Annual report on dugong tracking and habitat use in Gladstone in 2015

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This report has been produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program. The study was undertaken through a Consultancy Agreement (CA12000293) between Gladstone Ports Corporation and James Cook University to Increase understanding of dugong habitat use in the Port Curtis and Port Alma region: using satellite telemetry. This publication has been compiled by James Cook University.

Disclaimer:

Executive Summary

- This report summarises data collected in 2015 through the Consultancy Agreement (CA12000293) between Gladstone Ports Corporation and James Cook University to increase understanding of dugong habitat use in the Port Curtis and Port Alma region: using satellite telemetry.

- We used GPS-satellite telemetry to examine the movements and habitat use of a 2.32m sub-adult male captured in the Gladstone region on 12th July 2015.

- The dugong was tracked for 90 days. Immediately after its capture the dugong moved to Shoalwater Bay over a period of four days. It remained in Shoalwater Bay for the remainder of its tracking period, which was terminated when the transmitter detached.

- We examined the distribution and density of GPS and Argos data in our analysis of the dugong's activity space because the GPS unit did not transmit for the entire tracking period.

- The tracked dugong frequently used two distinct coastal areas in Shoalwater Bay located between Clara Island and the mainland and southwest of Towsnhend Island.

- The size and location of the 95% home range and 50% core area of the dugong in Shoalwater Bay is similar to those recorded from previous studies for this region.

- This study demonstrated connectivity between dugongs in the Gladstone region and Shoalwater Bay.

Introduction

Gladstone Ports Corporation (GPC) completed the Western Basin Dredging and Disposal Project in September 2013. The project removed a total of 22 million m^3 of material during 2011-2013. The project increased port access by deepening, widening and creating new shipping channels with depths of up to 13 metres to allow vessels to enter and exit the Western Basin. The project also included the construction of a bund wall and reclamation area at Fisherman's Landing.

To obtain the permit required to undertake these dredging activities, GPC was required to meet environmental conditions, including the development and implementation of an Ecosystem Research and Monitoring Program (ERMP). The ERMP was developed to acquire a detailed ecological understanding of the marine environment of Port Curtis and Port Alma that can be used to monitor, manage and/or improve the regional marine environment and to offset potential impacts from the project on listed threatened and migratory species and values of the Great Barrier Reef World Heritage Area and National Heritage Place, including the dugong, *Dugong dugon*.

The scope of this work is to deploy satellite tags on dugongs and examine the movement, behaviour, and habitat use in the Gladstone region as opportunity permits to increase understanding of habitat use by dugongs in the Gladstone region.

This report summarises data collected in 2015 through the Consultancy Agreement (CA12000293) between Gladstone Ports Corporation and James Cook University to increase understanding of dugong habitat use in the Port Curtis and Port Alma region: using satellite telemetry.

Methods

Dugong capture and tag attachment

A dugong was captured on the Pelican Bank in Port Curtis (Figure 1) using the rodeo method originally developed for sea turtles (Limpus 1978) and adopted for dugongs (Marsh and Rathbun 1990, Lanyon et al. 2006). The dugong was secured as described in Lanyon et al. (2006) during the deployment of a GPS-satellite tracking transmitter and measurement of body size. The dugong was released within 15 minutes of capture in the same area of its capture. This dugong appeared to be healthy at the time of the release.

Because dugongs lack dorsal fins, their peduncle is the only secure attachment point for external devices (Marsh and Rathbun 1990, Reid et al. 1995). Each GPS-satellite transmitter was attached to a dugong peduncle via a 3m long flexible tether attached to a padded tailstock belt. This system, which was developed for the Florida manatee (Reid et al. 1995), has been used on dugongs since the 1980s and enables the tag to float to the surface when the animal is in shallow water, increasing the frequency of signals successfully transmitted to satellites. The harness assembly incorporates a weak link that can be broken by the dugong if the assembly becomes entangled in marine biota such as coral or mangroves and a corroding link that slowly corrodes in a galvanic reaction in seawater and releases the harness.

Global positioning system

We used the Gen4 GPS receiver technology developed by Telonics. Gen4 systems incorporate a GPS receiver for obtaining positional data. The fix time of this GPS receiver ranges between 30 and 90 sec assuming a clear view of the sky (http://www.telonics.com). Typical GPS position accuracy is 2-10m. The units also contained a fast acquisition GPS tracking technology entitled Quick Fix Pseudoranging (QFP) developed for marine mammals that surface for only short periods of time. The QFP technology obtains location fixes with as little as 3 sec of surfacing time. QFP locations are categorised by locational accuracy into three categories: resolved QFP, resolved QFP (uncertain), and unresolved QFP. Telonics (2012) states that 98.4% of resolved QFP positions are within 30m of the actual position, resolved QFP (uncertain) positions are generally within 75m, and unresolved QFP positions are over 100m. Argos location fixes can be collected in addition to the GPS-QFP data described above. These fixes are categorised by location accuracy which ranges from < 250m to > 1500m (Table 1).

Data processing

GPS-QFP data are typically preferred over Argos data for fine-scale movement analysis because they are more accurate. However, exploratory data analysis showed that: (1) GPS-QFP location fixes were collected only during a short period of the time during which Dugong 652632A was tracked (for more details see Appendix A), and hence conducting a fine-scale analysis of its activity space using GPS-QFP data only would not provide a comprehensive picture of how this animal used space during its tracking period. Consequently, we included Class 3 Argos location fixes, the most accurate Argos fixes (< 250m), in the analysis. Argos location class 1, 2 and 3 were retained to make Figure 1 to capture details of the movement of the dugong between Gladstone and Shoalwater Bay (see Figure 1).

Each GPS-satellite unit was set to obtain a location fix every 60 min. Raw data was transmitted via the ARGOS network (http://www.argos-system.org) and then converted into GPS and Argos locations using manufacture-supplied software (Telonics Data Converter). We used ArcGIS 10.2 (ESRI 2013) for spatial analysis unless otherwise stated. ESRI imagery was used for visual inspection of location fixes and as background images for the maps. Statistical analysis was conducted using Microsoft Excel and the R software (R Development Core Team).

The data were initially filtered by location class, using only successful GPS, resolved QFP and Class 3 Argos location fixes to maintain accuracy of 250m. After initial filtering, the data were corrected for over-speed errors, temporal duplicates, and fixes obtained inland as explained in Gredzens et al. (2014) and using the data-driven method described by Shimada et al. (2012). After filtering and correcting the dataset, the location data from each dugong were standardised by dividing the remaining location points into 3 hour duty-cycles and selecting the most accurate location within each duty-cycle (detailed in Gredzens et al. 2014). Three hours was chosen to retain as many location points as possible while minimising differences in the number of location points per day per animal. In addition, duty cycles were used to reduce the effects of autocorrelation and effects resulting from differences in transmitter performance. These measures were necessary as sample size was shown to significantly affect home-range estimates (Boyle et al. 2009).

Home-range and core areas

We calculated utilisation distributions (UD) to define the core areas and home range of the tracked dugong. The UDs areas explain where an individual dugong spends 5 to 95% of its time. The fixed Kernel density estimation and isopleth tools were used in the Geospatial Modelling Environment software (GME; Beyer, 2012) at a resolution of 30m. This resolution was selected because the mean accuracy of filtered QFP GPS locations is within 30m of the true location. The CVh smoothing parameter was chosen as the most biologically relevant smoothing parameter for the dataset after exploring different types of smoothing parameters. This approach is consistent with other recent analyses of dugong home-ranges and core areas (Gredzens et al. 2014, Cleguer 2015, Zeh et al. 2015). Utilisation distribution was calculated using data from the period during which dugong 652632A was tracked. Any areas of the 95% and 50% polygons that overlapped with land were removed before the size of each polygon was calculated using the dataset representing the entire period for which dugong 652632A was tracked. The mean (±SD), minimum and maximum distances from the nearest land were determined using the near analysis tool in ArcGIS 10.2.

Results

Dugong capture, tagging and tracking information

Dugong 652632A, a 2.32m sub-adult male, was captured on the Pelican Banks and equipped with a Telonics GPS-satellite transmitter on 12th July 2015 (Figure 1 and Table 2). This animal was tracked for 90 days before the tag came off and was subsequently recovered from Shoalwater Bay by EHP staff.

Use of space

Dugong 652632A left Port Curtis on the day of its capture and travelled to Shoalwater Bay over four days, an approximate minimum distance of 209km (straight line distance between location points). There was no evidence of the animal stopping on its way to Shoalwater Bay. The animal mostly travelled close to the coast (mean distance from the coast of 0.2km (± 0.2km)) during its trip between Port Curtis and Shoalwater Bay and travelled along the outside of Curtis Island rather than through the Narrows (Figure 1 and Table 3). The location error of the offshore record north of Port Alma Figure 1) is large and it is impossible to be certain how far offshore the animal was at this location.

The dugong then remained in the coastal areas (mean distance = 0.9km ± 0.9) of Shoalwater Bay for the remainder of its tracking period intensively using two distinct areas: between the mainland and Clara Island and an area located southwest of Townshend Island (Figure 2). The home range size (95% KDE) and the size of the areas intensively used (50% KDE) of this dugong were 407km^2 and 58km^2 respectively (Table 3).

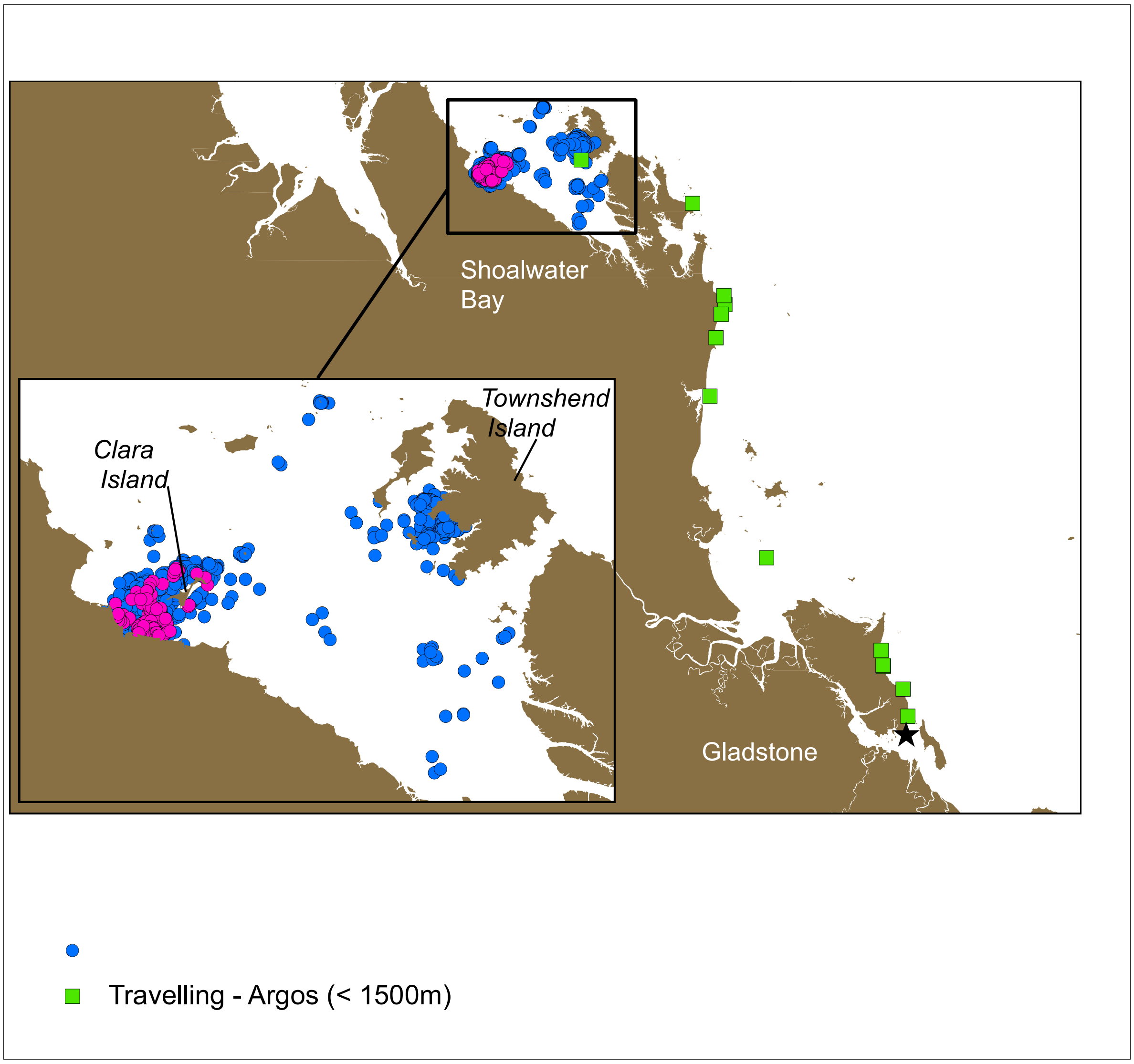

Figure 1: Movements (GPS and Argos location fixes) of dugong 652632A captured in the Port Curtis in 2015. This dugong undertook a large scale movement (> 15km) from the Port Curtis to Shoalwater Bay in four days (A). It then used various coastal areas in Shoalwater Bay for the remainder of its tracking period (B). The black star shows where this dugong was captured. This figure shows GPS-QFP and Argos location class 1, 2, 3 fixes received during the entire tracking period in order to display the trajectory taken by the dugong during its travel from the Gladstone region to Shoalwater Bay.

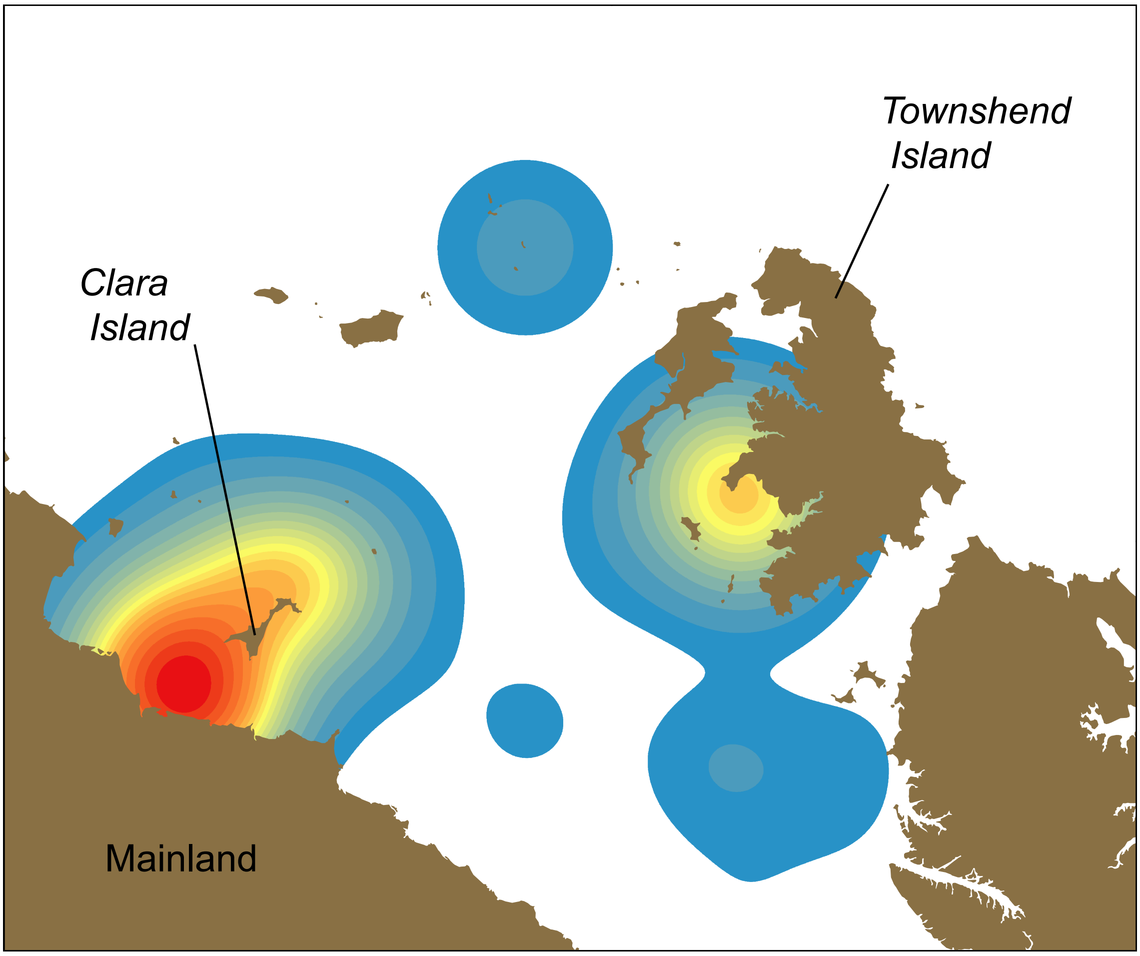

Figure 2: Utilisation distribution (UD) of dugong 652632A captured in the Gladstone region in 2015. Dugong density is high in red and low in blue. This figure clearly shows the two distinct areas frequently used by this dugong, close to Clara and Townshend Islands, during the period for which it was tracked.

Table 1: List of Argos location classes and estimated error (in meter) received through the Argos website.

Argos class	Estimated error (m)
3	< 250
2	250 < < 500
1	500 < < 1500
0	> 1500
A	No accuracy estimation
B	No accuracy estimation
Z	Invalid location (available only for Service Plus/Auxiliary Location Processing)

Table 2: Data summary for the dugong tracked using GPS-satellite units in the Gladstone region in 2015.

Argos No.	Secondary tag	Sex	Size (m)	Capture location lat/lon (decimal degrees)	Date tagged	Tracking period	Tracking days	Number of filtered fixes
652632A	QA58204	Male	2.32	-23.791/ 151.292	12/07/2015	12 Jul 2015 -09 Oct 2015	90	308

Table 3: Core habitats (50% KDE), home range (95% KDE) and distances to nearest land of the dugong tracked in the Gladstone region 2015.

Argos No.	50% KDE (km^2)	95% KDE (km^2)	Distance to nearest land (km) during travel to Shoalwater Bay		Distance to nearest land (km) during the tracking period in Shoalwater Bay	
			Max	Mean (± SD)	Max	Mean (± SD)
652632A	58	407	0.6	0.2 (0.2)	7.7	0.9 (0.9)

Discussion

We obtained information on the activity of an adult male dugong (652632A) that undertook a large scale movement (*sensu* Sheppard et al. 2006) from Port Curtis to Shoalwater Bay immediately after it was fitted with a GPS-satellite tracking device in July 2015. This dugong then stayed in Shoalwater Bay for the remainder of its tracking period. The ecological and management implications of the use of space displayed by Dugong 652632A are discussed below.

Ecological implications

Large scale movements

Dugongs do not undertake regular migrations. Their movements are individualistic (Sheppard et al. 2006, Marsh et al. 2011) and include long-distance movements up to 560 km (Sheppard 2006). Twenty percent of the 70 dugongs satellite-tracked by Sheppard et al. (2006) moved 100-560 km. Cope et al.'s (2015) dugong pedigree analysis suggests more large-scale movements between the locations along the Queensland coast than detected through repeated direct sampling of individuals (Seddon et al. 2014) or telemetry (Sheppard et al. 2006).

The movement of Dugong 652632A from Port Curtis to Shoalwater Bay immediately after he was released appears to be a flight response to capture. However, large scale movements (> 15km) by dugongs are not necessarily flight responses. Some such movements have been undertaken months after capture (Sheppard et al. 2006; Gredzens et al. 2014; Cleguer 2015; Zeh et al. in press). There was no evidence that the tracked dugong stopped during its travel from the Gladstone region to Shoalwater Bay suggesting a capacity for orientation and navigation. The sensory modalities used by sirenians to navigate are unknown. But the limitations on vision (Bauer et al. 2003) and a lack of active echolocation (Mann et al. 2005) suggest that other sensory modalities such as the well-developed tactile sensory systems may play an important role in spatial orientation (Reep et al. 2002; Reep and Sarko 2009; Reep et al. 2011). Sheppard *et al.* (2006) speculate that dugongs may use coastal geomorphology to navigate during long-distance moves via some combination of visual, magnetic, chemosensory, or tactile cues, concordant with observed travels below the surface. Navigation in dugongs remains largely unexplored and requires further investigation.

Similar patterns of direct dugong movements with no evidence of feeding stopovers have been reported in other regions of Australia and in New Caledonia. For example, two dugongs undertook one day return 'visits' from Hinchinbrook Island to Cleveland Bay located 150km to the south without exploring any known seagrass meadows *en route* (Sheppard et al. 2006). Another two dugongs moved from Hervey Bay to Great Keppel Island and Clearview respectively, bypassing Port Curtis, an area with significant seagrass (Sheppard et al. 2006). Dugongs used the fore reef shelf, a non-seagrass coral reef habitat located outside the lagoon surrounding the main island of the New Caledonia archipelago, to make return trips from one Bay to another (Cleguer 2015).

Sheppard et al. (2006) suggested that dugongs have a tendency to make direct movements to alternative areas as a functional response to unpredictable and patchy seagrass abundance. Even though the large-scale movement reported here appeared to be a flight response, the rapidity of this apparently directed movement is consistent with the hypothesis that dugongs maintain a spatial memory of specific habitat hotspots that may include patches of seagrass food resources that they visit periodically. Matrilinearly transmitted learned behaviour, commonly known as tradition, seems to play a large role in determining the use of space and migratory habits of Florida manatees and possibly dugongs (as detailed in Marsh et al. 2011). Although there is no evidence that sirenians show long-term social structure, a number of intriguing observations suggest that the use of space may follow matrilines that could enable both direct and indirect kin selection for seemingly altruistic behaviours (Marsh et al. 2011).

Home range and core areas

The sizes of the core areas and home range of Dugong 652632A in Shoalwater Bay were within the range reported in Gredzens et al's. (2014) study on the spatial ecology of dugongs in Shoalwater Bay (with 95% home-range areas ranging from 15.9 km2 to 72.8 km^2, median = 49.5 km^2, and 50% core areas ranging between 2.6 km^2 and 21.3 km^2, median = 4.2 km^2, encompassing a total area of 123.7 km2 (95%) and 28.5 km2 (50%)). Nonetheless, the sizes of the core areas and home range of the dugongs tracked in Shoalwater Bay are substantially smaller than that of dugongs tracked in Torres Strait, a vast dugong habitat (median range = 942.6km^2; Gredzens et al. 2014). Differences in the size and geomorphology of the bays in which the dugongs are tracked and the distribution of seagrasses may explain the regional differences in dugong range sizes.

The activity space and movement patterns of the tracked dugong likely reflect the distribution of seagrass in Shoalwater Bay because the distribution of dugongs generally coincides broadly with that of seagrass beds (Marsh et al. 2002, 2011). The areas frequently used by Dugong 652632A were also detected by Gredzens et al. (2014) in their independent satellite tracking study, suggesting that these areas are of importance to dugongs in the region. Dugongs also use areas devoid of seagrass for purposes other than feeding as reported in other regions. In Moreton Bay during winter, dugongs frequently undertake short trips outside the bay to rest for a few hours in warmer oceanic waters (Preen 1992, Daniel Zeh unpublished data). Similarly in New Caledonia during the cool season, dugongs form resting herds over the fore reef shelf outside the lagoon at low tide, presumably as a behavioural thermoregulatory response to changes in water temperature combined with the inaccessibility of inner-lagoon intertidal foraging sites at low tide (Cleguer 2015). Given that Dugong 652632A was tagged in mid-winter, his flight response to warmer northern waters is also consistent with thermoregulatory behaviour.

Management Implications

The apparently directed large-scale movement of Dugong 652632A between Port Curtis and Shoalwater Bay was close to the shore suggesting that the animal may have been exposed to the risk of entanglement in commercial gill nets. The tracked dugong stayed within less than a kilometre of the mainland. Zeh et al. (in press) found that four out of the 30 dugongs they captured in Moreton Bay travelled over 200km north to Hervey Bay, three of them moving along and very close to the coast (< 5km). Dugongs tracked by Sheppard et al. (2006) mostly stayed within 7km of the coast but were also found up to 20km offshore (whether this last result is real or an artefact of the technology is unknown).

The risks that dugongs face while travelling close to the coast vary with location. For example, between Moreton Bay and Hervey Bay in Australia, shark nets for bather protection are located immediately offshore from several beaches and 39 dugongs were recorded drowned in shark nets in this region between 1989 and 2011 (Meager et al. 2013). In the Great Barrier Reef World Heritage Area, an extensive series of Dugong Protection Areas and marine park zones have been established to protect relatively high density dugong areas in the World Heritage Area (Dobbs et al. 2008; Grech and Marsh 2008). Mesh netting has been banned from areas close to major headlands to protect dugongs travelling between bays in the Great Barrier Reef Marine Park (GBRMPA 2007), from some dugong movement corridors in the Great Sandy Marine Park (Sheppard 2008 and very recently a large net-free fishing zone has been declared in the region from Keppel Bay to the Fitzroy River https://www.business.qld.gov.au/industry/fisheries/commercial-fishing/net-free-zones/location. The information we obtained on the movement corridor used by the tracked dugong between the Gladstone region and Shoalwater Bay could be used by local management agencies to further reduce netting effort in the pathways used by dugongs. Tracking additional dugongs captured in Port Curtis and Shoalwater Bay is needed to increase our sample size and inform the protection of dugong movement corridors between these two regions.

Acknowledgements

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Appendix A

Data exploration - Tag 652632A

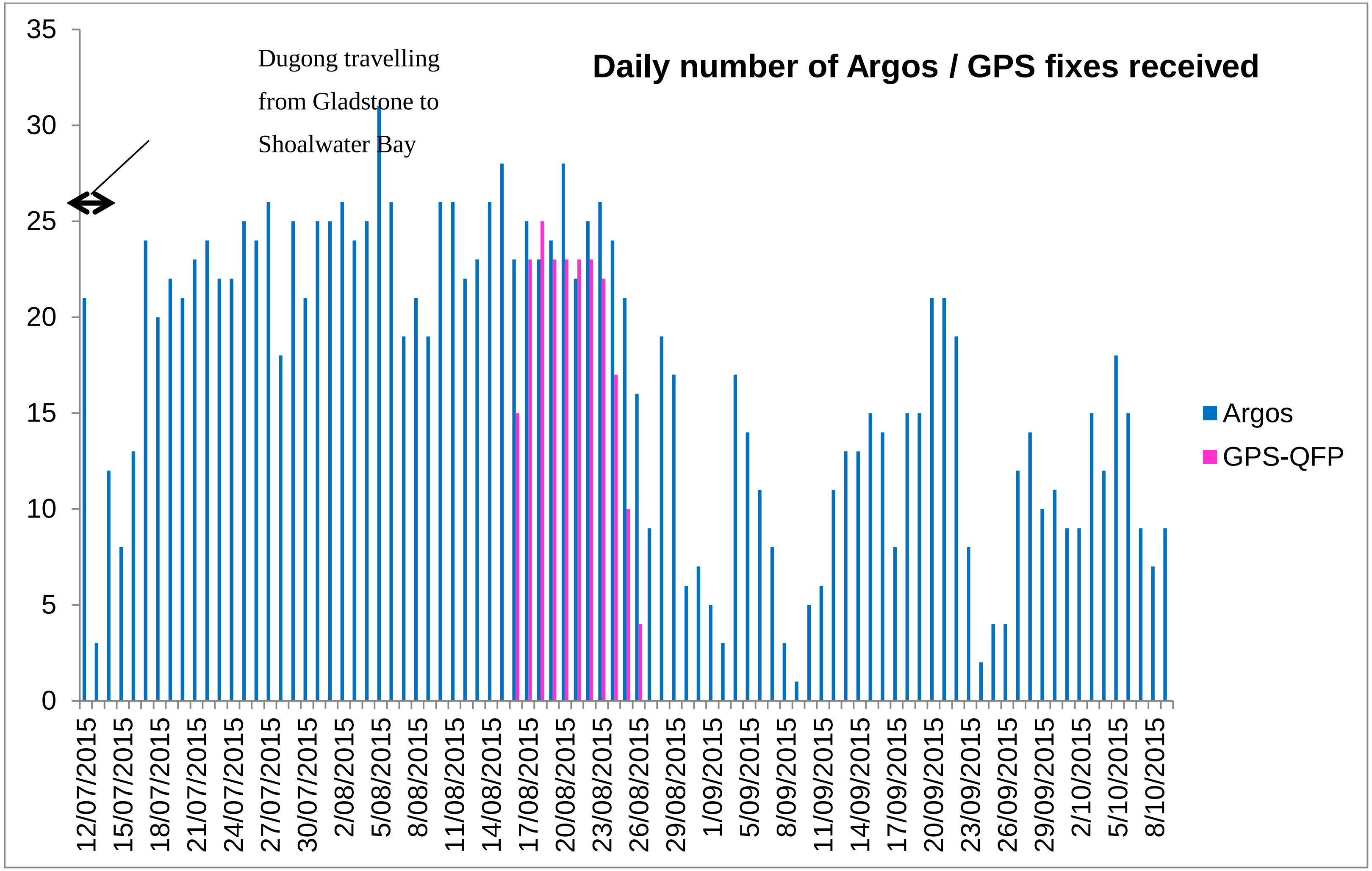

Figure A.2: Frequency distribution of GPS-QFP and ARGOS (classes 1, 2, 3) location fixes obtained during the total tracking period of individual 652632A. The number of Argos fixes received was low during the dugong's travel from Gladstone to Shoalwater Bay. GPS-QFP location fixes were only obtain for a short period of time (purple bars; n = 11 days out of the 90 days of tracking).

Table A.2: Number of Argos and GPS-QFP locations fixes received during the time period of reception of GPS-QFP location fixes.

Date	# Argos location fixes	# GPS-QFP location fixes
16/08/2015	23	15
17/08/2015	25	23
18/08/2015	23	25
19/08/2015	24	23
20/08/2015	28	23
21/08/2015	22	23
22/08/2015	25	23
23/08/2015	26	22
24/08/2015	24	17
25/08/2015	21	10
26/08/2015	16	4

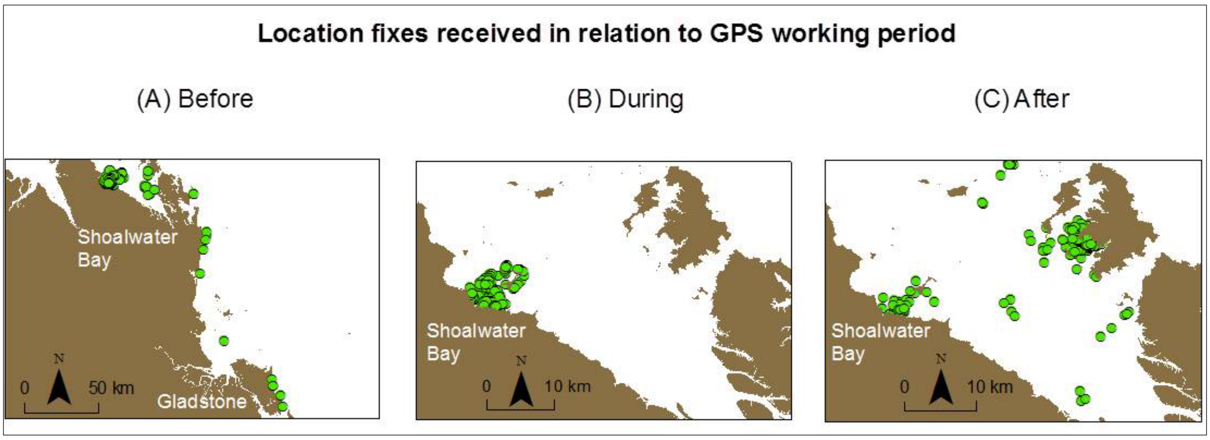

Figure A.3: Location of the tagged dugong before (A), during (B), and after (C) GPS-QFP locations were received. The green circles represent all GPS-QFP and Argos class3 location fixes.

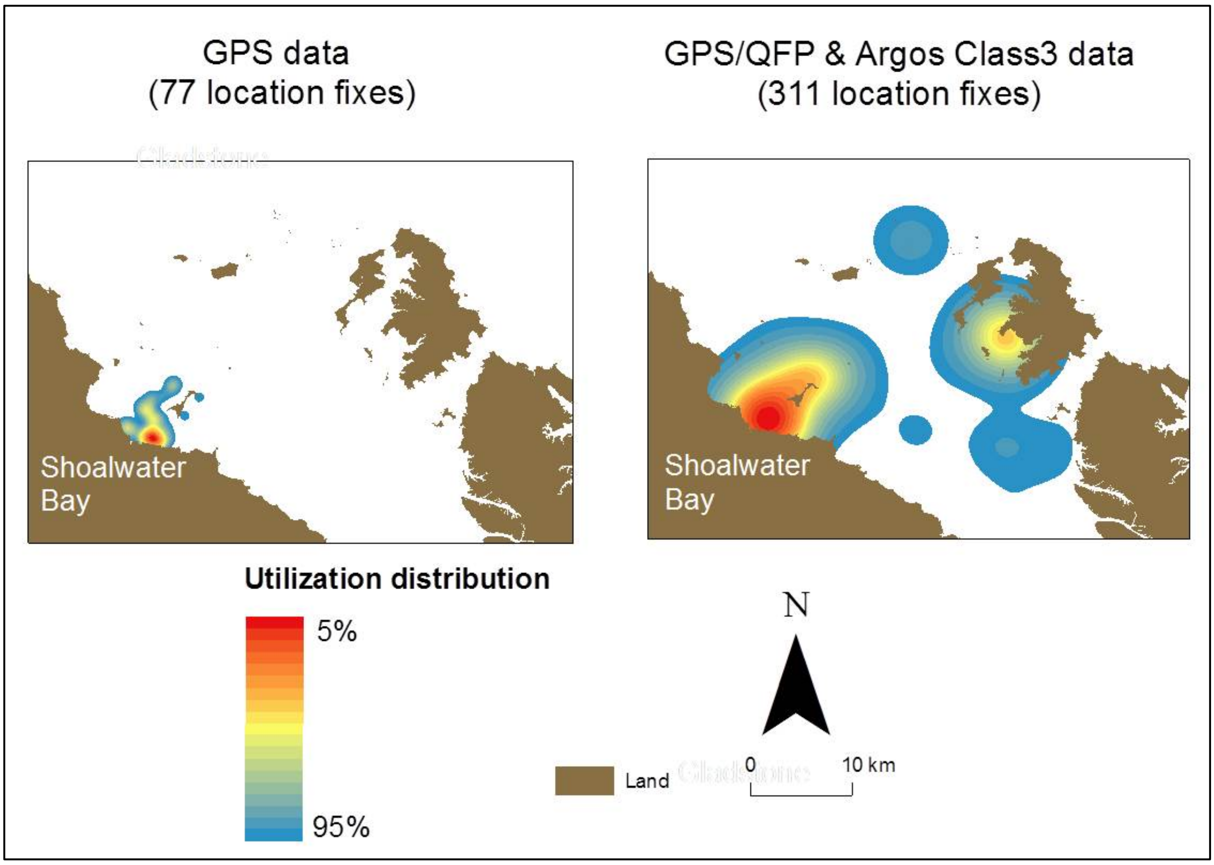

Figure A.4: Utilisation distribution of individual 652632A captured in Gladstone but which spent most of its tracking period in Shoalwater Bay. This figure shows how much information on dugong 652632 use of space is missed if only the GPS-QFP data were used.