) of groups overall contained females with dependent calves, however, slight differences were evident between sites (Tweed River = 50%, Richmond River = 71%; Gold Coast = 58%; Table 5).

The Richmond River also had higher LER and DPH in 2018/19 compared to all other sites (Figures 2, 3 and 4). Two large groups of 17 and 28 individuals were encountered in the Richmond River on separate surveys. When these outlying groups were excluded from the analysis, the patterns remained stable, whereby the largest groups still occurred in the Richmond River.

In the Tweed River, 2018/19 LER and DPH were less than half those of historic 2010/11 levels (Figures 2 and 3). Similarly, mean group sizes were also half the size in 2018/19 compared to 2010/11 (Figure 4). Comparably, the LER and DPH in the Gold Coast were similar between 2010/11 and 2018/19. However, mean group sizes in 2010/11 were also twice as large as those encountered in 2018/19 (Figures 2, 3 and 4).

In the Richmond River, the LER and DPH between 2016 and 2018/19 sampling periods remained comparable with a slight increase in the mean group sizes observed (Figures 2, 3 and 4). The large standard deviations evident in the Richmond River suggest high variability in LERs, DPH and group sizes.

Figures 5, 6 and 7 show the locations of groups encountered during the 2018/19 and historic surveys at each survey site. Groups were observed up to 13km upstream in the Tweed River and 19km in the Richmond River during 2018/19 surveys. It should be noted that reports were received from members of the public in April 2019, of a mother-calf group of four individuals feeding on mullet up to 65km upstream in the Richmond River. However, this appears to be an uncommon event. The majority of groups were observed less than 5km and 8km from the entrance to the river at both the Richmond and Tweed River sites respectively.

In the Gold Coast-Broadwater, more groups were observed in the southern reaches of the survey area, with relatively few groups encountered in the western and northern reaches. Groups were encountered up to 9km west of the Jumpinpin (main northern coastal entrance) and 5km south of the Gold Coast Seaway (main southern coastal entrance). A report received from a member of the community through the Dolphin Watch initiative recorded dolphins 22km upstream in the Nerang River on 4th January 2019.

Table 5: Number of groups and individuals along with the number of groups with calves observed at each site during 2018/19 surveys.

Site	# Groups	Range of Group Size	# Individuals Counted	# Calf Groups
Tweed River	10	1 to 4	36	5
Richmond River	14	1 to 28	77	10
Gold Coast Broadwater	12	1 to 7	43	7
Total	**36**	-	**156**	**24**

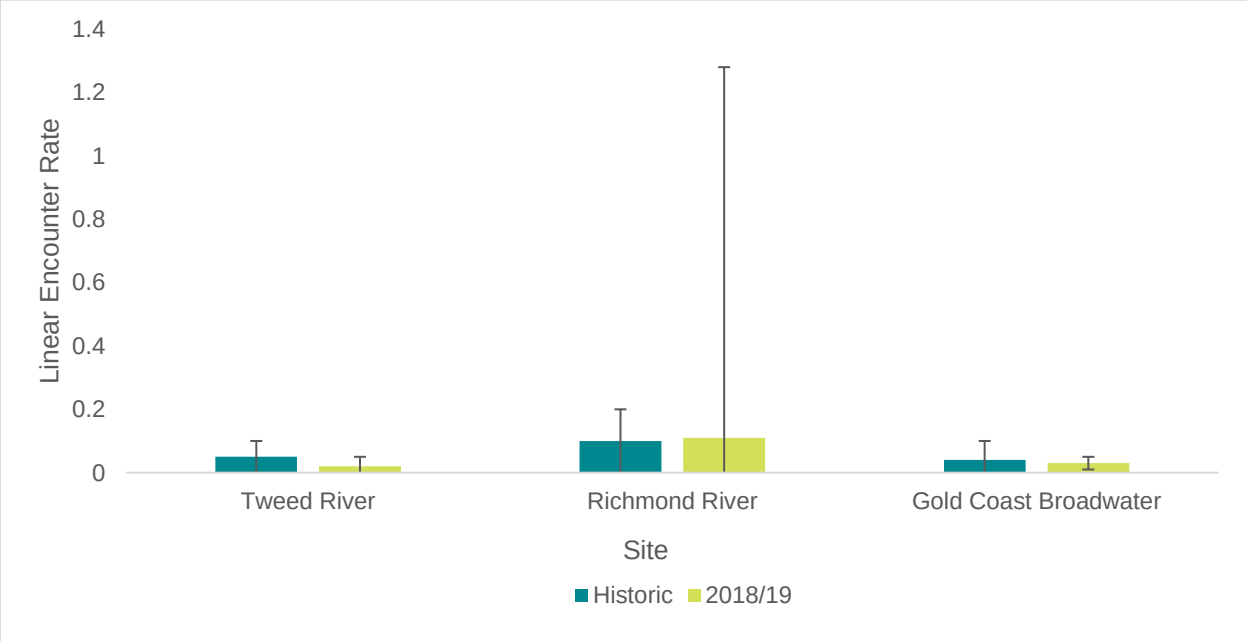

Figure 2: Mean linear encounter rate with standard deviation error bars for dolphins at each site for historic (pre 2018) and 2018-2019 surveys.

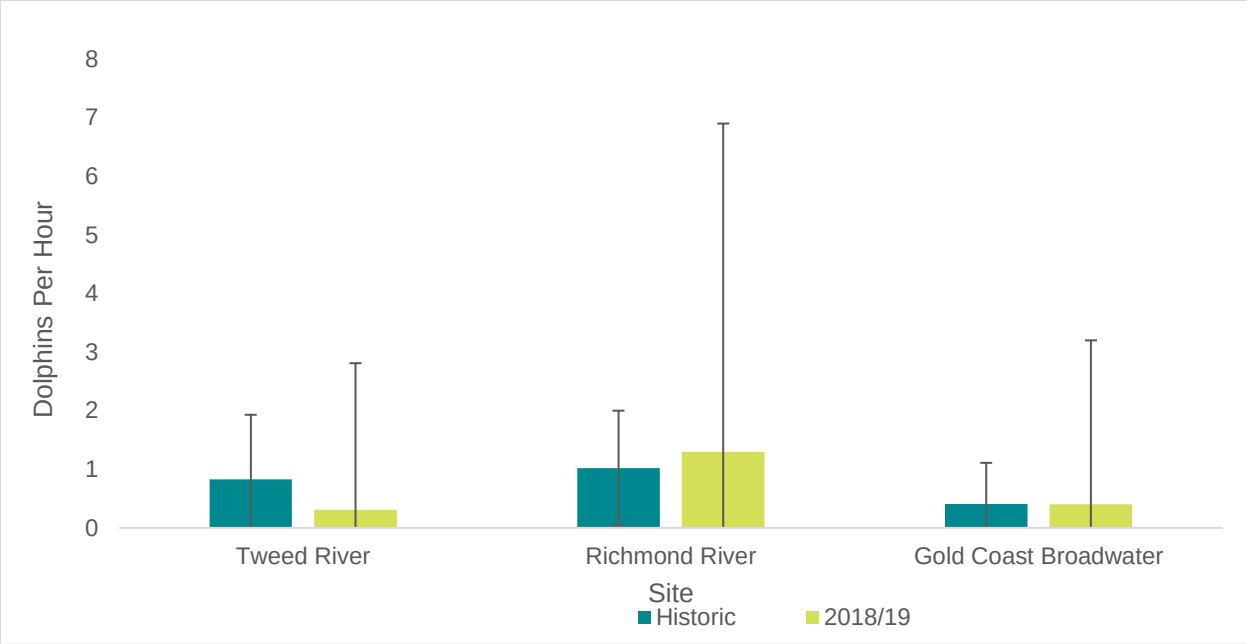

Figure 3: Mean number of dolphins observed per hour with standard deviation error for dolphins at each site for historic (pre 2018) and 2018-2019 surveys.

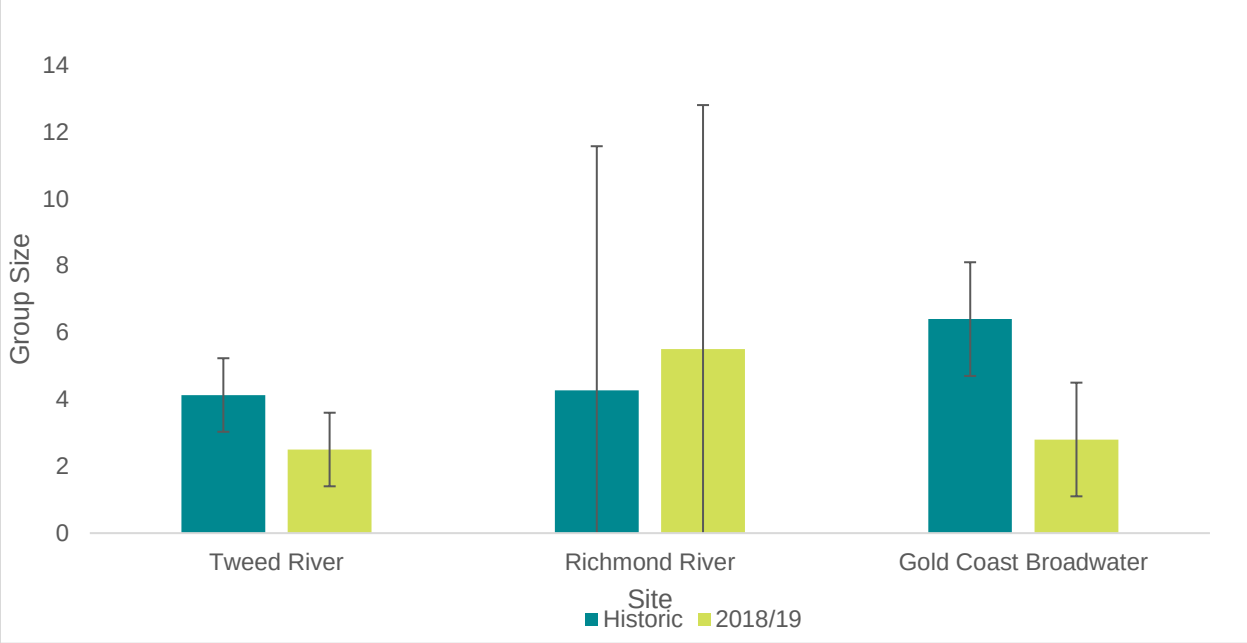

Figure 4: Mean group size with standard deviation error bars for dolphins at each site for historic (pre 2018) and 2018-2019 surveys.

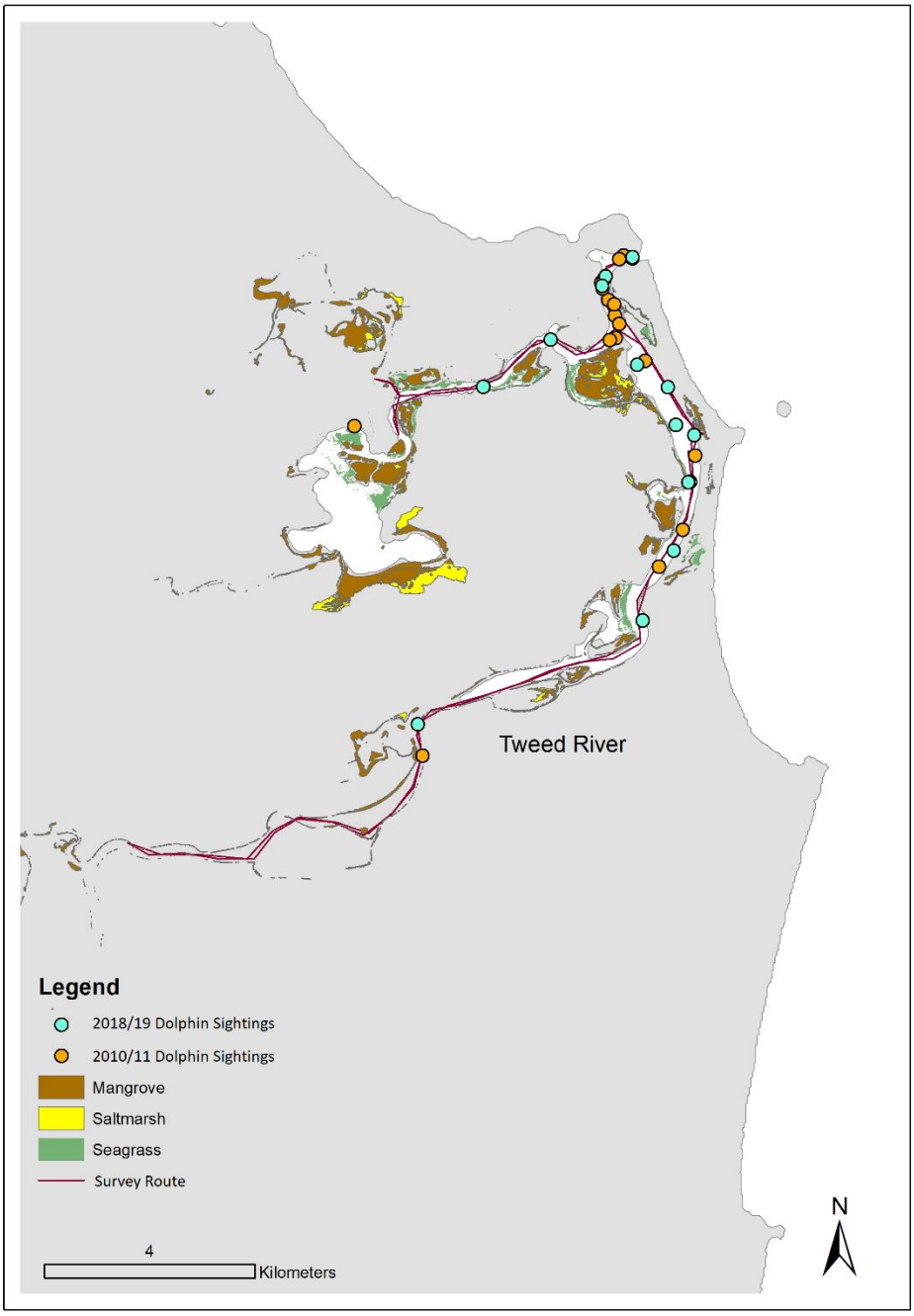

Figure 5: Locations of groups observed during the 2018/19 and historic surveys of the Tweed River with the survey route and habitat overlay.

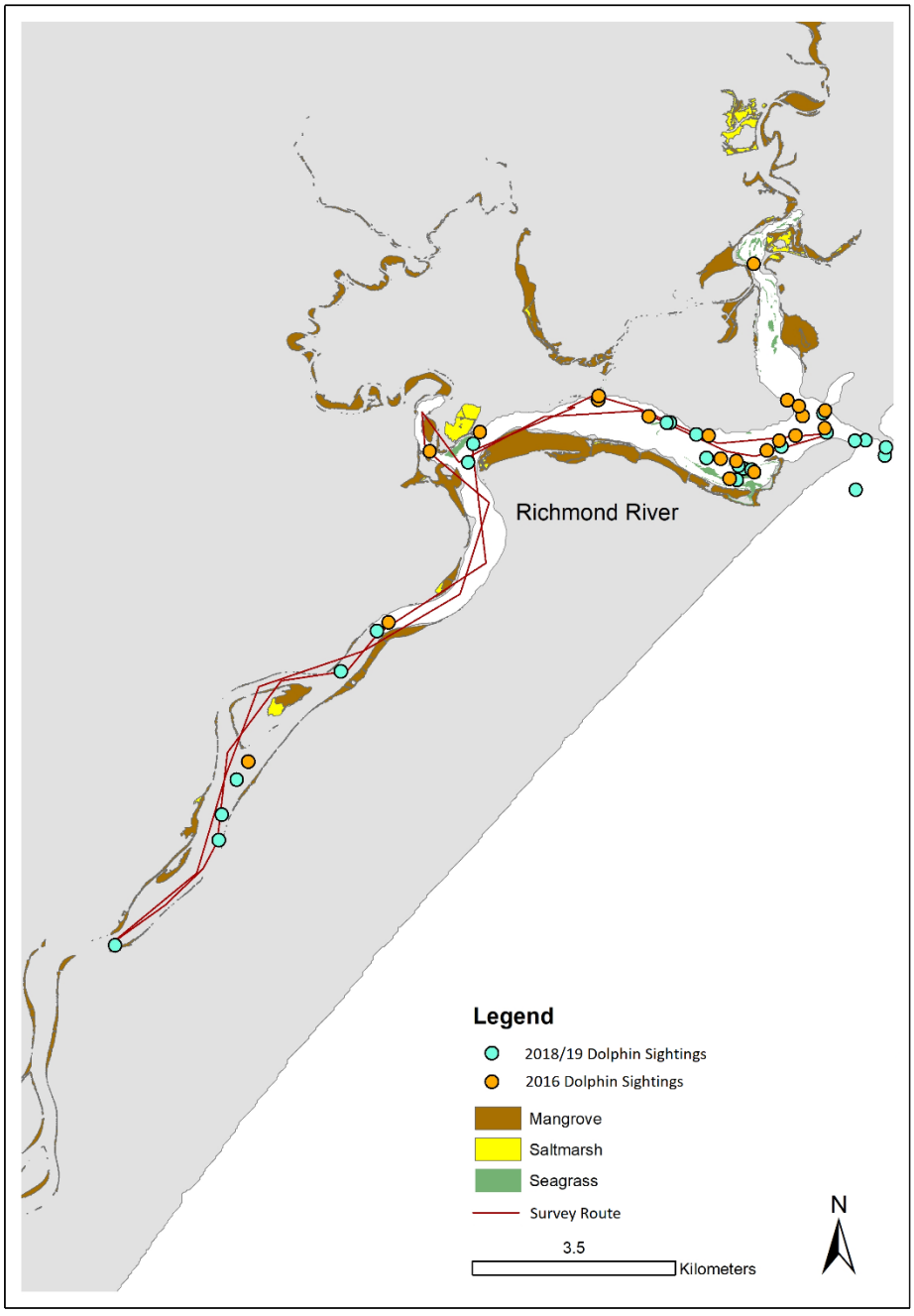

Figure 6: Locations of groups observed during the 2018/19 and 2016 surveys of the Richmond River with the survey route and habitat overlay.

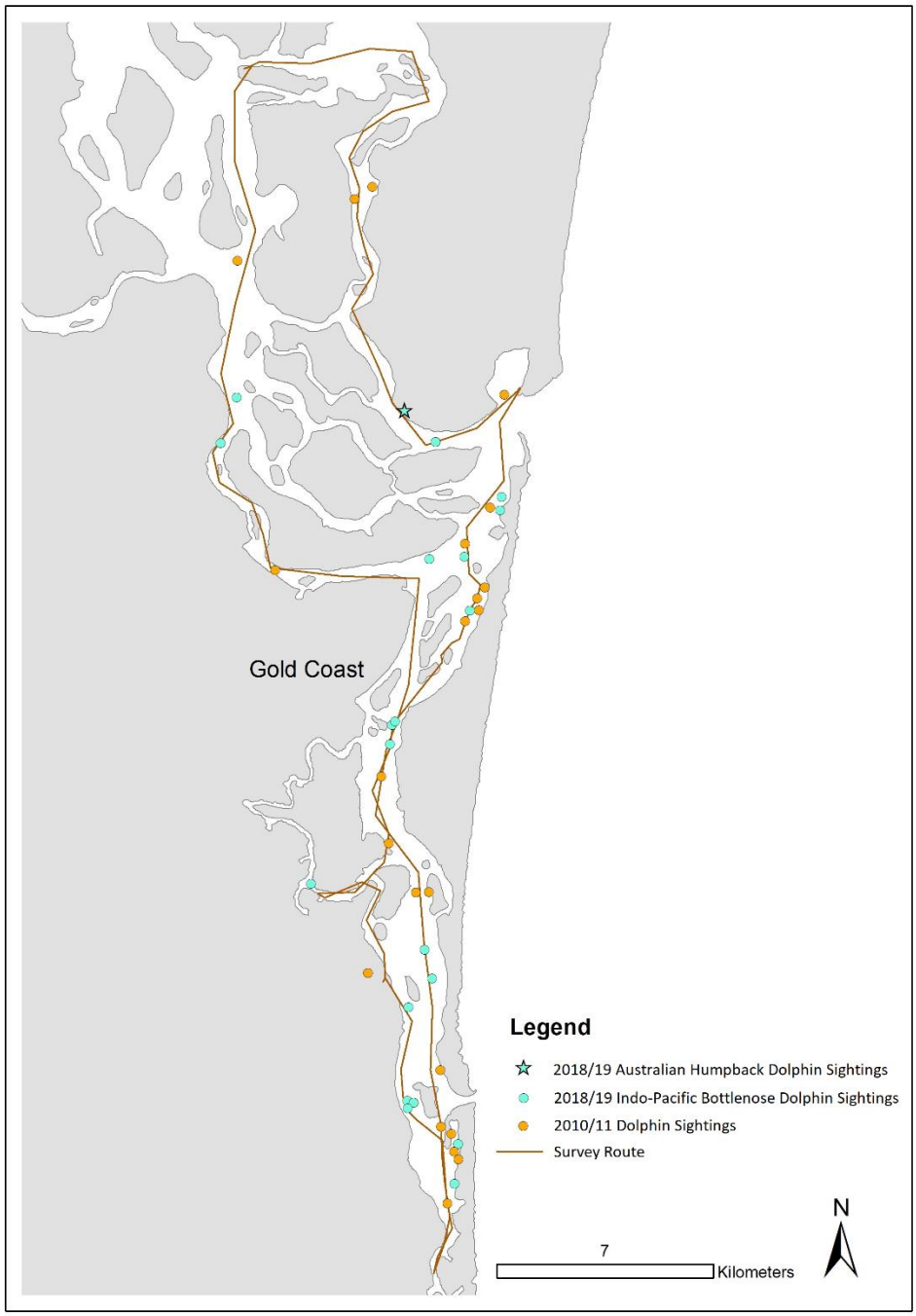

Figure 7: Locations of groups observed during the 2018/19 and 2010/11 surveys of the Gold Coast-Broadwater with the survey route.

4.4 Group Behaviour

Across all sites, the most prominent behaviour state observed was foraging (67%; n = 32 groups) with milling (n = 4 groups) and socialising (n = 3 groups) rarely observed (8 and 6% respectively). This pattern was consistent across all sites in 2018/19 (Figure 8).

The pattern of behavioural occurrence is similar between the 2018/19 and historic data sets for each site with foraging most frequently observed at all sites (Tweed River n = 6, Richmond River n = 11; Gold Coast-Broadwater n = 17; Figure 9).

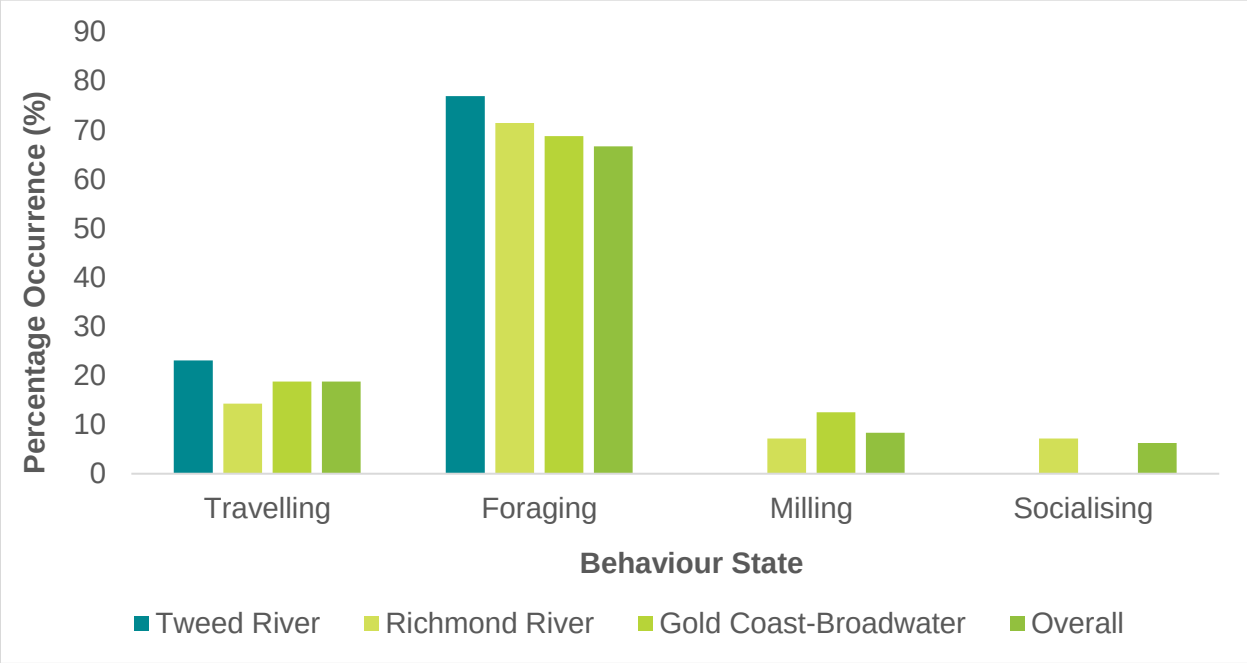

Figure 8: Percentage occurrence of different behaviour states observed from dolphin groups at all sites sampled in 2018/19.

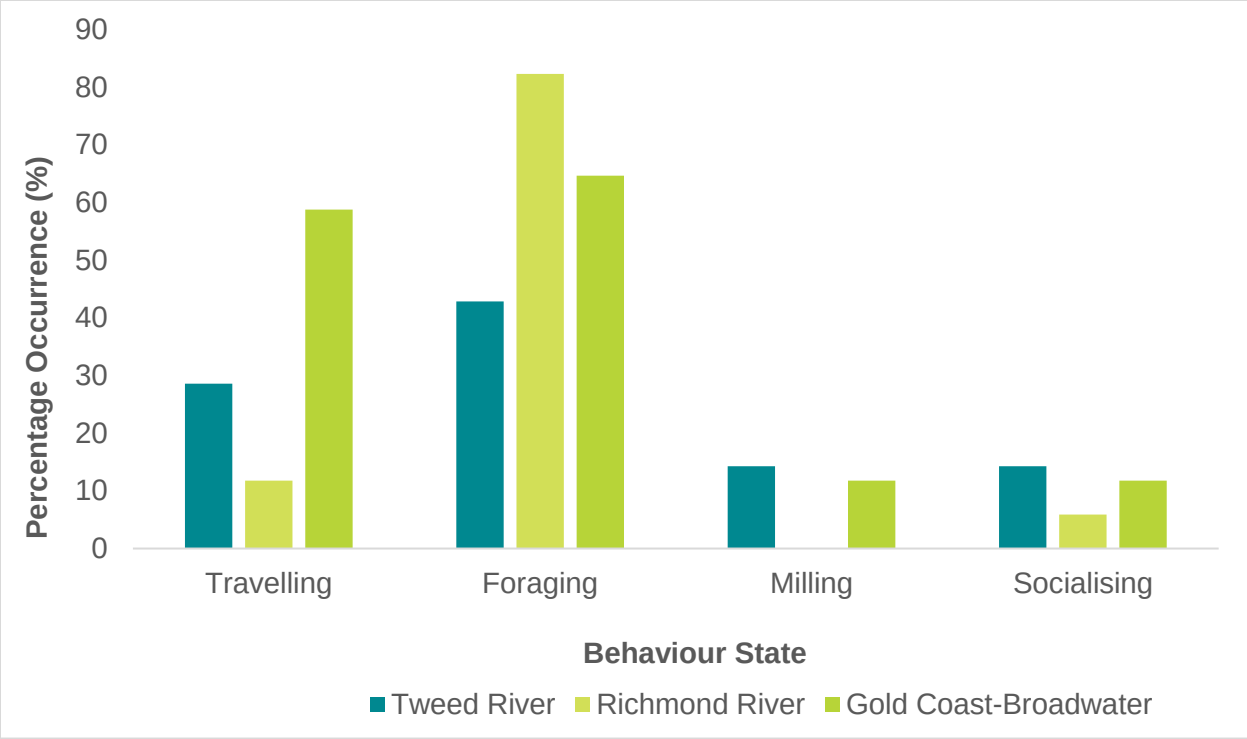

Figure 9: Percentage occurrence of different behaviour states observed from dolphin groups at all sites from historic sampling periods (2010-2011) Tweed River and Gold Coast-Broadwater; 2016 Richmond River).

4.5 Environmental Conditions

Environmental measures could only be summarised for the Tweed and Richmond River sites for 2018/19. Due to the low number of samples obtained from the Gold Coast (as the water quality meter was not available for the start of the project), these measures were omitted. Figures 10 to 15 summarise the average sea surface temperature, conductivity, dissolved oxygen, salinity, pH and turbidity from the Tweed and Richmond River sites. Differences were apparent between the conductivity and salinity measures in particular, with dolphins being present when these measures were higher. Levels of pH were also markedly higher when dolphins were present compared to absent. Whether these results are statistically different remains a focus for ongoing analysis.

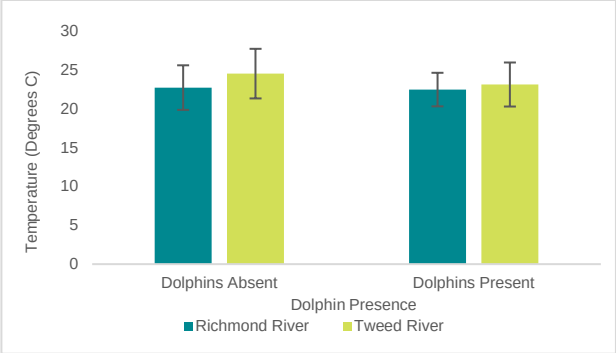

Figure 10: Mean water temperatures (˚C) with Standard Deviation error bars when dolphins were present and absent in the Richmond and Tweed Rivers.

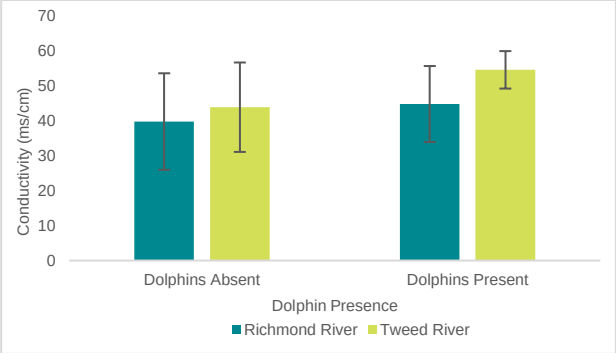

Figure 11: Mean conductivity (ms/cm) with Standard Deviation error bars when dolphins were present and absent in the Richmond and Tweed Rivers.

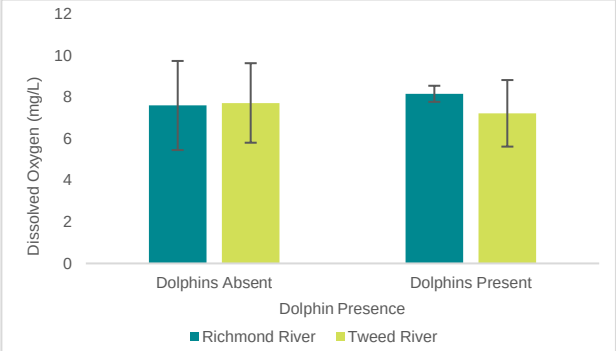

Figure 12: Mean dissolved oxygen (mg/L) with Standard Deviation error bars when dolphins were present and absent in the Richmond and Tweed Rivers.

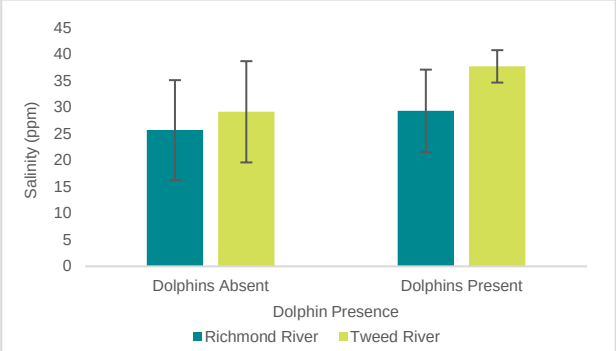

Figure 13: Mean salinity (ppm) with Standard Deviation error bars when dolphins were present and absent in the Richmond and Tweed Rivers.

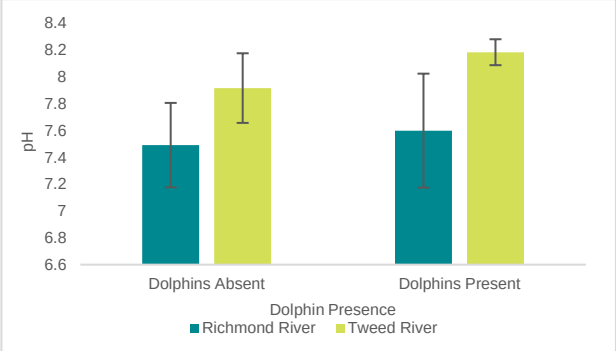

Figure 14: Mean pH measures with Standard Deviation error bars when dolphins were present and absent in the Richmond and Tweed Rivers.

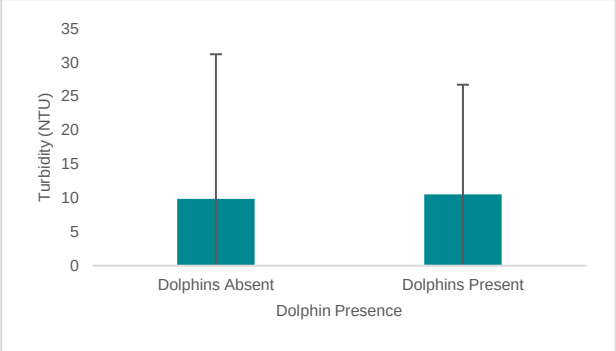

Figure 15: Mean turbidity (NTU) with Standard Deviation error bars when dolphins were present and absent in the Richmond River.

4.6 Identification of Individual Dolphins

During the 2018-2019 surveys, 38 'marked' dolphins were individually identified across all sites. The highest number of individuals were identified in the Richmond River. This does not include the number of 'unmarked' individuals encountered that lack long-lasting marks that can be used reliably for identification. Over the first year of surveys, the majority of individuals were seen once (Table 6). The highest number of times an individual was 'captured' (from photo-identification) was six.

Table 6: The percentage and number of individuals resighted during 2018-2019 surveys for each sample site.

	Tweed River		Richmond River		Gold Coast-Broadwater	
# Resights	**# Individuals**	**%**	**# Individuals**	**%**	**# Individuals**	**%**
1	7	64	15	83	8	80
2	2	18	2	11		
3						
4			1	6	1	10
5					1	10
6	2	18				
Total	11	100	18	100	10	100

The number of animals resighted between the historic surveys and 2018/2019 was highest for the Tweed River, with 56% (n = 6) seen in both periods, followed by the Gold Coast-Broadwater (50%; n = 4) (Table 7). Fewer individuals were resighted in the Richmond River (38%; n = 7), however, this is partially due to the different areas surveyed with the 2018/2019 surveys excluding adjacent coastal waters (surveyed between 2004-2006). However, surveys in 2016 are directly comparable with the 2018/2019 surveys and two individuals were seen in both sets of surveys.

Around half of newly identified individuals at Tweed River (n = 4) and Gold Coast-Broadwater (n = 2) were classed sub-adults with all others as adults. All newly identified individuals from the Richmond River were classified as adults. Incidentally, the adult female Australian humpback dolphin with the dependent calf observed in the Gold Coast-Broadwater was a resight from 2010/11 historic surveys where it was seen offshore of the Jumpinpin Bar.

Table 7: Number of individual dolphins identified (IDs) from 2018 to June 2019 surveys at each site with the number of individuals identified from historical surveys, the number of individuals resighted between the two survey periods and the number of newly identified individuals.

Site	# of Individual IDs	# Historic Individual IDs (prior to 2018)	# IDs Resight (between 2018/19 & Historic)	# New IDs (2018/2019)
Tweed River	11	15	6	5
Richmond River	18	95*	7	11
Gold Coast-Broadwater	10	29	6	4
Total	38	44	15	22

*number of historic IDs from the Richmond River include those identified both in the river and adjacent coastal waters.

4.7 Stranding & Incident Response

Fourteen deceased dolphins were reported between January 2018 and June 2019 along the Gold Coast and Northern Rivers (including Tweed, Byron and Ballina Shire boundaries). Table 8 lists the species and locations of deceased dolphins reported and combines records from the NSW National Parks & Wildlife database, Elements, those received from Sea World Research & Rescue Foundation and Dolphin Research Australia. Where possible, animals were sampled and a necropsy performed to assess the potential cause of death and overall health of the animal. Detailed assessments were possible for 12 of the 14 animals recorded. The cause of death for seven of the dolphins remained undetermined.

The most commonly recorded species were Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), the majority of which were male (Table 8). Four individuals were immature calves or juveniles. Three lactating females were recorded all of which were found in shark nets at Ballina and Evans Head (it should be noted that these nets were part of the North Coast NSW Shark Net Trial during the summer months of 2017-2018 and have since been removed). Samples from five of these animals have been submitted to the Griffith University Laboratory for toxicology analysis of 27 trace elements and persistent organic pollutants (POPs).

Table 8: List of deceased dolphins sampled between January 2018-June 2019 in Northern New South Wales (including the Ballina, Byron and Tweed Shires) and the Gold Coast region.

Date	Location	Name	Species	Age	Sex	Carcass Condition	Samples Y/N	Necropsy	Cause of Death
5/01/2018	7 Mile Beach, Broken Head, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Adult	Male	Good	Y	Y[2]	Undetermined
18/01/2018	Shark Control Program Ballina, NSW	Common Dolphin	*Delphinus delphis*	Adult	Lactating Female	Good	Y	Y[1]	Drowned in shark net
5/02/2018	Shark Control Program Ballina, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Adult	Lactating Female	Fair-decomposing	Y	N	Drowned in shark net
9/02/2018	Wooyung, NSW	Common Dolphin	*Delphinus delphis*	Juvenile	Female	Good	Y	Y[1]	Severe pneumonia caused by lungworms
23/02/2018	Airforce Beach, Evans Head, NSW	Fraser's Dolphin	*Lagenodelphis hosei*	Adult	Male	Good	Y	Y[1]	Clostridial enterotoxaemia
3/04/2018	Shark Control Program, Evans Head, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Adult	Lactating Female	Good	Y*	Y[1]	Drowned in shark net
3/04/2018	Shark Control Program, Evans Head, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Calf	Male	Good	Y*	Y[1]	Drowned in shark net
17/08/2018	Currumbin, QLD	Common bottlenose dolphin	*Tursiops truncatus*	Juvenile	Male	Good	Y	Y[2]	Undetermined
19/08/2018	Coolangatta, QLD	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Adult	Male	Good	Y*	Y[2]	Undetermined
2/09/2018	Hastings Point, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Adult	Unknown	Poor	N	N	Undetermined
14/10/2018	Sharpe's Beach, Ballina, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Subadult	Male	Good	N	N	Undetermined
19/11/2018	Lennox Head, NSW	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Neonate	Male	Alive but subsequently died	Y*	Y[1]	Undetermined

13/05/2019	Gold Coast, QLD	Common dolphin	*Delphinus delphis*	Adult	Female	Good	Y	Y[2]	Possibly caught in Gold Coast shark net
7/06/2019	Gold Coast Seaway, QLD	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Adult	Male	Good	Y*	Y[1]	Undetermined

*Samples submitted for toxicology analysis. [1]Necropsies performed in partnership with Dolphin Research Australia and Sea World Research & Rescue Foundation (SWRRF). [2]Necropsies performed by SWRRF.

5.0 Engaging the Community

There are a number of ongoing opportunities for the community to be involved in the project with differing levels of engagement. These opportunities include our Dolphin Ambassador program and Dolphin Watch Citizen Science Initiative.

5.1 Dolphin Ambassadors

Dolphin Ambassador program: participants assist with vessel-based surveys and receive training in the observation and recording of dolphin behaviour, identification and water quality measures. Ambassadors will be recruited through our Dolphin Ecology workshops held at least once per year. Expected participation/year = 50 people.

 # Dolphin Ambassadors signed up = 40

 # Dolphin Ambassadors participants June 2018 - June 2019 = 24

 # Dolphin Ambassador field survey hours June 2018 - June 2019 = 711.35hrs (all sites)

5.2 Dolphin Watch Citizen Science Initiative

Dolphin Watch Initiative: participants from the community who report their dolphin sightings through our online web-based platform or by phone. Each sighting report adds to the information collected during dedicated research surveys to monitor status of each population and contribute to the understanding of individual residency and life history, core areas of use, seasonal usage patterns and health. A handbook for Dolphin Watchers was written and provided to all workshop participants.

 # Dolphin Watch Citizen Science Reports received June 2018 - June 2019 = 273

 # Workshops delivered to June 2019 = 2 (Tweed & Ballina)

Workshop attendance = 65 (full capacity)

Dolphin Ambassadors in the field 2018-2019.

5.3 Education Materials for Citizen Scientists

A multi-media toolkit is being developed and made available on the Dolphin Research Australia website. This toolkit will provide information about not only dolphins in the region, but also how to assist in the research as a citizen scientist. Toolkit materials created and published to date:

- Informative videos on species identification, behavioural interpretation and group composition (available online),
- Interactive maps displaying Dolphin Watch reports received (available online),
- Education materials including posters on keeping our waterways healthy and how to monitor dolphins (available as downloadable resources and on display at our community education stalls).

Expected participation/year = 100 interactions (via video views and website hits).

In 2018-2019, information to the public was also provided through presentation evenings, workshops and Dolphin Research Australia's market stall at special events. Expected participation/year = 150 people.

 # Major events attended (June 2018-June 2019) = 3

 # Community talks (June 2018 – June 2019) = 13

 # Participants at community talks = 406

Social media = ~80 posts

6.0 Key Findings

- Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) are the most common species encountered in the Broadwater, Tweed and Richmond River estuaries. However, the vulnerable Australian humpback dolphin (*Sousa sahulensis*) is occasionally using the Gold Coast-Broadwater estuary.
- The majority of groups that utilise the Broadwater, Tweed and Richmond River estuaries consist of females with dependent calves.
- Dolphins primarily use estuaries for foraging and feeding.
- There is evidence that the sites are used by individual dolphins with long-term residency and/or site fidelity.
- Group sizes of dolphins encountered in all estuaries are typically small (compared to coastal zones see Hawkins and Gartside 2008) and slightly variable between sites. The Gold Coast-Broadwater and the Tweed River had comparably smaller group sizes than the Richmond River (averaging 2.5-5.6 respectively in 2018/19).
- The linear encounter rate, dolphins per hour and mean group sizes in the Tweed River were 50% lower than historic levels recorded in 2010/11. However, the number of individually identified dolphins were comparable between the two sampling periods (n 2010/11 = 15; n 2018/19 = 11). This suggests that the estuary was used less frequently by a similar number of individual animals. Whether this difference is due to environmental conditions, changes in abundance or sampling methods is subject to further investigation.
- Comparatively, the LER and DPH were similar between the 2018/19 and 2010/11 sampling periods in the Gold Coast-Broadwater. However, similar to the Tweed River over the same period, the average group sizes were 50% less in the 2018/19 period compared to 2010/11; while the percentage of surveys where dolphins were encountered substantially increased from 45% to 89% in 2018/19. This implies that the grouping patterns of dolphins has altered between time periods rather than a change in abundance. This difference may be influenced by environmental conditions. In 2010/11, high levels of rainfall were experienced in the South East Queensland and Northern New South Wales region with major flooding events taking place during the summer sampling period. Comparatively low rainfall conditions were experienced during 2018/19. Further investigation is warranted to determine the influence of rainfall and environmental conditions on grouping patterns in these communities of dolphins.

7.0 Next Steps

- Continue monthly vessel-based surveys with the assistance of our Dolphin Ambassador teams,
- Complete a preliminary toxicology analysis to assess levels of heavy metals and POPs from five bottlenose dolphins deceased from beach-cast events along the Northern NSW & SE Queensland region,
- Complete the media kit and Dolphin Watch interpretive materials,
- Promote the Dolphin Watch initiative through e.g. social media and media releases,
- Commence epidermal assessment of dolphins and compare the occurrence of lesions, scarring and injury rates between age-sex classes and sites,
- Determine the abundance of each estuarine community using mark-recapture models.

8.0 References

Bossley MI, Steiner A, Rankin RW, Bejder L (2016) A long-term study of bottlenose dolphins (*Tursiops aduncus*) in an Australian industrial estuary: Increased sightings associated with environmental improvements Marine Mammal Science:n/a-n/a doi:10.1111/mms.12368

Bossley MI, Woolfall MA (2008) Recovery from severe cutaneous injury in two free ranging bottlenose dolphins (*Tursiops* spp.)

Campbell R, Pratt K, Howland M (2011) Coastal Zone Management Plan for the Richmond Rivery Estuary Report Prepared on behalf of Ballina Shire Council, Lismore City Council, Richmond Valley Council and Richmond River County Council by Hydrosphere Consulting Volume 1: CZMP:95

Chabanne D, Finn H, Salgado-Kent C, Bejder L (2012) Identification of a resident community of Bottlenose dolphins ('*Tursiops aduncus*') in the Swan Canning Riverpark, Western Australia, using behavioural information Pacific Conservation Biology 18:247

Chabanne DB, Finn H, Bejder L (2017) Identifying the relevant local population for Environmental Impact Assessments of mobile marine fauna Frontiers in Marine Science 4:148

Cockcroft V (1992) Incidental capture of bottlenose dolphins (Tursiops truncatus) in shark nets: an assessment of some possible causes Journal of Zoology 226:123-134

Cockcroft VG, Ross GJB (1990) Food and Feeding of the Indian Ocean Bottlenose Dolphin off Southern Natal, South Africa. In: Leatherwood S, Reeves RR (eds) The Bottlenose Dolphin. Academic Press, London, pp 295-308

Creese RG, Glasby TM, West G, Gallen C (2009) Mapping the habitats of NSW estuaries. Industry & Investment NSW Fisheries Final Report Series 113. Port Stephens, NSW, Australia. ISSN 1837-2112. 95pp.,

Dawson K (2002) Fish kill events and habitat losses of the Richmond River, NSW Australia: an overview Journal of Coastal Research:216-221

Defran RH, Shultz GM, Weller DW (1990) A Technique for the Photographic Identification and Cataloguing of Dorsal Fins of the Bottlenose Dolphin (*Tursiops truncatus*) Rep Int Whal Commn:53-55

Dunn RJ, Waltham NJ, Benfer NP, King BA, Lemckert CJ, Zigic S (2014) Gold Coast Broadwater: Southern Moreton Bay, Southeast Queensland (Australia). In: Estuaries of Australia in 2050 and beyond. Springer, pp 93-109

Fury CA, Harrison PL (2008) Abundance, site fidelity and range patterns of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in two Australian subtropical estuaries Marine and Freshwater Research 59:1015-1027

Fury CA, Harrison PL (2011a) Impact of flood events on dolphin occupancy patterns Marine Mammal Science 27:E185-E205

Fury CA, Harrison PL (2011b) Seasonal variation and tidal influences on estuarine use by bottlenose dolphins (*Tursiops aduncus*) Estuarine, Coastal and Shelf Science 93:389-395

Fury CA, Reif JS (2012) Incidence of poxvirus-like lesions in two estuarine dolphin populations in Australia: Links to flood events Science of the Total Environment 416:536-540

Hammond PS, Mizroch SA, Donovan GP (1990) Individual Recognition of Cetaceans: Use of Photo-Identification and Other Techniques to Estimate Population Parameters. International Whaling Commission, Cambridge

Hawkins E (2008) Behaviour and Acoustics of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) in the Byron Bay region, NSW, Australia. PhD dissertation, Southern Cross University

Hawkins ER, Gartside DF (2008) Social and Behavioural Characteristics of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) in northern New South Wales, Australia Australian Mammalogy 30:71-82

Krogh M, Reid D (1996) Bycatch in the Protective Shark Meshing Programme off South-eastern New South Wales, Australia Biological Conservation 77:219-226

Mann J (2000) Unraveling the dynamics of social life - Long-term studies and observational methods. In: Mann J, Connor R, C., Tyack P, L., Whitehead H (eds) Cetacean Societies - Field Studies of Dolphins and Whales. University of Chicago Press, Chicago, USA, pp 45-64

Martin P, Bateson P (1993) Measuring Behaviour, An introductory guide. 2nd Edition edn. Cambridge University Press, Cambridge
Moreno P, Mathews M (2018) Identifying Foraging Hotspots of Bottlenose Dolphins in a Highly Dynamic System: A Method to Enhance Conservation in Estuaries Aquatic Mammals 44
Peterson A (2012) Population Ecology and Social Systems of *Sousa chinensis* and *Tursiops aduncus* on Queensland's Gold Coast.
Pratt K, Seccull O, Conroy R (2017) Coastal Management Program for the Tweed River Estuary: Ecological Assessment Report by Hydrosphere Consulting for the Tweed Shire Council, New South Wales, Australia:188
Riches M, Gilligan, D., Danaher, K., Pursey, J. (2016) Fish Communities and Threatened Species Distributions of NSW NSW Department of Primary Industries Report
Ryder D (2012) Ecohealth: A healthcheck for our waterways. Disgn, methods and reporting of waterway health in coastal northern NSW, Australia. Report to the Northern Rivers CMA University of New England, Armidale, NSW, Australia:47
Ryder DR, Mika S, Richardson M, Schmidt J, Fitzgibbon B (2015) Richmond Ecohealth Project 2014: Assessment of River and Estuarine Condition, Final Technical Report. University of New England, Armidale, New South Wales, Australia
Stone BM, Blyde DJ, Saliki JT, Morton JM (2012) Morbillivirus infection in live stranded, injured, trapped, and captive cetaceans in southeastern Queensland and northern New South Wales, Australia Journal of wildlife diseases 48:47-55
TSC (2019) Tweed River Report 2019 Tweed Shire Council Report, Tweed Heads, NSW
Walters K (2015) Historical information on dolphins in the Gold Coast Broadwater and offshore; comparisons with recent years; and avenues for future research Unpulished report, Griffith University, Gold Coast, Queensland
Waltham NJ, Teasdale PR, Connolly RM (2011) Contaminants in water, sediment and fish biomonitor species from natural and artificial estuarine habitats along the urbanized Gold Coast, Queensland Journal of Environmental Monitoring 13:3409-3419
Water HL (2018) Report Card: Methods Manual Report by Healthy Land & Water, Brisbane, Queensland
Wells RS et al. (2004) Bottlenose dolphins as marine ecosystem sentinels: developing a health monitoring system EcoHealth 1:246-254
Woinarski J, Burbidge A, Harrison PL (2014) Action Plan for Australian Mammals 2012. CSIRO Publishing, Collingwood, VIC, Australia
Wursig B, Jefferson TA (1990) Methods of Photo-Identification for Small Cetaceans Rep Int Whal Commn:43-52

Appendix A: Behaviour Ethogram

BEHAVIOUR **STATE**	**Abbreviation**	**DESCRIPTION**
Travelling	TR	Dolphin moves in a consistent direction with regular surfacing intervals. Typically with consistent breathing pattern and down times.
Socialising	SOC	Two or more dolphins are clearly interacting with each other by direct physical contact such as body rolls, petting and tail slapping. Frequent splashes and disturbance at the surface.
Milling/Resting	MI	Group frequently changes travel direction (no consistent travel direction). Individuals may surface facing different directions. Dolphins have slow movements with variable, but frequent, dive intervals and often remain floating at the surface for a short amount of time between dives.
Feeding/Foraging	FE	Dolphins are actively pursuing prey and feeding (often confirmed by visual observation of fish or prey item). Usually associated with deep diving (fluke-up dives), fast swims or porpoising, frequent changes in travel direction and inconsistent inter-breath intervals. Group may be in a circular formation, spread over a wide area and individuals surface facing different directions.
Travel-Foraging	TF	Dolphins forage and feed whilst travelling in a consistent direction. Often associated with bottom feeding. Dolphins have long down times, surface for one-two breathes before diving (often having a deep dive or fluke-out dive after the last breath).
BEHAVIOUR		**DESCRIPTION**

EVENT		
Against-current feeding	ACF	Dolphins feeding typically on the tidal front with heads directed into the flow of the tidal current.
Aggressive/Agonistic	Agg	Threatening or intensely dominating behaviour displayed towards another dolphin/s.
Affiliation	Aff	When two separate pods join and interact.
Alloparental	All	Supervising dolphin interacted with or tended younger dolphin, where the relationship of focal dolphin/s were known.
Approach	App	When one or more dolphins approach a vessel or swimmer often within 50m.
Belly-to-belly	Bb	Animals swim together underside to underside, usually related to sexual interaction.
Belly-up	Be	Animal swims with underside towards the surface.
Body roll	Bll	One animal rolls over another animal using their whole body.
Bow Riding	Br	Dolphin riding on bow of boat
Breaching	Bch	Animal jumps out of water
Bunched	Bu	Animals are tightly grouped together
Circling	Ci	Where the dolphin continuously travels in a circular motion with frequent changes in travel direction.
Chase	Che	When one or more other individuals are pursuing another individual.
Cooperative feeding	Coop	Dolphins are engaged in a cooperative feeding bout where many individuals are involved to herd fish into a tight ball. Dolphins will often be in a circular formation.
Deep diving	Dd	When an animal dives and the tail flukes are exposed above the surface and the position of the body is descending vertically.
Disaffiliation	Di	When two or more individuals or pods separate following an association.

Echelon Position	Ep	Refers to the position of a young calf to its mother. Usually associated with faecal fold calves.
Fast travel	Ft	Animal/s consistently swim quickly in a defined direction.
Fish Toss	Ftoss	Dolphin throws fish at surface of the water
Fluke up	Flup	Fluke up dive (tail flukes clearly seen above surface)
Forced Blow	Fbl	Where the dolphin breathes heavily on its surfacing, making a loud exhalation blow.
Head lunge	Hl	Head is slapped on the water's surface and often towards or on another pod member.
Head-to-head	Hh	Two individuals confront each other rostrum to rostrum, usually associated with aggressive or dominating behaviour.
Infant position	Inf	Refers to the position an infant calf will travel in proximity to its mother.
Interact	Int	Where one or more dolphins approach a vessel or swimmer and have a direct interaction, such as bowriding or wakeriding.
Inverted Tail Slap	InTsl	The dolphin will be at the water's surface with its belly-up and slaps its tail on the surface.
Leaping	Le	When animal jumps clear out of the water a number of meters above the surface.
Learned behaviours & interactions	Lb	Behaviours that may be related to cultural transmission, often observed in juveniles.
Long submergence	Ls	Intervals between surface blows are long.
Nipping	Ni	Usually associated to aggressive or dominating behaviours. One or more animals bite another individual, will often leave rake marks on victim.
Nudging	Nu	One animal gently or aggressively pushes another individual with their rostrum.
Petting	Pe	One animal actively moves its pectoral fin up and down the body part/s of another animal (Mann 2000).

Porpoising	Porp	Often observed during feeding and travelling. Animals will break the surface of the water with their rostrums and melons above exposed creating a bow wave effect as they move.
Resting	Re	Often observed during milling. Resting or sleeping individuals may be seen snagging on the surface or have slow movements remaining on the surface for a longer time.
Scanning	Sc	Animal is moving its head from side-to-side while emitting a non-directional click sequence.
Short submergence	Ss	Intervals between surface blows are short.
Spread	Sp	Individuals in pod are not tightly bunched and occupy a large area.
Spy Hop	Sh	Head of animal rises vertically above the water surface.
Snack Foraging	Sf	Individual dolphin is chasing and feeding on fish at the surface of the water often causing prey to jump out of water where the animal will consume it.
Suckling	Skl	Refers to mother and calf pairs where the calf is seen in the infant position with its rostrum underneath its mother in the position of the mammary glands.
Surface active	Sa	Water's surface is clearly being disturbed as a result of animal activity.
Surfing	Su	Dolphin is riding waves.
Sexual Activity	Sxa	Where two or more dolphins display sexual behaviours and interactions.
Synchronous surfacing	Syn	When two or more individuals surface and behave e.g. blow, at the exact same time.
Tail slap	Tsl	Animal lifts its tail above the surface and slaps it on the water.
Back slap	Bsl	Dolphin emerges out of the water head first and slaps the back of its head on the surface.

Side slap	Ssl	Dolphin emerges out of water head first and slaps the side of its body on the surface.
Change in Travel Direction	CTD	When animals change their direction of travel, may happen continuously.
Change in Behaviour	CIB	If an animal has previously displayed a distinct type of behaviour e.g. travelling and then begins displaying another behaviour e.g. milling.
Behavioural Descriptions for Swimmer & Provisioning		
Swam Past 1	SmPst1	Dolphins swim past swimmers and display no sign of altering their behaviour and no interest in the swimmers.
Swam Past 2	SmPst2	Dolphins alter their travel direction or their behaviour to avoid swimmers and boats
Interaction	Int	Dolphins remain within a 5m radius of swimmers with an obvious interest in them often changing their behaviour. On vessels interactions may occur within a 15m radius of the vessel.