Dolphin Research Australia

Knowledge, Awareness, Action – Conserving Our Seas

Looking Out for Yugirr (Dolphin) Mob – Nambucca Heads

2014-2018

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Project Report 2014-2018

Acknowledgements

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Project Introduction

Science is definitive, dynamic, and culturally embedded in many indigenous systems. It consists of both a specific body of knowledge and the processes used to obtain and pass on that knowledge. Approaching the future, involves a mentality change, from independent western science and the one universal perspective of science, to exposing the intersections of these many lenses that are culturally defined ways of knowing, the project aims to fuse and combine these fundamentals to gain holistic perspectives on marine mammal knowledge.

Indigenous science represents the cumulative place-based observations of natural phenomena that includes humans and non-human others, and fully integrates and acknowledges humans as part of the natural world and its ecosystem processes. The use of traditional knowledge and Indigenous science has been suggested as a way to mitigate the current weaknesses in current ecological and species knowledge.

This project presents an integrated and innovative method to involve, and understand cultural importance, to distinguish and utilise long-term ecological knowledge and understanding of yugirr (dolphins) that are indicators of environmental health. Long-term research and monitoring studies are essential to gain insight into the population dynamics, habitat utilization, life histories, health and conservation of coastal dolphins. This is difficult to achieve without collaborative science based on robust methodologies.

Indigenous Protected Area managers can play a vital role in furthering the understanding and knowledge of these ecologically important animals and the development of monitoring programs that integrate Traditional Ecological Knowledge (TEK). The study has also provided professional skills for indigenous Sea Country managers that addresses a more ***equitable Australia***, with concerted focus on maximizing the potential of people who may not previously have had interest in, or access to, science engagement activities.

By strengthening the relationships between research scientists and Indigenous environmental managers, a greater understanding of coastal dolphins can be acquired and more effective conservation and management initiatives can be implemented.

This project is a partnership between Gumma Indigenous Protected Area (IPA) and Dolphin Research Australia and consists of three objectives;

- Objective 1: Establish a research and monitoring program for dolphins utilizing the Nambucca River estuary;
- Objective 2: Provide opportunities for training and skill development for IPA staff and guides along with citizen scientists;
- Objective 3: Provide opportunities for community engagement to increase and encourage stewardship for the care of natural habitats and wildlife.

This report provides a summary of the major milestones of the project between 2014-2018 with a focus on Objective 1.

Education, Training & Community Engagement

In addition to the dolphin research surveys, Dolphin Research Australia and Gumma Indigenous Protected Area have presented numerous opportunities for community engagement and training. These include:

- Presentation of a Dolphin Ecology Workshop for the community,
- Promotion of the Dolphin Watch citizen science initiative to encourage the community to report their dolphin sightings and contribute to population monitoring,
- Nambucca Whale Festival for community,
- Development for stranding and incident response course followed by staff training,
- Development and facilitation of compliance training for staff in relation to cetacean watching regulations,
- Delivery of Cetacean guide & Operator Training Course for IPA guides and staff,
- Training of Gumma IPA staff, guides and volunteers to assist in collecting survey data for the assessment and monitoring of dolphins in the Nambucca Estuary,
- Presentations at international conferences and workshops including the World Indigenous Network Conference (Darwin, 2013) and 20th Biennial Conference for the Biology of Marine Mammals (Otago, NZ, 2013).

Dolphin Research & Monitoring

Cultural connections to Yugirr

The Gumbaynggirr dolphins are embedded in cultural storylines, place and ceremony. A common practice was "singing the dolphins". There are many stories of the kinship associated to dolphins and the role they played in Gumbaynggirr people's lives. The women of Gumbaynggirr Jagun were the keepers of ocean knowledge and ocean ceremony as Uncle Milton Duroux explains, "The women, they'd go out into the water, wade out to their waists and sing, to sing in the dolphins, and these dolphins would bring in the fish into the traps, and then the men did the fishing using the traps," (Arrawarra Sharing Culture, http://www.arrawarraculture.com.au/fact_sheets/pdfs/00_Fact_Sheets_Booklet.pdf).

Dolphins & Estuaries

Estuaries are amongst the most important, dynamic and rich coastal ecosystems. Estuarine habitats not only support 75% of Australia's commercial and 90% of recreational fish species that spend at least part of their life in cycle within estuaries, but also for apex predators, including Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). Despite the dynamic nature, estuarine systems are under considerable pressure with growing stresses stemming from urbanisation and land-use. Most Australian estuaries have experienced considerable modification since European settlement with increasing human populations in catchments along with the establishment of recreational, commercial and industrial activities, adding to the changes in these environments (Creighton 2013). Modification through land clearing and drainage, for example, has resulted in changes to tidal and river flow conditions, poor flushing and increased acid sulphate soils which in turn has contributed to, for example, loss of seagrass beds, mangroves, riparian vegetation (Creighton 2013). Over the last 30-40 years, an estimated 85% loss of seagrass beds in NSW estuaries alone has occurred (Creighton 2013).

With many coastal towns and cities economically reliant on the natural assets of estuaries including fisheries resources and tourism and aesthetic appeal attracting domestic and international visitors, estuaries are not only biologically, but also economically, important habitats (Pendleton 2011). It is therefore essential that the maintenance and improvement of the environmental quality, health and ecological function of estuaries be prioritised through management initiatives.

Indo-Pacific bottlenose dolphins range extensively throughout the tropical and temperate coastal waters of Australia. However, this species often exists in relatively 'self-contained entities' (Ross 2006) with tendencies for relatively high levels of site fidelity and philopatry (Chabanne et al. 2012a; Fury and Harrison 2008; Tsai and Mann 2013). These tendencies, coupled with slow reproductive rates, are likely to make these populations more vulnerable to individual losses (Woinarski et al. 2014). Both Ross (2006) and Woinarski (2012) emphasise the need to improve the knowledge of local populations and understand localised threats to ensure the quality of habitat and protection.

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 (Camphuysen 2006). Growing evidence

indicates the importance of major estuarine systems in Australia for localised resident populations of Indo-Pacific bottlenose dolphins (Chabanne et al. 2012a; Fury and Harrison 2008; Passadore et al. 2018; Wiszniewski et al. 2010; Zanardo et al. 2016). In recent years, concerns have increased in relation to the impacts of threats including coastal development, habitat degradation, pollutants, poor habitat quality, fishing interactions and vessel traffic, on dolphin populations inhabiting estuarine areas in Australia (Bossley et al. 2016; Bossley and Woolfall 2008; Chabanne et al. 2012a; Chabanne et al. 2017; Holyoake et al. 2010; Holyoake et al. 2011). These cumulative pressures increase the vulnerability of dolphins to the risk of displacement, injury, entanglement, disease and mortality (Chabanne et al. 2012b; Fury and Reif 2012; Holyoake et al. 2011; Marley et al. 2017; Paiva et al. 2015; Stephens et al. 2014). Despite these concerns, there remains very little knowledge of the status of regional dolphin populations and the relationships between estuarine health and dolphin health (on an individual, community and population level).

Study Objective

This study provides the first baseline knowledge on the abundance, habitat use and influence of natural environmental factors (i.e., tidal state, time of day and water quality) on dolphins utilising the Nambucca River, New South Wales.

Methods

Study site

Bordered by urban, agriculture and nature reserve, the Nambucca River (-30.65; 153.01) is a relatively small (12km^2), dominated barrier estuary with an open, trained entrance and a catchment area of 1299km^2 (Office of Environment and Heritage, www.environment.nsw.gov.au). A recent study (Ecohealth Project) reported that the Nambucca estuary is of moderate condition (Mika et al. 2018). The study uses standardised methods to assess the quality of estuaries and river systems as informed by a number of indicators including the hydrology, water quality, riparian vegetation, habitat quality, geomorphic condition and macroinvertebrate assemblages. Measures from the indicators were combined to provide an overall grade of condition (C-). Mika et al. (2018) noted for the Nambucca River, that the water quality was 'consistently poor across the catchment, driven by high nutrient concentrations and low dissolved oxygen'. Macroinvertebrates, fish assemblages and riparian vegetation were also in moderate to poor condition. Furthermore, boating and fishing are popular recreational activities in the Nambucca River with fluctuations in these activities occurring over peak holiday periods.

Data collection

Boat-based surveys were completed in the study site during intensive data collection blocks between 2014 and 2018. A pre-defined 42km survey route which included the main river channel and Warrell Creek, was followed to search the entire area for dolphins and other marine megafauna (e.g., turtles) and birds of prey (not reported here) (Figure 1). During the two survey blocks in 2014, more intensive survey effort was completed to establish initial baseline data. Survey effort for subsequent survey blocks was designed such that there was equal effort with eight surveys per sample block. Surveys were also made according to tidal and time of day conditions to account for these factors. Whereby, surveys were either completed during an outgoing or ebb, incoming or flood tide and in the morning (<12:00 AEST) or afternoon (>12:00 AEST). The high tide phase included the one hour of the high tide time plus one hour prior to and subsequent to. The low tide phase equated to one hour of the low tide time, plus one hour prior to and subsequent to. Flood was considered the three hours between low and high tide. Ebb was considered as the three hours between high and low tide (Fury and Harrison 2011b). Therefore, it was possible to complete up to two surveys on the same day if there was a complete tidal change (e.g., from flood to ebb) within daylight hours. Survey tracks were plotted using a Cybertracker platform specifically developed (by Gumma IPA and Dolphin Research Australia) for marine megafauna data. A geographic position (latitude and longitude) was recorded at 2-minute intervals using the platform installed on a mobile phone.

Boat-based surveys were carried out on a small vessel (3m or 4m in length with 30hp engine) that was driven at <12knots speed and in calm conditions (Beaufort <3). A minimum of two experienced or trained observers were positioned on the vessel such that the entire area around the vessel could be observed.

When a group of dolphins were sighted, a group follow commenced for up to one hour. A group was defined as all dolphins within a 100m radius engaged in similar behaviours (Bossley et al. 2016; Mann 2000). Continuous scan sampling was used to record behavioural states and events of the group (see

Appendix A for definitions) (Martin and Bateson 1993). The location and depth were recorded at the commencement and cessation of the group follow in addition to transitions between behaviour states. The group composition according to age-class (i.e., number of adults, juveniles and calves) was also recorded (Table 1). If no age-class could be confirmed for an individual it was noted as of 'unknown' age. Identification of an individual dolphin's sex was made by direct observation of the genital slits and/or an erect penis for males or by the presence of calves for females.

Photographs of all individuals within each group were taken using a digital Canon D60 SLR camera with a 300mm lens. Attempts were made to photograph both the left and right side of dorsal fins for the purposes of individual identification. Images were also taken of other areas of the body where possible for epidermal assessment (not reported here).

A Horiba multi-meter probe was used to obtain measures of water quality including dissolved oxygen, salinity, temperature, pH and conductivity. Turbidity was measured using Secchi depth. Water quality measures were made both where dolphins were sighted (typically at the end of a focal follow) and at random locations and times where there were no dolphins. Tidal state was also noted when water quality measures were taken. A minimum of four water quality recordings were made during each survey where there were no dolphins present.

Table 1: Age-class definitions used to define group compositions.

Age	Definition
Adult	Full grown individual around 2m in length. Ventral speckling is also present in mature animals with greater density indicative of age.
Juvenile	<2/3 the length of an adult and post-weaning age.
Calf	<1/2 the length of an adult and dependent on mother. Calves are typically in infant or echelon position next to an adult (although may have brief (number of minutes) periods of separation)
Unknown	Individuals where no age class could be confirmed.

Data analysis

Due to the small dataset acquired, only descriptive analysis was possible. To compare the sighting rates two standardised measures were calculated; the Linear Encounter Rate (LER) and the number of dolphins per hour (DPH). The LER was calculated by dividing the overall total length (km) of survey effort by the number of dolphins observed for each year and overall. Following Fury and Harrison (2011b), the number of dolphins encountered per hour was calculated by dividing the total number of hours of overall survey effort by the number of dolphins observed for each year and overall.

The mean group sizes overall were then calculated separately according to group composition (i.e., those groups observed with calves and those without calves). The percentage of groups observed to be engaged in each behaviour state was calculated. If more than one behaviour state was observed during the group follow, then all states were tallied separately (e.g., if a group was observed to socialise and feed during a follow, each behaviour was scored).

Standardised photographic identification methods were used to assess animals with long-lasting nicks and notches on the trailing edge of the dorsal fin (Wursig and Jefferson 1990). Images were initially graded for quality on a scale of 1 (poor) to 10 (excellent) based on the exposure, focus, and clarity of the dorsal fin. If a photo had a grade of ≥3, it was considered for the matching and cataloguing processes. A lesser quality image was discarded. The best image of each individual per sighting was used to perform subsequent matching and cataloguing. Each individual was classified based on the level of distinctiveness of the dorsal fin based on the number of nicks and damage. Each individual with sufficient marks and photo quality was matched against the entire catalogue to search for previous sightings. If no match was found, the individual would then added to the catalogue. An Access 2000 (Microsoft Corp.) database was used to record all sighting information of individuals, including images of their dorsal fins, date, location and behaviour of the group along with other individuals that were identified in the same group on the same day. If an animal did not have any long-lasting marks (notches or damage), it was considered 'unmarked'. A discovery curve showing the cumulative number of individuals identified over time was developed along with a summary of sightings across years and individuals identified.

Survey routes and dolphin locations were mapped using ArcGIS v 10.5 (Esri Corp.). As an indicator of the proximity groups were observed to different broad habitat types, base-map layer supplied by the NSW Department of Primary Industries was also used. The number of groups encountered per tidal state was then summarised along with the mean environmental measures for when dolphins were present and absent.

Results

Survey Effort

Between 2014 and 2018, 143 hours of effort equating to 1,260km travelled on 30 surveys were completed (Figure 1). There was, however, unequal effort between years due to logistics and weather conditions. More surveys were completed in 2014 than other years (Table 3). No surveys were completed during 2015. Three sampling blocks were completed during April and May (2014 and 2018) with one block completed in October (2016). There was an equal number of surveys completed for high, incoming and outgoing tidal states and fewer in low tidal states (Table 4). However, due to the shallow depth of the estuary at low tide, it was not possible to navigate the entire survey route and this restricted the number of surveys possible at this tidal state.

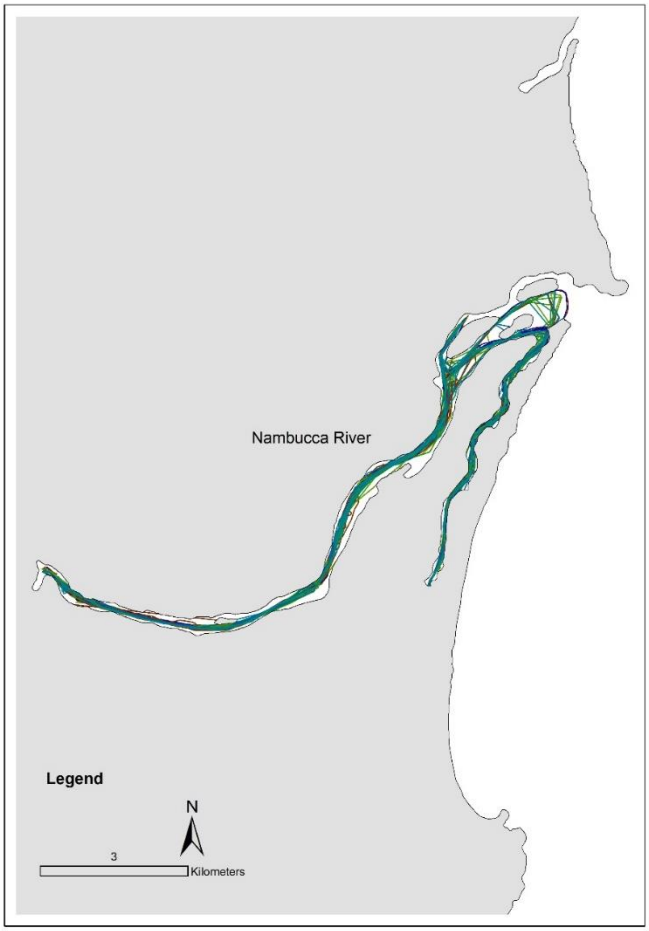

Figure 1: Vessel survey tracks 2014-2018 for Nambucca River Estuary.

Groups of dolphins were observed on 28% of surveys with an average Linear Encounter Rate of 0.02 dolphins/km (S.D. 0.04) which varied little between years (Table 2). There were nine groups of dolphins observed across all surveys with a total of 25 dolphins counted with most observed in 2014 and 2016. The number of dolphins encountered per hour of survey ranged between 0.15 (S.D. 0.28) in 2014 and 0.21 (S.D. 0.44) in 2018 with a rate of 0.21 (S.D. 0.52) DPH overall.

Table 2: Survey effort, the number of groups and individuals counted in the Nambucca River Estuary with Linear Encounter Rates (L.E.R.) and number of dolphins per hour (D.P.H.) for each year.

Year	# Hours Effort	# Surveys	# Groups Observed	# Dolphins Counted	L.E.R.	D.P.H.
2014	88:40	16	5	11	0.02	0.12
2016	34:30	8	3	6	0.02	0.17
2018	20:28	6	1	8	0.03	0.39
Total	**143:38**	**30**	**9**	**25**	**0.02**	**0.17**

Table 3: Survey effort by time of day category and year.

Year	Time of Day	# Surveys
2014		**16**
	AM	8
	PM	8
2016		**8**
	AM	6
	PM	2
2018		**6**
	AM	2
	PM	4
Total		**30**

Table 4: Survey effort by tidal state category.

Tidal State	# Surveys
High	16
Incoming	16
Low	9
Outgoing	16

Group size & Behaviour

The majority of groups (78%; N = 7) were composed of adults, juveniles and/or calves. The overall mean group size was 2.8 (S.D. = 2.2) with those groups containing at least one calf or juvenile being slightly larger (mean = 3.3, S.D. = 2.2) than non-calf (adult-only) groups (mean = 1; S.D. = 0). All groups were observed to be engaged in travel-foraging during the group follow. Other behaviour states were comparatively less common (Table 5).

Table 5: Number and percentage of groups engaged in the different behaviour states.

Behaviour State	# Groups	% of Groups
Travelling	1	11.1
Milling/Resting	1	11.1
Socialising	2	22.2
Feeding	1	11.1
Travel-Foraging	9	100.0

Individual identification & population assessment

It was not possible to apply population modelling to ascertain the population abundance of dolphins in the Nambucca estuary due to the low detection rate and the low number of individual recaptures.

A total of 8 dolphins were photographically identified from distinct long-lasting marks on the trailing edge of the dorsal fin (Appendix B). The proportion of unmarked dolphins from all age-classes was 13.0%, with 2.8% of all adults encountered considered unmarked. These animals were therefore not included in the following descriptive analysis. The majority of animals were identified in the first two years of surveys (Table 6). Figure 2 shows the cumulative number of dolphins identified with survey effort. This included 5 adults (female = 4; unknown sex = 1), 1 sub-adult (unknown sex) and 2 juveniles (unknown sex). Of those dolphins identified, 2 were encountered on 4 occasions (or surveys), one on 3 occasions, 1 on 2 occasions and 4 were encountered once. Three dolphins (38%) were seen in more than one year (Table 7).

Table 6: Number of dolphins photographically identified and the number of newly identified dolphins per year surveyed.

Year	# Dolphins Identified	# New Dolphins Identified
2014	8	6
2016	6	0
2018	3	2
Total	**17**	**8**

Table 7: Number of encounters per individual per year.

	Year			
Dolphin ID	2014	2016	2018	Total
1	3			3
2	1			1
3	1	3		4
4	1	3		4
5	1		1	2
6	1			1
7			1	1
8			1	1
Total	8	6	3	17

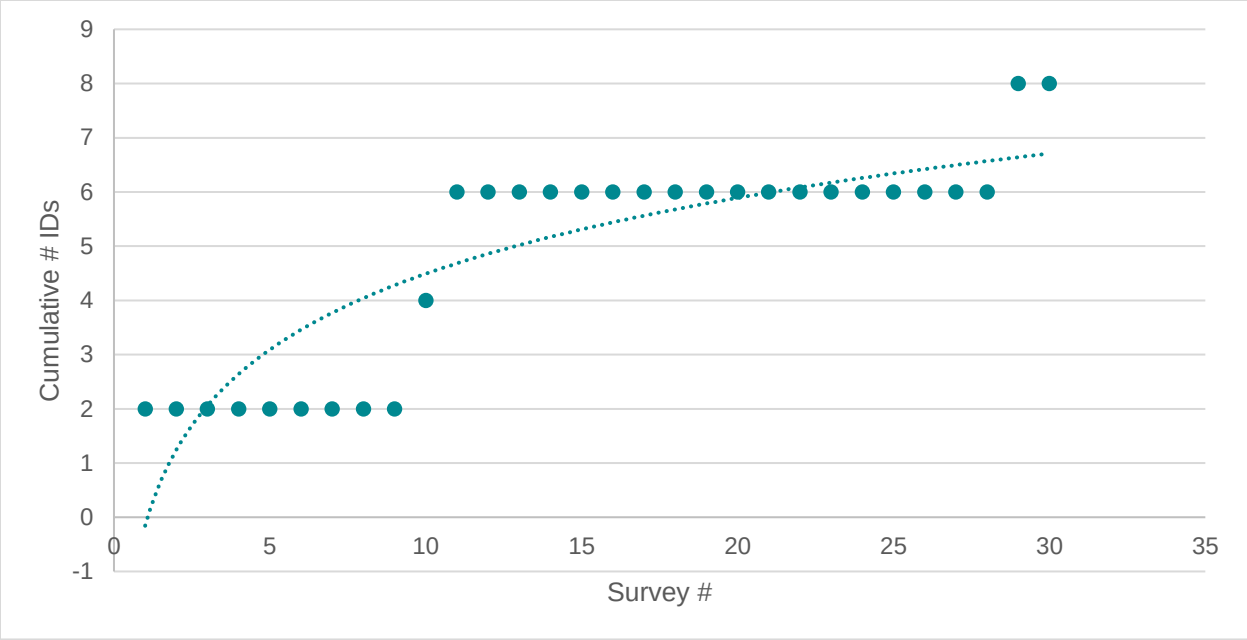

Figure 2: The cumulative number of dolphins identified between 2014 and 2018 over the number of surveys with logarithmic trendline.

Habitat use

During surveys, dolphins were encountered up to 14km from the river mouth (which also coincided with the end of the survey route) and in the main channel. The majority of groups were encountered less than 9km from the river mouth. Anecdotal reports received from local fishermen indicated that dolphins very occasionally are seen as far as the town of Bowraville, approximately 30km upstream. Figure 3 shows the location of each group encountered and all respective behaviour states observed.

The average depth in which groups were encountered was 2.4m (S.D. 1.5m). Four groups were encountered during morning surveys (6am-12pm) and five were observed in the afternoon (12pm-5pm). The majority of groups (66.7%) were observed during an incoming tide (Table 8). There was little difference in the environmental measures where dolphins were present (n = 9) compared to absent (n = 143) with the exception of turbidity. Dolphins were present where turbidity levels were also, on average, higher (Table 9).

Table 8: Number and percentage of groups observed per tidal state.

Tidal state	# Groups	% of Groups
Full	1	11.1
Incoming	6	66.7
Low	1	11.1
Outgoing	1	11.1

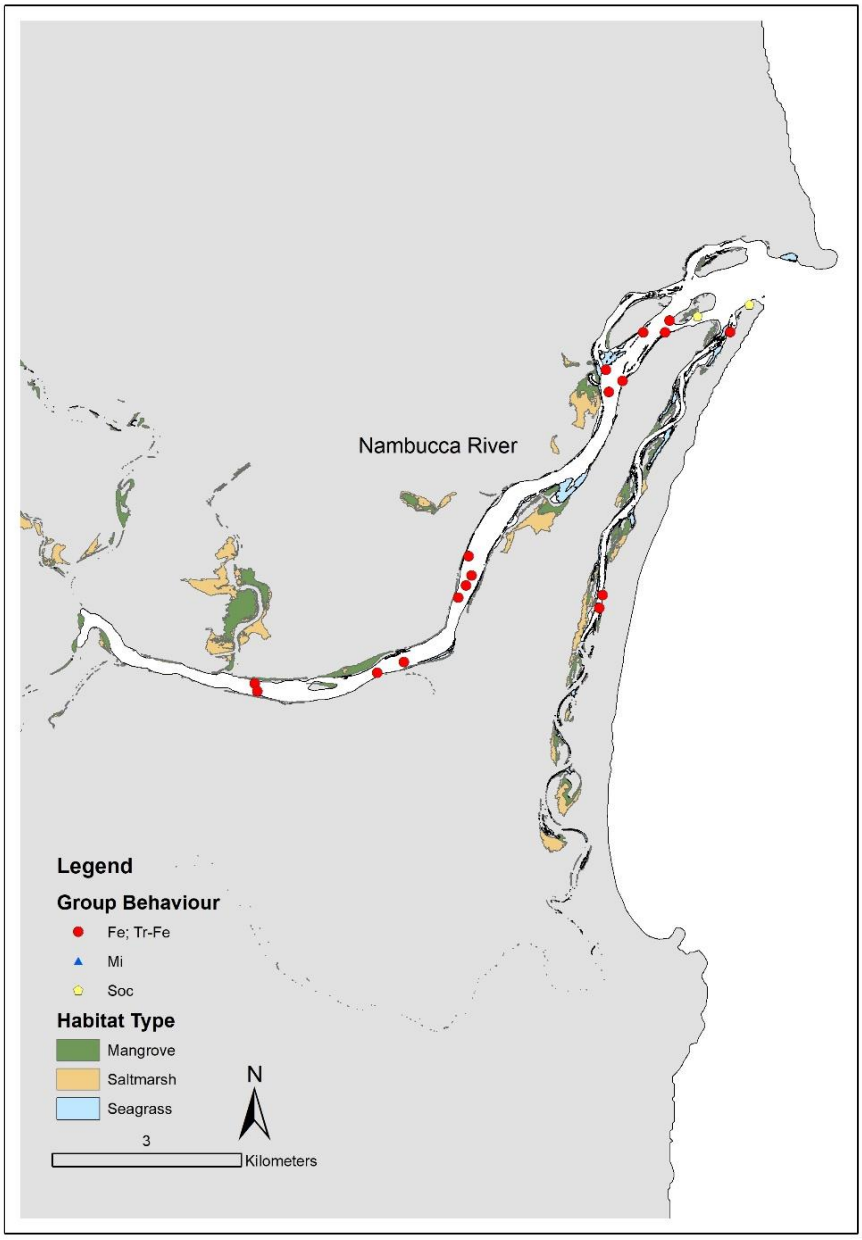

Figure 3: Locations and behaviour of groups observed with habitat type.

Table 9: Average and standard deviation (S.D.) of environmental measures recorded in the presence and absence of dolphin groups.

	Mean Temperature (˚C)	S.D. Temperature	Mean Conductivity (µS/Cm)	S.D. Conductivity	Mean Dissolved Oxygen (mg/L)	S.D. Dissolved Oxygen	Mean Salinity (µScm-1)	S.D. Salinity	Mean pH	S.D. pH	Mean Turbidity (cm)	S.D. Turbidity
Dolphins Absent	22.06	1.85	43.71	8.03	6.75	2.30	2.88	0.56	8.15	1.40	125.48	86.53
Dolphins Present	21.12	2.35	43.56	6.42	6.64	2.57	2.92	0.55	8.00	0.38	150.71	55.42
Overall	22.03	1.91	43.43	8.17	6.67	2.37	2.85	0.64	8.13	0.40	122.86	77.72

Discussion & Key Findings

This report provides the first baseline information on the use of the Nambucca River estuary by a community of Indo-Pacific bottlenose dolphins. Despite the small sample size, it was evident that the community is relatively small, with nine individual dolphins identified across three years of the study (or 30 surveys). Furthermore, the estuary was utilised primarily by small mother-calf groups for foraging. Environmental factors, including tidal state and turbidity, appear to influence the use of the estuary by dolphins.

Fury and Harrison (2008) hypothesise that larger estuaries are likely to support a higher abundance of dolphins. We identified eight individual dolphins with distinct marks. Due to the low sample size, abundance estimates were not possible; however, it is predicted to be relatively small as indicated by the number of individuals identified per survey and group encounter rates (Figure 2). Table 10 provides a brief comparison of abundance estimates for Indo-Pacific bottlenose dolphin communities that utilise estuaries in Australia.

Bottlenose dolphin group sizes vary with habitat type where groups tend to be larger in exposed coastal zones and smaller in enclosed and sheltered bays. For example, along the exposed coastal habitat of Byron Bay, Northern South Wales, the average group sizes for Indo-Pacific bottlenose dolphins are much larger (13 individuals; S.D. = 12) (Hawkins and Gartside 2008) than those reported for a sheltered bay 6.8 (± 0.37) in Port Stephens, New South Wales (Moller et al. 2002). Comparatively, the average group sizes in the Nambucca River estuary were also relatively small (mean 2.8; S.D. = 2.2) compared to other sites. In the Broadwater-Gold Coast, Tweed River and Swan-Canning River estuary, group sizes averaged around five animals (Author's unpublished data; Chabanne et al. 2012).

Features within the habitat of dolphins can cause natural barriers and influence both the movement of community and social dynamics of dolphins (Cagnazzi et al. 2011; Titcomb et al. 2015). For example, Titcomb (2015) reported that the movement and community division in bottlenose dolphins (*Tursiops truncatus*) in the Indian River Lagoon, Florida, appeared to be related to the narrowness of the estuary. Nambucca estuary is a relatively small, shallow and complex estuary and it is not unexpected that the size of the community is also small. The shallow bar at the entrance to the estuary is also likely to create a barrier for dolphins to enter the river. The bar can become extremely shallow at low tide and therefore, the river is often only likely to be accessible to dolphins during higher tides. It is also interesting to note that the coastal region adjacent to the Nambucca estuary is frequented by larger groups of dolphins (>20 individuals) (pers. obs.). This suggests that a very small portion of a larger coastal population enters the estuary.

A number of environmental factors also influence the presence of dolphins in estuaries. Dolphin communities in the Richmond and Clarence Rivers, New South Wales were more likely to be present during an incoming tide (1-2hr prior to a high tide), when salinity and turbidity measures were higher (Fury and Harrison 2011a; Fury and Harrison 2011b). Similar patterns were observed in the current study with the majority of groups observed on an incoming tide and when salinity and turbidity levels were higher.

Prey resources and availability are likely to be the primary drivers for the utilisation of the estuary by dolphins as indicated by the prevalence of foraging behaviours in all groups observed. Similarly, bottlenose dolphins were observed to primarily feed in other estuaries including the Sado Estuary, Portugal (Harzen 1998). It has also been suggested that the year-round availability and predictability of prey resources in estuarine environments can drive higher residency and limited movement patterns of these dolphin communities (e.g., Titcomb et al. 2015).

Estuaries appear to be particularly significant for females with dependent offspring. In the present study, the majority of groups encountered, and adults identified, were females with dependent offspring. Three dolphins were seen in multiple years, suggesting that there is a degree of residency within the community for females in particular. Due to the shallow and complex nature of the estuary, the small number of animals, and the likelihood of residency within the community, it is hypothesised that the use of the estuary requires a degree of foraging specialisation by individuals.

Small communities of estuarine dolphins with year-round residency and site fidelity are particularly vulnerable to cumulative stressors, due to the intensity of human activity and environmental degradation through, for example, coastal development and pollution (Bossley et al. 2016; Chabanne et al. 2017). The Nambucca River estuary is a degraded system with poor water quality, higher nutrient loads and lower dissolved oxygen levels being reported along with moderate to poor conditions in macroinvertebrate, fish assemblages and riparian vegetation (Mika et al. 2018). These declines in environmental quality are influenced by the adjacent urban and agricultural land uses. Additionally, the Nambucca River estuary is also a popular recreational fishing and boating destination. As emphasised by Chabanne et al. (2017), due to the risk of local extirpation for small resident estuarine dolphin communities, it is pertinent that these communities are considered in the assessment of coastal development proposal and associated activities in line with best-practice (Hawkins et al. 2017). Furthermore, in agreement with Chabanne et al. (2012), management of estuarine areas in relation to dolphin communities, should focus on enhancing protective measures and addressing major threatening processes. In the case of the Nambucca River estuary, it is recommended that management address key threatening processes for this region to strengthen the protection and preservation of this localised dolphin community. This includes the enhancement of prey species habitat, reduction

in agricultural runoff, fisheries and boating interactions and marine litter, in addition to the incorporation of risk and mitigation into environmental impact assessments for proposed developments. Lastly, it is recommended that frequent seasonal surveys are conducted to continue to improve the knowledge and monitor the abundance, residency, habitat use and seasonal changes of dolphins that use the Nambucca River estuary.

Next Steps

Following the acquisition of the baseline dataset collected between 2014 and 2018, the next steps are listed below.

- Integrate these data into multi-site datasets to compare:
    - the habitat use, community abundance and structure with other sites,
    - the health of dolphin communities using epidermal photographic assessments,
    - state of the environment to the community structure and health of dolphins that utilise estuaries along northern New South Wales and South East Queensland.

This will then contribute to the development of a Vulnerability Index Framework for estuarine dolphin communities.

Table 10: Catchment areas, survey effort and population estimates for Indo-Pacific bottlenose dolphins utilising estuaries in Australia.

Site	Catchment Area Km^2	Estuary Area Km^2	Duration of Study	Survey Effort (# Surveys)	# Dolphin Identified	Population Estimate	95% CI	Reference
Clarence River, New South Wales	22,446	89	3 years	87	43 (adults)	71	62–81	(Fury and Harrison 2008)
Tweed River, New South Wales	1,055	23	1 year	22	42 (adults)	52	49-54	Authors unpublished data
Richmond River, New South Wales	6,861	38	3 years	100	19 (adults)	34	19–49	(Fury and Harrison 2008)
Broadwater-Gold Coast, Queensland	5,872	99	1 year	64	24 (adults)	27	22-31	Authors unpublished data
Swan-Canning River, Western Australia	2,090	55	3 years	222	43 (adults)	17-18 (resident community)	Na	(Chabanne et al. 2012a)
Nambucca River, New South Wales	1,299	13	3 years	30	5 (adults)	Na	Na	This study

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Appendix A

Ethogram of behaviour states and events

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 breaths before diving (often having a deep dive or fluke-out dive after the last breath).
BEHAVIOUR **EVENT**		**DESCRIPTION**
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.

Approach	App	When one or more dolphins approach a vessel or swimmer especially 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 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 reveals vertical descent.
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 foetal 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.

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 bow-riding or wake-riding.
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 metres 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 with 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 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 it's rostrum underneath its mother in the vicinity 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, simultaneously.
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.

Appendix B

Nambucca River estuary Photo-ID Catalogue April 2014- May 2018

ID #	Left Dorsal	Right Dorsal
ID # 001		
ID # 002		
ID # 003		

ID # 004		
ID # 005		
ID # 006		
ID # 007		

ID # 008		
ID # 009*		

***Note:** Individual ID#009 (Hope) was added to the catalogue following a successful rescue in 2013. Hope had become stranded on a shallow sandbank in the Nambucca River and was subsequently rescued and assessed by veterinary staff at the Dolphin Marine Magic facility in Coffs Harbour. On 18th October 2013, Hope was released back into the Nambucca River estuary and was observed to exit the river mouth shortly after. She has not been seen during research surveys after this release.