Tropical Water Quality Hub

National Environmental Science Programme

Final Report

Working with the community to understand the use of space by dugongs and green turtles in Torres Strait

Christophe Cleguer, Shane Preston, Rie Hagihara, Takahiro Shimada, Vinay Udyawer, Mark Hamann, Tristan Simpson, Frank Loban, Gerald Bowie, Ron Fujii, and Helene Marsh
In collaboration with the Mura Badulgal Registered Native Title Bodies Corporate

JAMES COOK UNIVERSITY AUSTRALIA

Mura Badulgal (TSI) Corporation RNTBC
PRESCRIBED BODIES CORPORATE

Australian Government

TSRA
www.tsra.gov.au

Working with the community to understand the use of space by dugongs and green turtles in Torres Strait

A project in collaboration with the Mura Badulgal Registered Native Title Bodies Corporate

Christophe Cleguer[1], Shane Preston[1], Rie Hagihara[1], Takahiro Shimada[1], Vinay Udyawer[1], Mark Hamann[1], Tristan Simpson[2], Frank Loban[2], Gerald Bowie[2], Ron Fujii[2], and Helene Marsh[1]

[1]College of Science and Engineering, James Cook University
[2] Land and Sea Management Unit, Torres Strait Regional Authority

Australian Government

National Environmental Science Programme

Supported by the Australian Government's
National Environmental Science Programme
Project 3.2: Improving historical estimates of abundance and distribution of dugongs and large green turtles in Western and Central Torres Strait

National Library of Australia Cataloguing-in-Publication entry:
978-1-925088-98-4

This report should be cited as:
Cleguer, C., Preston, S., Hagihara, R., Shimada, T., Udyawer, V., Hamann, M., Simpson, S., Loban, F., Bowie, G., Fujii, R., and Marsh, H. (2016) *Working with the community to understand use of space by dugongs and green turtles in Torres Strait: A project in collaboration with the Mura Badulgal Registered Native Title Bodies Corporate.* Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns (62pp.).

Published by the Reef and Rainforest Research Centre on behalf of the Australian Government's National Environmental Science Programme (NESP) Tropical Water Quality (TWQ) Hub.

The Tropical Water Quality Hub is part of the Australian Government's National Environmental Science Programme and is administered by the Reef and Rainforest Research Centre Limited (RRRC). The NESP TWQ Hub addresses water quality and coastal management in the World Heritage listed Great Barrier Reef, its catchments and other tropical waters, through the generation and transfer of world-class research and shared knowledge.

Cover photographs: Shane Preston, James Cook University

This report is available for download from the NESP Tropical Water Quality Hub website:
http://www.nesptropical.edu.au

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

CITES ..... Convention on International Trade in Endangered Species
DOE ..... Department of the Environment
GPS ..... Geographical Positioning System
IUCN ..... International Union of Conservation and Nature
JCU..... James Cook University
MCP..... Minimum Convex Polygons
NESP ..... National Environmental Science Programme
PZJA..... Protected Zone Joint Authority
QDEHP ..... Queensland Department of Environment and Heritage Protection
RRRC..... Reef and Rainforest Research Centre Limited
SD..... Standard Deviation
TSRA ..... Torres Strait Regional Authority
TWQ..... Tropical Water Quality
UD..... Utilisation distributions

ACKNOWLEDGEMENTS

The research team thanks the National Environmental Science Programme (NESP) Tropical Water Quality (TWQ) Hub and the Torres Strait Regional Authority (TSRA) and James Cook University (JCU) for funding this project; the Mura Badulgal Registered Native Title Bodies Corporate for their permission to conduct the project; and all the participants whose hard work contributed to the successful project. The dugong and turtle catching skills of the members of the Badu team members were essential to the project and all team members thoroughly enjoyed working alongside and learning from them, Big Esso! The project management skills of TSRA and the Mura Badulgal Rangers under the leadership of Ron Fujii and Gerald Bowie, was instrumental in creating a strong work ethic and positive team spirit. The Badu community welcomed the JCU team to their island.

EXECUTIVE SUMMARY

- This research is a result of a very successful collaboration between the Mura Badulgal Representative Native Title Bodies Corporate, the Badu community, TSRA rangers and JCU researchers.

- We used GPS-satellite telemetry to examine the use of space by 10 dugongs and nine green turtles captured around Badu Island in October 2015.

- All but one of the tracked dugongs spent most of their tracking period ranging around Badu and Moa Islands. One dugong had a larger range than the others, undertaking a two exploratory trips to the southern coast of Boigu Island in a month.

- Three female green turtles migrated 250 km to nesting sites at either Moulter Cay or Raine Island. After nesting, these turtles then returned to the same area in Torres Strait as the place of their initial capture.

- Five other tracked green turtles, four females and one male, did not migrate. These four females are unlikely to have bred in the summer of 2015-2016. These animals returned to their capture locations immediately after their release from Badu Island.

- A large portion of the range of the tracked dugongs and green turtles overlapped with the Sea Country of the local communities. In contrast, the animals made little use of the Dugong Sanctuary where dugong hunting is banned. We did not attempt to catch animals in the Dugong Sanctuary.

- The size of the home ranges of the tracked dugongs and turtles were similar to those of dugongs and green turtles tracked from north of Mabuyag Island in 2010. As in 2010, the tracked non-migrating green turtles used smaller areas than the dugongs. The space use of the animals captured close to Badu in 2015 overlapped to a limited extent with the ranges of dugongs and green turtles captured from Mabuyag Island in 2010.

- This research contributes to the evidence-base to enhance the conservation and management of dugongs and green turtles in Mura Badulgal Sea Country and Torres Strait more generally by enhancing understanding of dugong and green turtle spatial ecology in a vast tropical coral reef environment.

RECOMMENDATIONS

- That a systematic multi-year project for satellite tracking dugongs and sea turtles be designed and implemented jointly by Torres Strait Communities and JCU researchers to enhance collaboration between Traditional owners and JCU researchers, increase the evidence base for community-based management of these cultural keystone species and build trust in western science in the local communities.

- That this study is used along with other evidence base materials to support dugong and green turtle management decisions in Torres Strait and neighbouring regions.

1. INTRODUCTION

Torres Strait supports the largest dugong (*Dugong dugon*) population in the world (Marsh *et al*. 2015) and is adjacent to some of the most important nesting grounds for the largest population of green turtles (*Chelonia mydas*) in the world (Limpus *et al*. 2003). Thus, Torres Strait is an important foraging area for these two species, both of which are listed as threatened by the IUCN and under Appendix I of CITES (IUCN 2015).

Dugong and green turtle hunting in Torres Strait are Traditional fisheries guaranteed by the Torres Strait Treaty between Australian and Papua New Guinea and in Australia by the Native Title Act Commonwealth 1993. Australia has obligations and responsibilities for the conservation and management of dugongs and green turtles as signatory to the Convention on Biological Diversity, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the Convention on the Conservation of Migratory Species of Wild Animals. As a signatory to the Convention on Biological Diversity, Australia also has responsibilities for the conservation of the customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements. These responsibilities and obligations are recognized in legislation by the Commonwealth (EPBC Act) and Australian States/Territories.

Dugongs and green turtles play an important role in the culture of Torres Strait communities (Johannes and MacFarlane 1991, Marsh *et al*. 2004, Kwan *et al*. 2006, Marsh *et al*. 2015). Archaeological evidence indicates that green turtles (and possibly dugongs) have been harvested in Torres Strait for 7000 years (Wright 2011). Dugongs have certainly been harvested for 4000 years (Weisler *et al*. 2007) and the harvest has been substantial for at least 400-500 years (McNiven and Bedingfield 2008). Nonetheless, several lines of evidence indicate that the Indigenous fishery for dugongs in Torres Strait is sustainable (Marsh *et al*. 2015, Hagihara *et al*. 2016). The status of the population of green turtles in Torres Strait is less certain (Fuentes *et al*. 2015, Hagihara *et al*. 2016, Jensen *et al*. 2016).

Understanding how dugongs and green turtles use space in Torres Strait can help to enhance spatial management strategies for these two species. Marsh *et al*. (2015) pointed out that spatial management of dugongs and green turtles has considerable potential in this region because it has: (1) already been incorporated in community-based management plans and the Dugong Sanctuary; (2) is less susceptible to errors in population data than quotas; (3) could pre-empt expansion of hunting with improved technology; and (4) could be implemented in stages to minimize the initial impact on communities and provide time and opportunities for capacity building.

Quantifying the use of space by dugongs and green turtles requires animals to be captured and tracked, preferably using remote GPS-satellite tracking devices. Over the last decade, increased collaboration between Torres Strait Islanders and researchers, improvements in remote tracking, and greater acceptance of scientific research within Torres Strait Islander communities has greatly enhanced this understanding. Dugong and green turtle tracking projects conducted in 2004 (Lawler *et al*. 2005) and 2010 (Gredzens *et al*. 2014) around Mabuyag Island confirmed what was known from research conducted in other regions of Australia and abroad: (1) dugongs and green turtles are highly mobile and use large areas,

(2) some individuals cross jurisdictional boundaries, and (3) the space use of both species overlaps. These overlapping ranges indicate that spatial closures can be used to manage both species but need to be coordinated across jurisdictional boundaries (Gredzens *et al*. 2014).

The aim of this project was to improve the knowledge of dugong and green turtle spatial ecology to inform the management of these species in Torres Strait, especially management by the Mura Badulgal Representative Native Title Bodies Corporate. This aim was addressed by working with TSRA Rangers and Badu Islanders including Traditional Owners to track and quantify the use of space of additional dugongs and green turtles in Torres Strait. We captured and tracked 10 dugongs and nine green turtles around Badu Island. We then used the tracking data to investigate: (1) the extent of movement of the tracked dugongs and green turtles and whether they return to their capture site after release, (2) and the space use of the tracked animals.

2. METHODS

2.1 Ethics statement

All animals were handled in strict accordance with local and international regulations. The field work was conducted under the Animal Ethics Approvals obtained from JCU (A2072), Commonwealth Scientific Purpose Permit E2014/0091 and Queensland Scientific Purpose Permit *WISP15058214* and the *Permit for Scientific Purposes* obtained from Torres Strait Regional Authority under the *Torres Strait Fisheries Act 1984*.

2.2 Daily activities during the fieldtrip

The JCU team arrived on Badu Island on October 5 2015 (Table 1). The next day, the JCU team, Badu Islanders and TSRA rangers had their first briefing to: (1) ensure that all participants were aware of, understood and agreed with the Research Partnership Agreement for the project between James Cook University, Mura Badulgal Representative Native Title Bodies Corporate, and the Torres Strait Regional Authority Land and Sea Management Unit (Appendix I); (2) define the role of each participant, and (3) go through the dugong and turtle catching, tagging and safety procedures.

Fieldwork commenced on October 7 (Table 1). All participants attended daily briefings and debriefings at the Mura Badulgal Ranger Station on Badu Island to address any issues with the aim of improving work efficiency and maintaining good communication (Figure 1). Table 2 lists the project participants.

Table 1: Details of daily activities during the dugong and green turtle fieldwork in Torres Strait in 2015.

Date	Activity	Start of the search time	Finish of the search time	Approx. number of dugongs sighted	Number of dugongs caught/ tagged	Number of green turtles caught/tagged
05/10/2015	JCU team arrived on Badu Island	-	-	-	-	-
06/10/2015	JCU-TSRA-Hunter meeting. Gear organization	-	-	-	-	-
07/10/2015	Tagging Day 1	12h30	17h30	20	1	Not attempted
08/10/2015	Tagging Day 2	12h20	15h30	3	1	Not attempted
09/10/2015	Tagging Day 3	11h30	17h00	10	1	Not attempted
10/10/2015	Tagging Day 4	06h50	17h30	20	1	2
11/10/2015	Day off	-	-	-	-	Not attempted
12/10/2015	Tagging Day 5	07h30	16h00	11	3	Not attempted
13/10/2015	Tagging Day 6	07h30	16h00	9	0	Not attempted
14/10/2015	Tagging Day 7	06h30	17h30	13	2	Not attempted
15/10/2015	Tagging Day 8	06h30	17h30	14	1	7
16/10/2015	Turtle release	09h30	11h30	-	-	-

Table 2: List of Badu Islanders, JCU researchers and TSRA rangers who participated in the dugong and green turtle tracking project in Torres Strait in October 2015.

Name	Organisation	Role
Mohamet Ahmat	Badu Islander – Assistant 1	Assisted with the dugong and green turtle catching activities
Johnny Baira	Badu Islander – Catcher 1	Assisted with the dugong and green turtle catching activities
Charles Wilkie Elisala	Badu Islander – Catcher 2	Assisted with the dugong catching activities
Stanley Jackonia	Badu Islander – Assistant 2	Assisted with the dugong catching activities
Yathimo Kebisu	Badu Islander – Catcher 3	Assisted with the dugong and green turtle catching activities
Eddie Nona	Badu Islander – Assistant 3	Assisted with the dugong catching activities
Joel Tamwoy	Badu Islander – Assistant 4	Assisted with the dugong catching activities
Willie Babia	TSRA	Visiting ranger
Gerald Bowie	TSRA	Provided cultural advice to the project and expert advice on timing of the field work. Helped with dugong catching, organized the hunters, and ensured that all Islander participants understood the agreed operational procedures.
Ron Fuji	TSRA	Provided cultural advice to the project and expert advice on timing of the field work. Helped organize the hunters and field logistics.
Frank Loban	TSRA	Senior NRM Officer (Senior Ranger Supervisor) Near Western Cluster Land and Sea Management Unit Torres Strait Regional Authority
Ted Whap	TSRA	Visiting ranger.
Terrence Whap	TSRA	Visiting ranger
Christophe Cleguer	JCU	JCU team fieldtrip leader. Organized the field logistics during the fieldtrip. Lead the dugong and green turtle capture and tag deployment procedures. Acted as primary dugong catcher.
Shane Preston	JCU	JCU team fieldtrip co-leader. Organized the field logistics prior to the fieldtrip and worked with TSRA rangers as a cultural broker between members of the field team as required. Acted as primary dugong catcher.
Takahiro Shimada	JCU	Assisted with the dugong catching activities. Acted a secondary dugong catcher and primary green turtle catcher– data collection assistant
Vinay Udyawer	JCU	Assisted with the dugong catching activities and trial of transmitters. Acted a secondary dugong catcher – data collection assistant

Figure 1: TSRA rangers, Badu Islanders and JCU researchers meeting at the Mura Badulgal Ranger Station before a day at sea.

2.3 Capture and tagging

2.3.1 Dugongs

Ten dugongs were captured near Badu Island using the technique of Fuentes *et al*. (2013) that was developed in Torres Strait in 2010 with the assistance of the Torres Strait islanders in order to safely catch dugongs in turbid and deeper waters (> 5 m). Dugongs were secured against one of the research boats immediately following the capture as shown in Figure 2A. All animals appeared healthy and swam away strongly after their release.

Each dugong was fitted with: (1) a GPS (Global Positioning System)/Argos System unit (Telonics, Inpala, USA), hereafter GPS-satellite transmitter, to record its space use; and (2) a pop-up archival tag MiniPAT (Wildlife Computers, Redmond, USA), hereafter dive recorder, to record its diving pattern as discussed in Hagihara *et al*. (2016). Because dugongs lack dorsal fins, their peduncle is the only secure attachment point for external devices (Marsh and Rathbun 1990, Reid *et al*. 1995). Thus, each GPS-satellite unit was attached to a dugong peduncle with a padded tailstock belt. The belt was covered with pliable tube to minimise friction against the dugong's skin. The GPS-satellite transmitter was attached to the belt via a 3 m long flexible plastic tether. This tether incorporated a weak link that could be broken by the dugong if the assembly became entangled in marine biota such as coral or mangroves and a corroding link that slowly corroded in a galvanic reaction in seawater to release the harness. 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. Each dive recorder was attached with a nylon tether to the padded belt very close to the dugong's peduncle (Figure 2B).

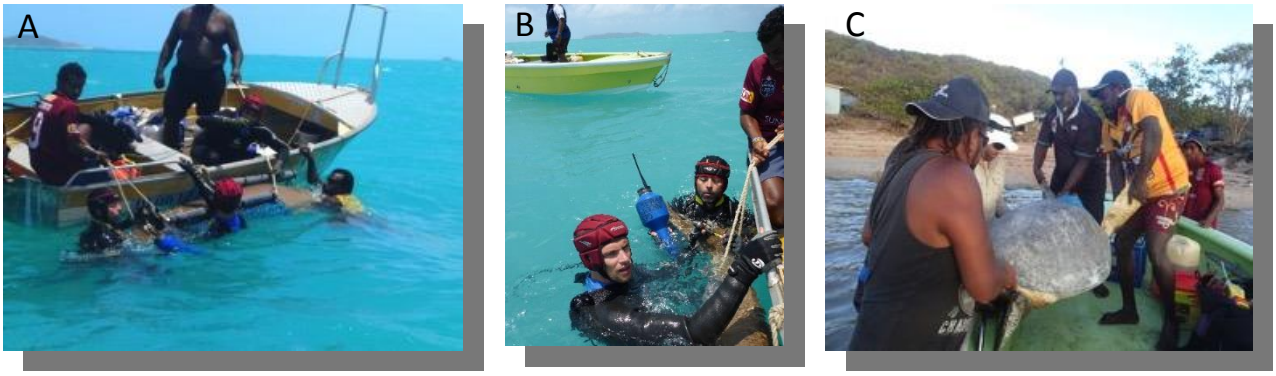


Figure 2: Photographs showing: (A) Badu Islanders and JCU researchers securing a dugong against one of the Badu Islanders' boats; (B) JCU researchers holding the GPS-satellite transmitter (in blue) and the diver recorder (in black) while a Badu Islander assists in holding the tail of the dugong (right side of photograph); and (C) Badu Islanders and JCU researchers preparing a tagged green turtle for release. A TSRA ranger had oversight of the activities at all times to ensure that the research crew was working safely and in a culturally appropriate and humane manner (background in (B)).

2.3.2 Green turtles

Nine green turtles were captured in shallow (< 5 m) clear waters using the rodeo technique described by Limpus (1978) and equipped with tracking units as outlined in Shimada *et al*. (2012). The captured turtles were brought to land to deploy the telemetry devices, a process that takes up to 24hrs.

Each turtle was kept in cool conditions at the Mura Badulgal Ranger Station on Badu Island during the process of attaching either a: (1) GPS SPLASH10-F-296A System unit (Wildlife Computers, Redmond, USA) or (2) a FastlockTM System unit (Sirtrack, Havelock North, New Zealand), hereafter GPS-satellite transmitter. Seven of the nine turtles were also equipped with a pop-up archival tag MiniPAT (Wildlife Computers, Redmond, USA), hereafter dive recorder. The satellite unit was attached high on the carapace (approximately vertebral scales 1 and 2) following the procedure described in Shimada *et al*. (2012) to increase the likelihood of satellite fixes (Figure 3A). The dive recorders were attached on the lower left side of the turtle's carapace (Figure 3A). The turtles were released the day following their capture.

2.3.3 Islander involvement

TSRA Rangers and Badu Islanders were essential to the successful capture of dugongs and green turtle for this project. The Badu Islanders used their skills to find the animals, assist the JCU researchers capture the animals safely and with data recording.

The TSRA rangers ensured the safety of all the crew members and of the captured animals at all times. The TSRA rangers also provided logistical support throughout the entire project (e.g., housing the green turtles at the Mura Badulgal Ranger Station overnight while the tags were attached to the animals, and allowing the researchers to use the ranger's workshop).

The JCU researchers gave a talk on dugong and sea turtle ecology and conservation to the Badu school children and answered questions from the children and teachers. The children subsequently participated in the release of five of the nine turtles equipped with GPS-satellite transmitters and dive recorders (Figure 3B).

Marsh visited Badu in April 2016 to repatriate the results of the project to the Mura Badulgal Representative Native Title Bodies Corporate and to obtain their permission to release the resultant reports.

Figure 3: JCU researcher, Takahiro Shimada demonstrating the telemetry devices deployed on a green turtle to the Badu children (A) before the turtles were released (B). Note the GPS-satellite transmitter glued at the top of the carapace close to the turtle's head and the dive recorder glued to the left hand side of the lower part of the carapace on photograph (A).

2.4 Data processing

The satellite data were retrieved from the Argos website and decoded using software supplied by the manufacturers. We selected dugong location data with higher quality indicators: GPS (± 2 to < 10 m) and resolved QFP (± < 30 m) location fixes; turtle location data with GPS (± 2 to < 10 m) and Fastloc (± < 50 m). The data were then filtered using *SDLfilter* (Shimada *et al*. 2012) in R 3.1.3 (R Development Core Team 2015). This filter removes location points that are spatially or temporally duplicated, or that are highly unlikely given the individual's travel speed and turning angle (Shimada *et al*. 2012, Gredzens *et al*. 2014, Zeh *et al*. 2014, Cleguer 2015). The processing and analysis of the dive data collected using the diver recorders is described in the companion report by Hagihara *et al*. (2016).

2.5 Use of space

Four out of ten GPS-satellite transmitters deployed on dugongs and one out of nine GPS-satellite transmitters deployed on green turtles did not transmit any location fixes after

deployment (Table 3). Three of the eight turtles for which location data were obtained migrated to their nesting grounds.

2.5.1 Non-migrating animals

The analysis described in this section was conducted on the filtered data obtained from six tracked dugongs and the five non-migrating green turtles. The filtered location data from each dugong and each green turtle were standardised by dividing the relevant location points into 1 hour duty-cycles and selecting the most accurate location within each duty-cycle. This process retained as many location points as possible while minimising individual differences in the number of location points per day. Duty cycles were also used to reduce the effects of autocorrelation and effects resulting from differences in transmitter performance.

Minimum convex polygons (MCP) were calculated using the Minimum Bounding Geometry tool in ArcGIS 10.2 (ESRI 2013) to define the extent of movement of the tracked dugongs and green turtles for the non-migratory period for which they were tracked. The mean (± SD), minimum and maximum distances from the nearest land and from each animal's respective capture location were determined for each tracked dugong using the 'Near' tool in ArcGIS 10.2.

Utilisation distributions (UD) were calculated to define the home ranges and core areas of each tracked dugongs and green turtle. UDs quantify where an individual spends 5 to 95% of its tracking time. The fixed Kernel density estimation and isopleth tools were used in the Geospatial Modelling Environment software to generate the UDs (GME; Beyer 2012). Resolutions of 30 m (dugongs) and 50 m (green turtles) were selected according to the mean accuracy of the filtered GPS locations (QFP locations in the case of the satellite tags used for tracking dugongs). The CVh smoothing parameter was chosen as the most biologically relevant smoothing parameter for the dataset, after exploratory analysis. This approach is consistent with other recent analyses of dugong and green turtle home-ranges and core areas (Gredzens *et al*. 2014, Cleguer 2015, Cleguer *et al*. 2015a, b, Zeh *et al*. 2015).

Utilisation distributions were calculated for: (1) for each tracked animal, and (2) the combined ranges of all individuals of each species group. The latter were generated by adding the UD of each tracked animal using the 'Raster Calculator' tool in ArcGIS 10.2. The combined UDs were not weighted for the tracking period of each tracked dugong because our aim was to provide an overview of the combined area used by dugongs and green turtles in the region. Any area of UD overlapping with any land was removed to calculate the size of each UD polygon.

2.5.2 Migrating turtles

Three green turtles migrated to their nesting grounds within a week of release. We investigated the start and end of their migrations, their targeted nesting locations and how long each turtle stayed at the nesting ground. A research team was present at Raine Island when one of the turtles came ashore to lay one of her egg clutches. The research team used the tracking data to estimate the number of clutches laid by each tracked turtle.

2.6 Use of space in relation to the Dugong Sanctuary and areas where hunting is most likely to occur

We evaluated the proportion of time each tracked dugong and non-migrating green turtle spent in: (1) the Dugong Sanctuary, and (2) within the areas in which most hunting occurs to inform the management of the Torres Strait dugong and green turtle fisheries. The combined utilisation distribution layers of the six tracked dugongs and the five non-migrating green turtles were overlaid with the layers of the spatial extent of the Dugong Sanctuary (Torres Strait Fisheries Management Notice, 2003) and areas where most hunting occurs as modelled by Marsh *et al*. (2015). Torres Strait Islanders mostly harvest dugongs and green turtles in shallow waters (< 5 m) as explained in Marsh *et al*. (2015). We colour-coded the UDs of the tracked dugongs and green turtles according to their overlap with areas < 5 m deep or not as an indication of where these animals would likely be harvested.

3. RESULTS

3.1 Catching, tagging and durations of tracking

The capture and tagging of the 10 dugongs and nine green turtles required eight days of work at sea (Table 1). Our priority was to capture and tag the 10 dugongs because dugongs are more difficult to find and capture than green turtles. Thus the green turtles were caught on Day 4 and Day 8 only (Table 1).

3.1.1 Dugongs

All 10 dugongs were caught around Badu Island. While mother-calf pairs were frequently sighted during our search, the 10 dugongs captured and equipped with telemetry devices were all males. The straight line body length of the captured dugongs ranged from 2.1 m - 2.80 m (mean = 2.46 m, ± SD = 0.24 m), (Table 3).

The 10 dugongs were caught in water depths ranging between 2.8 m and 13.2 m (median = 6.0 m; Table 3). They were held for between 4 and 15 min (mean = 10 min 10 sec, ± SD = 0.003 sec), while the telemetry devices were attached.

Four GPS-satellite transmitters deployed on the dugongs did not transmit any location fix after the animals were released, despite no evidence of malfunction prior to deployment (Appendix II Figure A1-3). The transmitting periods of the other six GPS-satellite devices ranged between 20 and 77 days (Table 3).

3.1.2 Green turtles

Two green turtles were captured south of Badu Island; seven others between Mabuyag Island and Badu Island. The green turtles were captured in clear waters in depths ranging between 2 m and 4 m (median = 2.9 m; Table 3). Although turtles were caught opportunistically, eight of the nine captured turtles were females (Table 3). The length of the captured turtles ranged from 90.7 - 110.5 cm (mean length = 102.8 cm ± SD = 6.8 cm), (Table 3).

One of the nine GPS-satellite devices did not transmit any location fix after deployment, despite no evidence of malfunction prior to deployment (Takahiro Shimada pers. comm.). The GPS-satellite transmitters sent location fixes for periods ranging between 104 and 133 days. Three transmitters (deployed on turtles T2, T5, and T8) were still working when the analysis in this report was undertaken on February 22 2016 (Table 3).

Table 3: Identification numbers and capture and tagging details of the dugongs and green turtles. Note that green turtle T3 and T5 were captured during courtship.

Decimal Argos ID	Individual ID	Sex	Length (cm)	Date of capture (dd/mm/yyyy)	Depth of water at capture location (m)	Date of release (dd/mm/yyyy)	Satellite tracking period (days)
			Dugongs				
117863	D1	M	260.0	7/10/2015	13.2	7/10/2015	No data
34433	D2	M	210.0	8/10/2015	7.1	8/10/2015	57
109774	D3	M	230.0	9/10/2015	4.8	9/10/2015	No data
67389	D4	M	240.0	10/10/2015	2.8	10/10/2015	20
67468	D5	M	270.0	12/10/2015	4.9	12/10/2015	57
34435	D6	M	240.0	12/10/2015	8.8	12/10/2015	46
109776	D7	M	210.0	12/10/2015	12.9	12/10/2015	77
109778	D8	M	280.0	14/10/2015	7.9	14/10/2015	No data
34428	D9	M	270.0	14/10/2015	4.9	14/10/2015	20
117864	D10	M	250.0	15/10/2015	4.7	15/10/2015	No data
			Green turtles				
152621	T1	F	90.7	10/10/2015	3.9	11/10/2015	112
152622	T2[a]	F	109.1	13/10/2015	3.1	14/10/2015	133
54531	T3[b]	M	99.6	15/10/2015	3.1	16/10/2015	109
152625	T4	F	107.5	15/10/2015	2.8	16/10/2015	130
95895	T5[a, b]	F	106.7	15/10/2015	2.0	16/10/2015	121
152624	T6	F	110.5	15/10/2015	2.0	16/10/2015	123
152626	T7	F	95.5	15/10/2015	2.4	16/10/2015	104
152623	T8[a]	F	107.0	15/10/2015	2.9	16/10/2015	130
95893	T9	F	98.9	15/10/2015	3.0	16/10/2015	No data

[a] Transmitter still attached to the turtle and transmitting location fixes when the analysis was undertaken on 22 February 2016.
[b] Turtles captured during courtship.

3.2 Movement patterns

3.2.1 Dugongs

All but one of the tracked dugongs spent most of their tracking period ranging around Badu and Moa Islands, close to where they were captured (Figure 4) with location fixes ranging at mean distance of between 11.2 km (± SD = 6.3 km) and 29.3 km (± SD = 34.1 km) from the animals' capture location (Appendix III Table A3).

Dugong D6 had a larger range than the other tracked dugongs. This animal took a two-day trip to the southern coast of Boigu Island close to the Papua New Guinea coast, 100 km north from Badu Island. Dugong D6 then remained near the coast of Boigu Island for a day before swimming back to the east coast of Badu and Moa Islands. This dugong undertook a second two-day trip to Boigu Island, a month after the first. The GPS-satellite transmitter stopped working as the animal neared Boigu Island on its second trip.

The tracked dugongs remained away from the coast during their tracking periods ranging on average at distances of between 3.4 km (± SD = 3.1 km) and 6.6 km (± SD = 7.9 km) from the coast (Appendix III Table A4).

3.2.2 Green turtles

3.2.2.1 Non-migrating turtles

Four female green turtles T1, T4, T6 and T7, and the only male green turtle (T3) returned to their capture locations soon after their release from Badu Island (Figure 5) and remained within 2.0 km to 13.6 km from these locations during their entire tracking period (Appendix III Table A3).

3.2.2.1 Migrating turtles

Green turtles T2, T5, and T8 started to migrate to their nesting area, located approximately 250 km southeast from their capture location within a week of their release from Badu Island (Figure 6 and Table 4). These animals took seven to 13 days to reach their nesting destinations, either Moulter Cay or Raine Island (Figure 6 and Table 4). After the nesting season, these animals returned to their capture locations in Torres Strait. The migrating turtles spent between 94 and 104 days at their nesting grounds. Green turtles T2 and T5 likely laid 6 to 8 clutches each; T8 at least three clutches on Raine Island. One clutch for turtle T5 was observed in person by the QDEHP marine turtle monitoring team at Raine Island. Turtle T8 was in the Raine Island region for approximately 3.5 months and had likely laid two clutches of eggs on Raine Island before migrating back to Torres Strait in early February only to reach the eastern edge of the Torres Strait region and then turn around and swam back to Raine Island (Figure 6). She then laid a third clutch of eggs and migrated back to Torres Strait. More details on the activities of individuals T2 and T8 are available in Appendix IV Table A5.

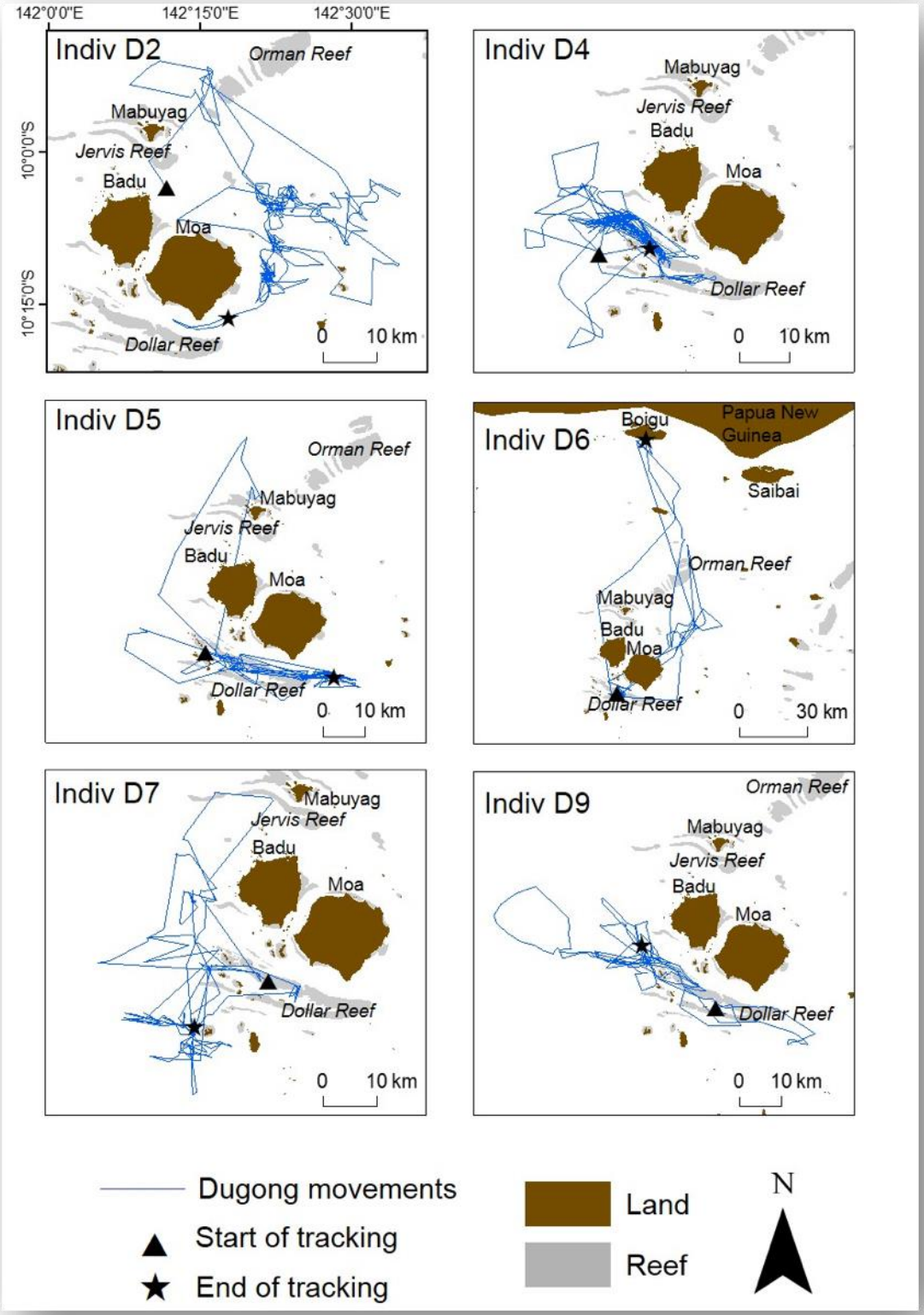


Figure 4: Movements of the six dugongs caught and tagged near Badu Island in Torres Strait in October 2015 based on the total tracking period of each tracked individual. All dugongs except individual D6 remained close to their capture locations but away from the coasts of the islands.

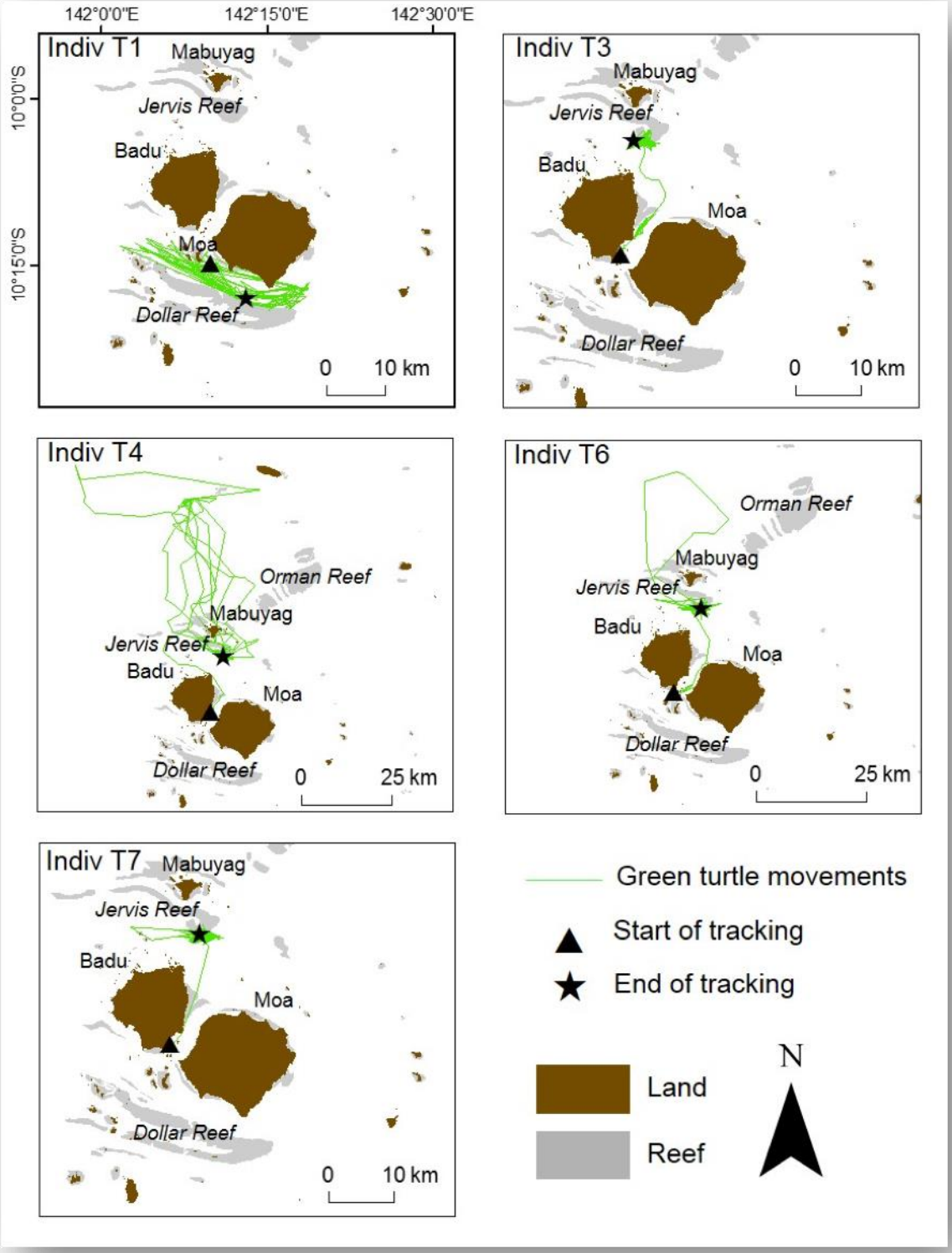


Figure 5: Movements of the five non-migrating green turtles caught and tagged near Badu Island in Torres Strait in October 2015 based the total tracking period of each tracked individual. These turtles returned to their capture locations soon after their release from Badu Island.

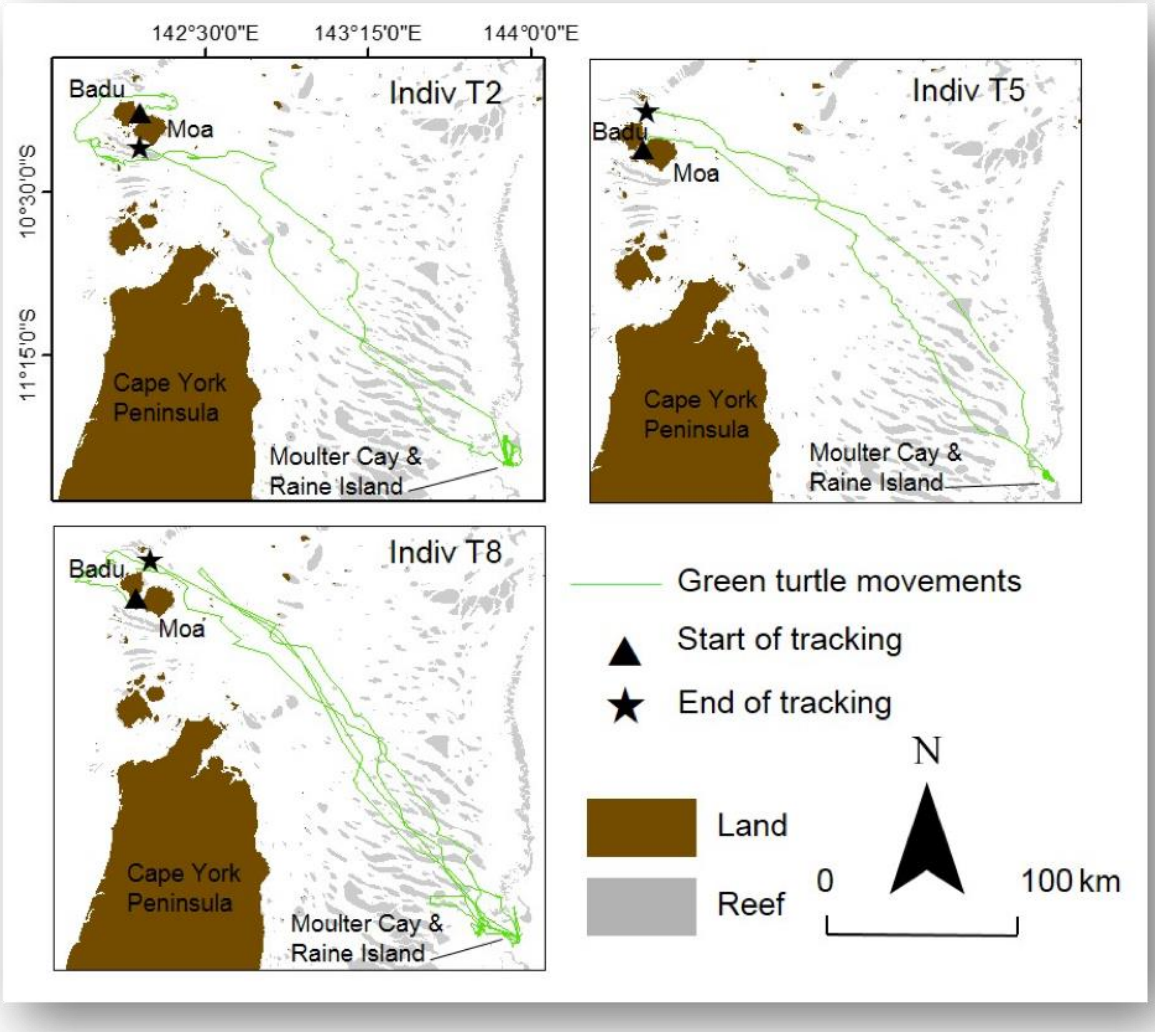


Figure 6: Movements of the three migrating green turtles caught and tagged near Badu Island in Torres Strait in October 2015 based the total tracking period of each tracked individual. These turtles migrated to their nesting areas within a week of their release from Badu Island. Turtle T8 migrated twice between Torres Strait where it was captured and Raine Island where it nested. As far as we are aware, this is the first time a near double migration has been recorded for a marine turtle in one nesting season. Note that the GPS-satellite transmitters deployed on these three individuals were still transmitting when the data analysis was undertaken on 22 February 2016.

Table 4: Information on the migration and nesting season for three green turtles caught and released from Badu Island in Torres Strait in October 2015

Turtle ID	Date migration started	Date migration ended	Nesting location	Number of days at nesting location	Estimated number of clutches
T2	21 Oct 2015	28 Oct 2015	Raine Is, GBR[a]	104	6 to 8 clutches
T5	17 Oct 2015	27 Oct 2015	Moulter Cay, GBR	94	~ 6 clutches
T8	17 Oct 2015	30 Oct 2015	Raine Is, GBR[a]	102	At least 3 clutches

[a] GBR = Great Barrier Reef

3.3 Extent of movements and space use by the tagged dugongs and green turtles that did not migrate

3.3.1. Dugongs

The 95% home-range areas of the tracked dugongs ranged from 258.5 km^2 to 928.7 km^2 (median = 453.2 km^2); their 50% core areas ranged between 37.3 km^2 and 130.3 km^2 (median = 74.4 km^2; Appendix V Table A6). Dugong D6 ranged over substantially larger spatial scales than the other tracked dugongs (95% home-range = 928.7 km^2 and 50% core area = 99.0 km^2), (Figure 4). The tracked dugongs mainly used Dollar Reef and areas located to the east of Badu and Moa Islands (Figure 7; the use of space of each tracked dugong is available in Appendix VI Figure A4).

3.3.2 Green turtles

The areas used by the four of the five non-migrating tracked turtles were substantially smaller than home ranges and core areas of the tracked dugongs. The 95% home-range areas of these tracked turtles ranged between 11.4 km^2 and 752.5 km^2 (median = 75.7 km^2, Appendix V Table A6); their 50% core areas between 1.4 km^2 and 36.2 km^2 (median = 6.1 km^2). These turtles intensively used Jervis and Dollar Reefs, the sites where they were initially captured (Figure 7. The use of space of each non-migrating tracked green turtle is detailed in Appendix VI Figure A5).

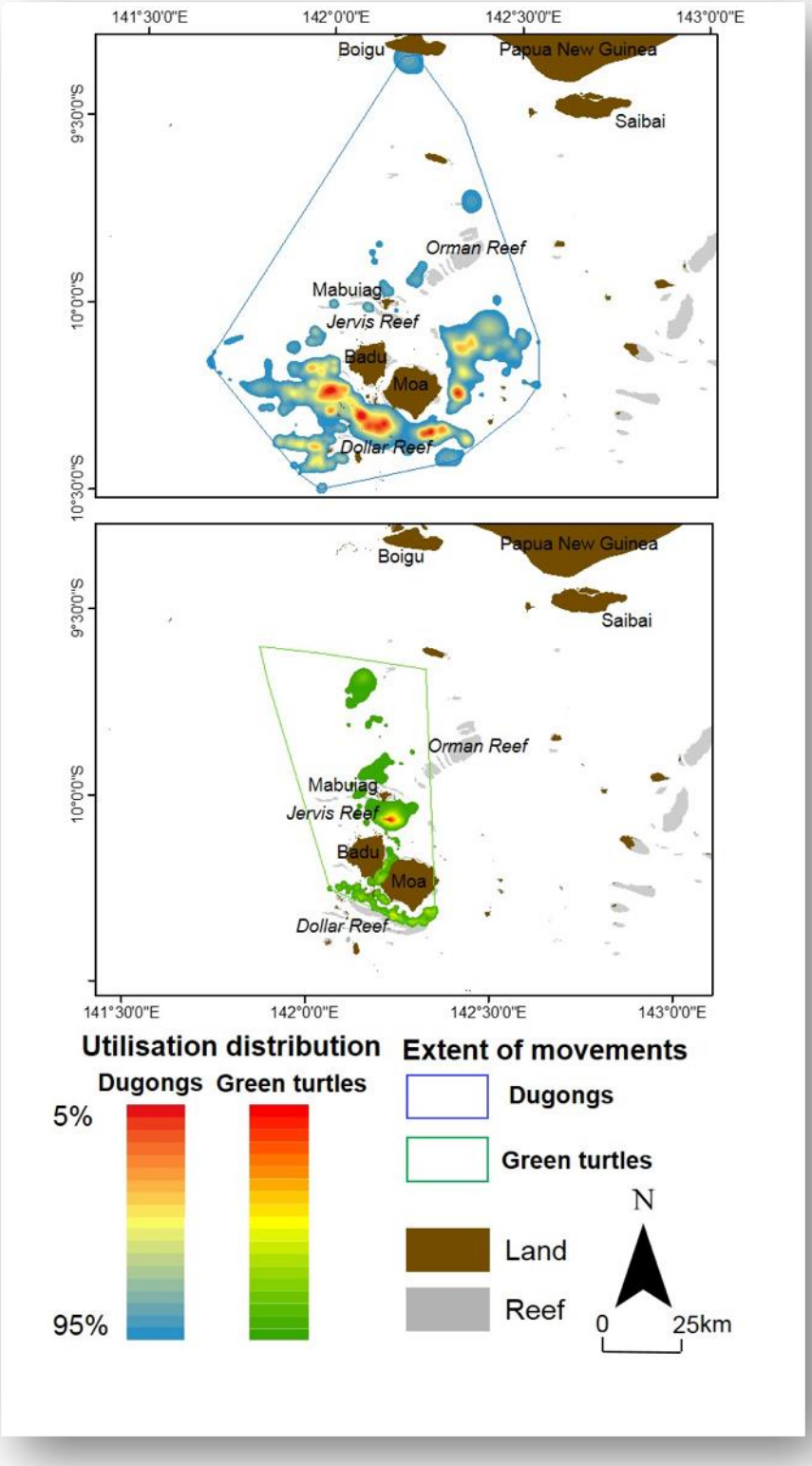


Figure 7: Combined utilisation distributions (UD) and extent of movements (MCP) of the six dugongs and five non-migrating green turtles captured around Badu Island in Torres Strait in October 2015. The density of space use ranged from high (red) to low (blue or green). The utilisation distributions were not weighted for the tracking period of each tracked dugong and green turtle as the aim of the figure is to provide an index of the combined area used by the two species in the region.

3.4 Use of space by the tagged dugongs and green turtles that did not migrate in relation to the Dugong Sanctuary and areas where hunting is most likely to occur

3.4.1 Dugongs

A large portion of the range of the tracked dugongs overlapped with the areas around Badu and Moa Islands where most hunting is believed to occur (Marsh *et al*. 2015). In contrast, these dugongs used only a small portion of the Dugong Sanctuary, an area where hunting is banned (Figure 8). The proportion of the 95% home range of each tracked dugong that overlapped with the area around Badu where most hunting occurs ranged from 62% to 94% whereas the proportion of 95% home range of each tracked dugong overlapping with the Dugong Sanctuary ranged from 0% to 41% (Figure 9). Similarly the proportion of 50% core areas of each tracked dugong highly overlapped with areas where most hunting occurs but not with the Dugong Sanctuary (Figure 9). The shallow areas (< 5 m) intensively used by the tracked dugongs were located over Dollar Reef, south of Badu , an area which is used for hunting (Figure 8).

3.4.2 Green turtles

As for dugongs, the feeding ground space use of green turtles dugongs is influenced by their capture site (Shimada *et al*. 2016), (Figure 10). Between 72% and 100% of the 95% home ranges of each tracked non-migrating turtle overlapped with the area where most hunting occurs. The corresponding figures for the 50% core areas was between 80% and 100% (Figure 11). The tracked turtles intensively used the shallow waters (< 5 m) of Jervis Reef south of Mabuyag Island. In the Dollar Reef area, these animals tended to remain in deeper waters (> 5 m) on the edge of the reef (Figure 10).

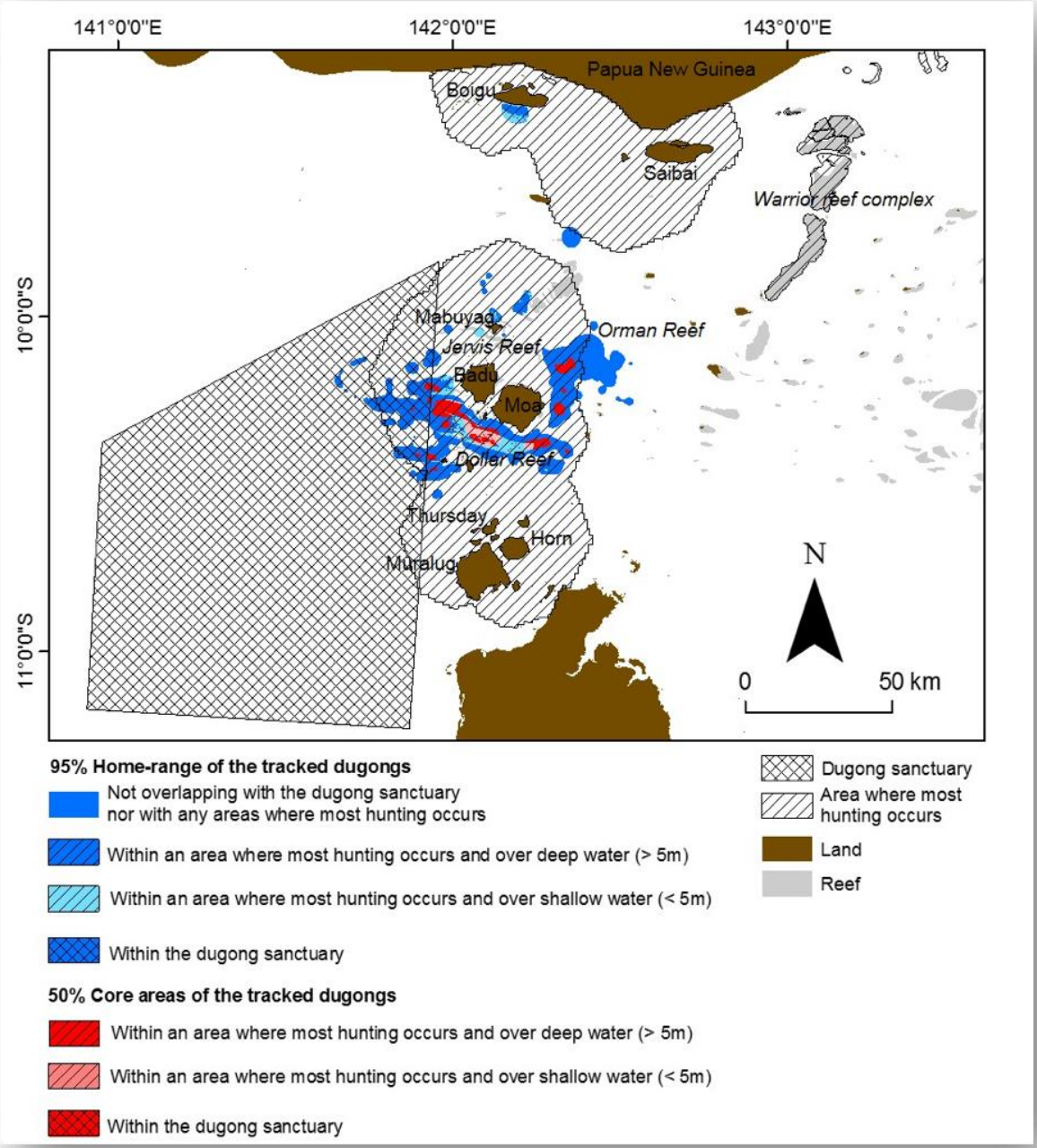


Figure 8: Use of space by the six dugongs captured and satellite captured around Badu Island in Torres Strait in October 2015 in relation to areas where hunting is most likely to occur, the Dugong Sanctuary and water depth. The tracked dugongs mostly used areas where hunting is likely to occur plus a small part of the eastern edge of the Dugong Sanctuary. The different colour shadings in the figure enable areas of shallow (< 5 m) and deep (> 5 m) waters used by the tracked dugongs to be distinguished. The dugongs made an intensive use of the shallow waters located over Dollar Reef area but also the deeper waters located to the east of Moa Island.

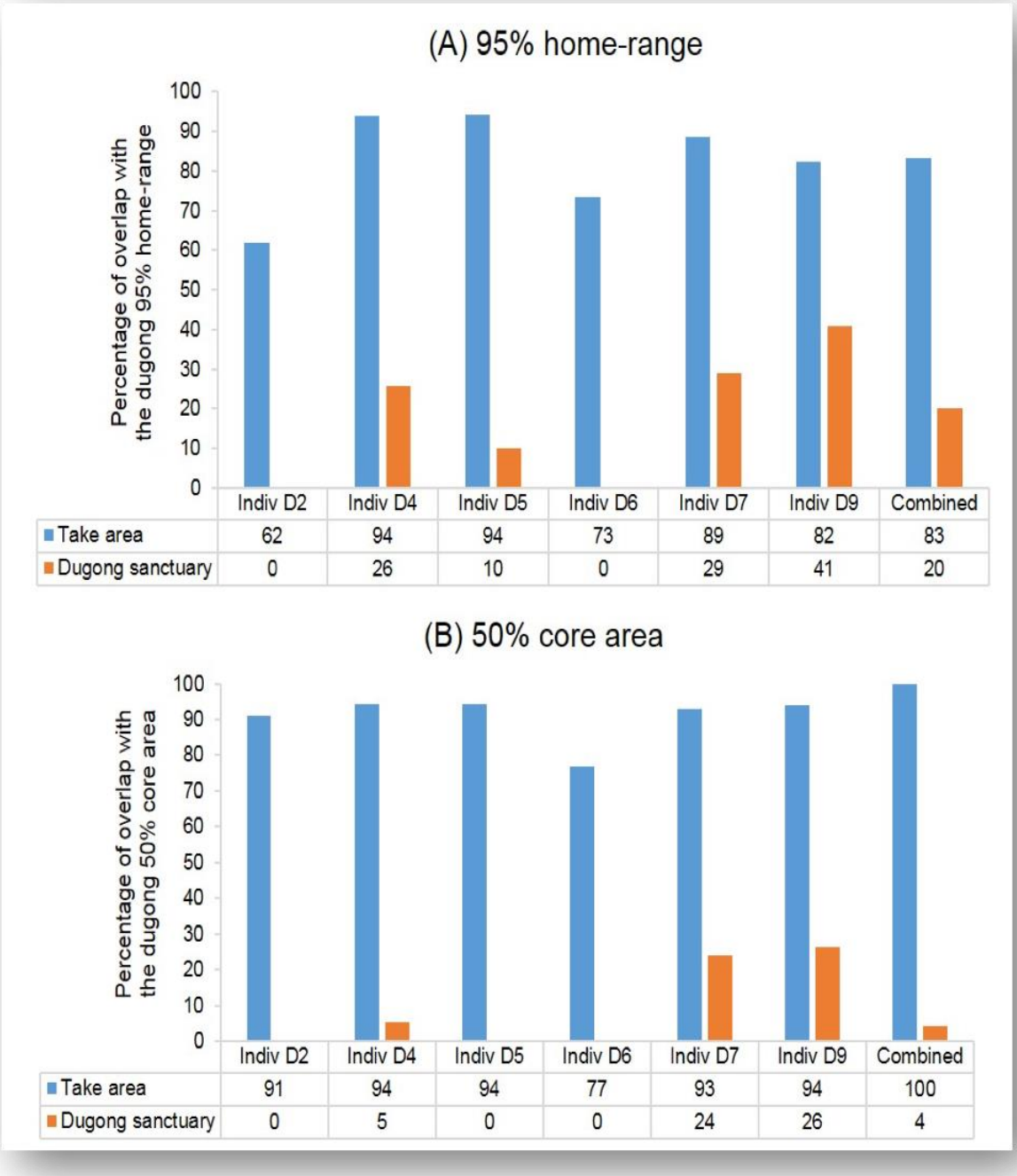


Figure 9: Percentage of overlap between the 95% home-range and 50% core areas of the dugongs captured around Badu Island in Torres Strait in October 2015 and the Dugong Sanctuary and the areas where hunting is likely to occur. These dugongs spent most of their tracking time within areas where hunting is likely to occur and very little time in the Dugong Sanctuary.

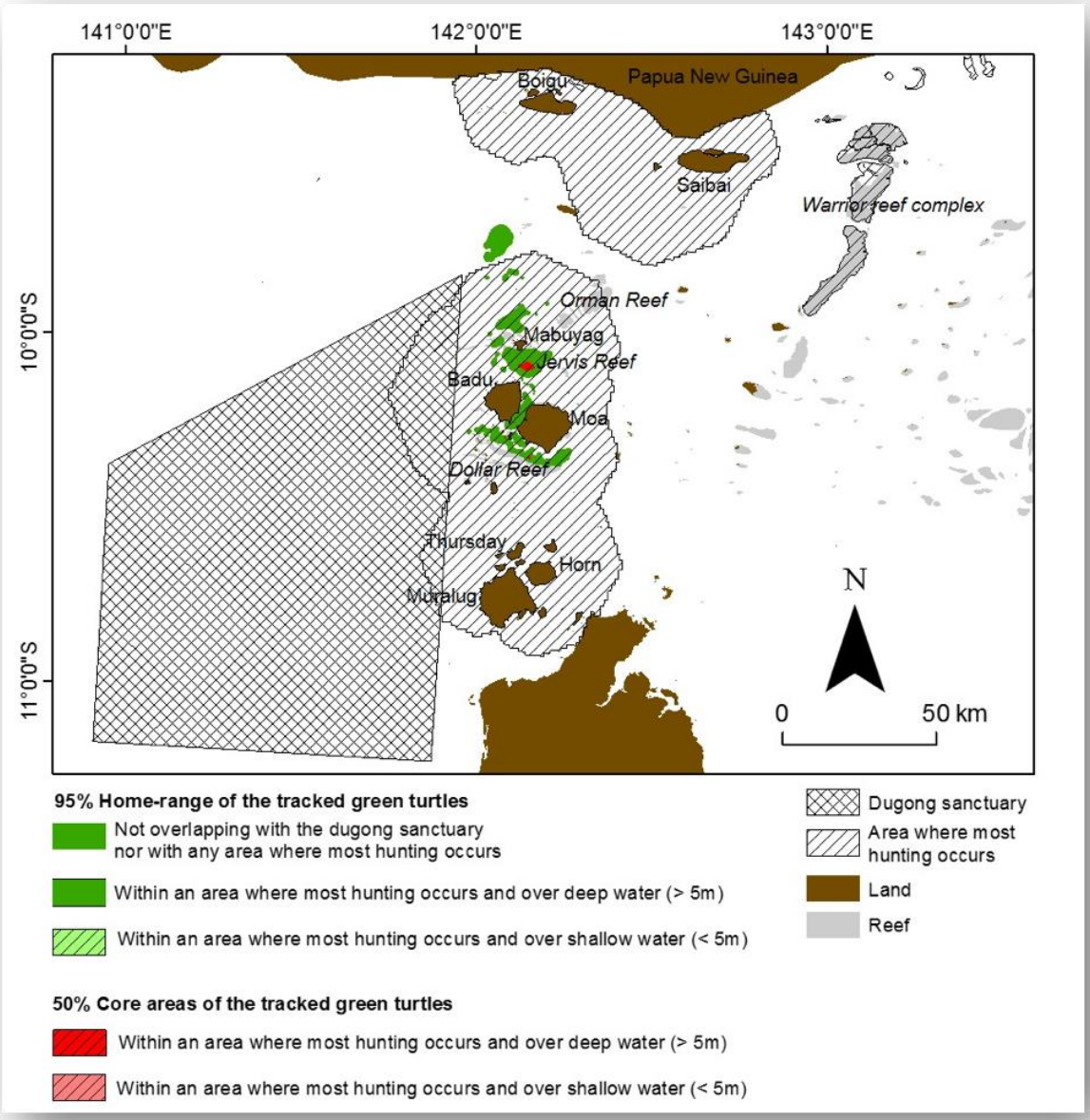


Figure 10: Use of space by the five non-migrating green turtles captured around Badu Island in Torres Strait in October 2015 in relation to areas where hunting is likely to occur, the Dugong Sanctuary and water depth. The tracked turtles mostly used areas that overlapped areas where hunting is likely to occur. They did not use the Dugong Sanctuary during their tracking time. The different colour shadings in the figure enable areas of shallow (< 5 m) and deep (> 5 m) waters used by the tracked turtles to be distinguished. The turtles made intensive use of the shallow waters located over Jervis Reef as well as deeper areas north of Mabuyag and south of Badu Islands.

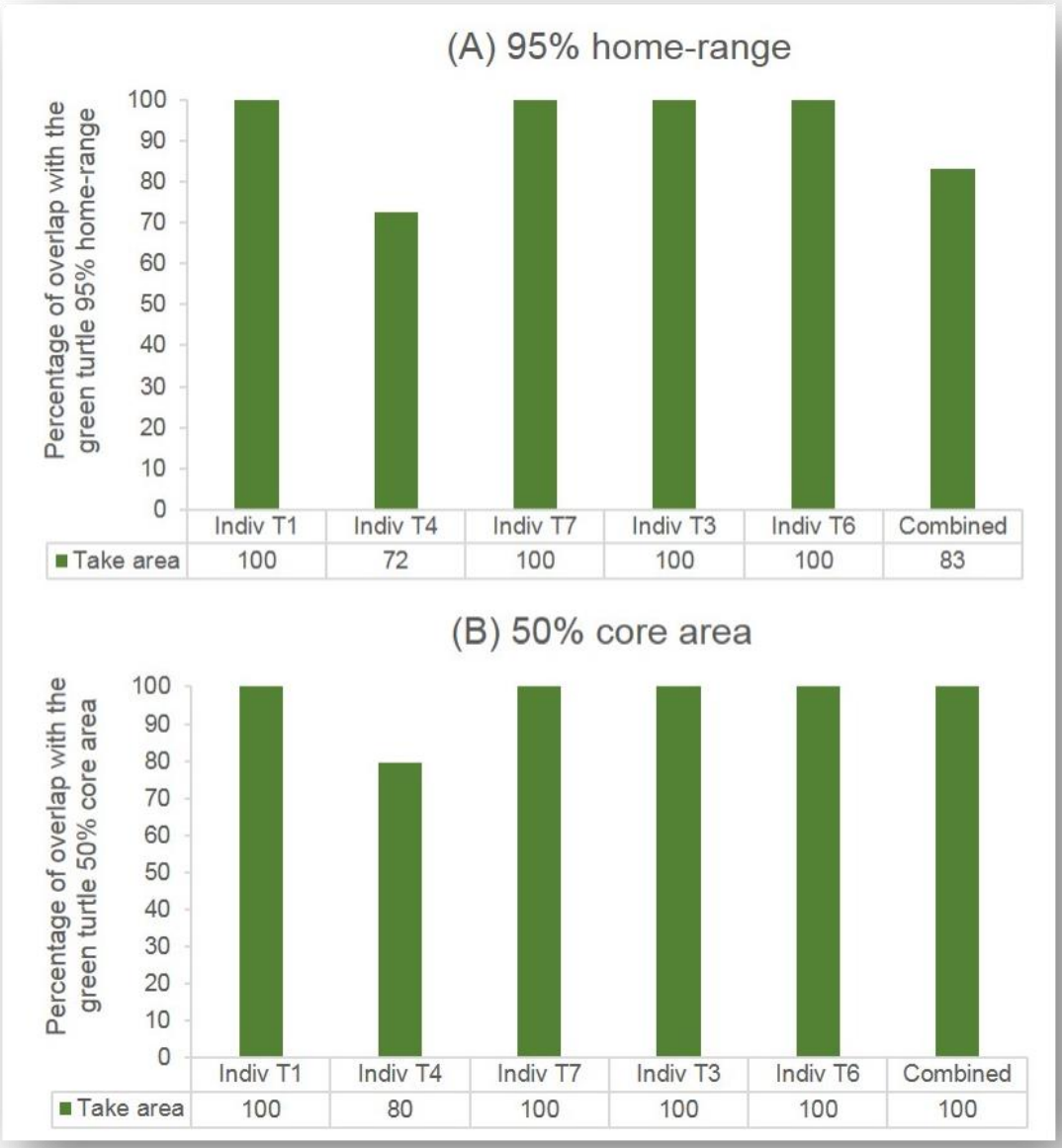


Figure 11: Percentage of overlap between the 95% home-range and 50% core areas of the green turtles captured in Torres Strait in October 2015 and the Dugong Sanctuary and the areas where hunting is likely to occur. The turtles spent most of their tracking time within areas where hunting is likely to occur. These animals did not use the Dugong Sanctuary during their tracking time.

4. DISCUSSION

This report is results from a successful research partnership between the Mura Badulgal Representative Native Title Bodies Corporate, the Badu community, TSRA rangers and JCU researchers. The field team efficiently and safely caught 10 dugongs and nine green turtles in the coastal waters of Badu and fitted them with telemetry devices to study their space use and diving behaviour (see the companion report by Hagihara *et al*. (2016) for the insights gained into the diving behaviour of these two species). This study added to the information about dugongs and green turtle space use in Torres Strait, providing insights into the biology of both species that has the potential to inform their community-based management.

4.1 Biological insights

4.1.1 Dugongs

Individuality and scale of movements
Even though all but one of the tracked dugongs spent most of their tracking period ranging around Badu and Moa Islands close to where we captured them, each individual used space differently (Appendix VI, Figure A.4). Similar individuality in the movements of tagged dugongs has been reported from: Torres Strait (Lawler *et al*. 2005, Gredzens *et al*. 2014); other parts of Australia (Marsh and Rathbun 1990, Holley 2006, Sheppard *et al*. 2006, Gredzens *et al*. 2014, Cleguer *et al*. 2015a, Zeh *et al*. 2015, 2016); Indonesia (De Iongh *et al*. 1998) and New Caledonia (Cleguer 2015).

Dugong D6 had a larger range than the other tracked dugongs, undertaking two trips to the southern coast of Boigu Island, close to the PNG coast and 100 km north from Badu Island. A similar large scale exploratory movement to the coastal waters of PNG was also undertaken by a dugong caught close to Mabuyag Island in 2010 (Gredzens *et al*. 2014). Satellite tagged dugongs have consistently exhibited heterogeneous movement patterns ranging from small scale commuting movements (< 15 km, n = 26 individuals) to large scale moves (> 15 km, n = 44 individuals; Sheppard *et al*. 2006) in other parts of Australia (Marsh and Rathbun 1990, Holley 2006, Sheppard *et al*. 2006, Gredzens *et al*. 2014, Cleguer *et al*. 2015b, Zeh *et al*. 2015, 2016); Indonesia (De Iongh *et al*. 1998) and New Caledonia (Cleguer 2015).

Some apparently direct large scale movements of tracked dugongs appear to be flight responses to capture and tagging e.g., a dugong captured in Port Curtis, Queensland swam to Shoalwater Bay immediately after its release (Cleguer *et al*. 2015b). However, not all direct large scale movements can be attributed to flight responses. Some such movements have been undertaken months after capture (Sheppard *et al*. 2006, Gredzens *et al*. 2014, Cleguer 2015) e.g., a dugong tracked in Cap Goulvain, on the mid-west coast of the main island of New Caledonia, undertook a large scale movement 110 days after it was captured (Cleguer 2015). D6 swam from Badu Island to Boigu Island two days after it was captured, suggesting that this movement was not a flight response, especially as this animal repeated this large-scale movement to Boigu a month later after its first trip.

Home range size

The mean size of the range of the dugongs tracked near Badu Island (mean dugong range= 530km^2 ± SD = 253 km^2) was relatively large but not as large as the mean range of the dugongs tracked from around Mabuyag Island in 2010 (mean dugong range = 838 km^2, ± SD = 415 km^2; Gredzens *et al*. 2014). Taken together these results suggest that dugongs range over much larger areas of Torres Strait than in the other regions of Australia where they have been tracked (mean ranges from other regions = 24.0 – 63.6 km^2; Marsh and Rathbun 1990, Holley 2006, Sheppard *et al*. 2006, Cleguer *et al*. 2015a, b). Similar differences in the range of tracked dugongs were found in New Caledonia between dugongs tracked in the vast lagoon of Noumea compared to two other sites, Cap Goulvain and Ouano, where the lagoons are much smaller (Cleguer 2015). Differences in the extent of the seagrass meadows in the regions in which the dugongs are tracked and the distribution of seagrasses may explain the regional differences in dugong range sizes. Torres Strait is estimated to contain between 13,425 km^2 (Coles *et al.* 2003) and 17,500 km^2 (Poiner and Peterkin 1996) of seagrass habitat.

Site fidelity

Dugong D6 returned to its capture location after its first exploratory trip to Boigu Island. Similarly, in the Nouméa region in New Caledonia, a tracked dugong undertook two 60 km trips using very similar routes to visit the area near Puen Islet for a day and then returned to a location only metres away from its capture location (Cleguer 2015). Two dugongs undertook exploratory trips to Cleveland Bay located 150 km to the south before returning to their capture location near Hinchinbrook Island (Sheppard *et al*. 2006). Why dugongs make these trips and whether they always return to their initial point of departure is difficult to determine using remote tracking methods. Cope *et al*. (2015) inferred the movements of dugongs distributed across four spatially distinct foraging locations in southern Queensland, Australia, using reconstructed pedigrees based on their genetic profiles. Their study indicates that; (1) dugongs undertake large-scale movements more often than suggested by satellite tagging or genetic studies, (2) male dugongs move undertake such movements more frequently than females, and (3) most movements are not breeding movements.

The capacity to undertake seemingly directed large-scale movements and return to the point of departure suggests that dugongs have considerable capacity for orientation and navigation, especially as there is no apparent diel pattern in these movements (see Cleguer 2015, Zeh *et al*. 2016). Dugongs tend to travel close to the shore or reefs in coastal environments (Cleguer 2015, Zeh *et al*. 2016). D6 was tracked close to Buru Island on each of his trips between the waters of Badu and Biogu suggesting that he may have used that island as a staging post. Sirenians are considered to have limited visual capacities (Bauer *et al*. 2003) and lack active echolocation (Mann *et al*. 2005), suggesting that a combination of other sensory modalities may play an important role in spatial orientation (Reep *et al*. 2002, Reep and Sarko 2009, Reep *et al*. 2011). These modalities include: (1) their highly developed tactile sensory systems (Reep and Sarko 2009), (2) exceptional acoustic sensitivity (Hartman 1979, Popov and Supin 1990, Gerstein 2002), and (3) highly developed tastebuds (Levin and Pfeiffer 2002). Although there is no evidence that dugongs have long-term social structure, their use of distinct movement pathways and tendency to bypass seagrass habitats *en route* may also reflect matrilineal transmitted learned behaviours and spatial memory (Sheppard *et al*. 2006, Marsh *et al*. 2011). Navigation in dugongs remains largely unexplored and requires further investigation.

4.1.2 Green turtles

Home range size on the feeding grounds

In contrast to the dugongs, the non-migrating tracked green turtles (T1, T3, T4, T6 and T7) used small, restricted ranges, with high site fidelity; a result remarkably similar to green turtles tracked from around Mabuyag Island in 2010 (Gredzens *et al*. 2014) (mean green turtle range in 2010 = 193.9 km^2, ±SD = 370 km^2; this study = 193.1, SD = 358 km^2), and in other regions (Whiting and Miller 1998, Hays *et al*. 2002, Seminoff *et al*. 2002, Hazel 2009, Hazel *et al*. 2013).

Site fidelity

The green turtles we tracked did not remain near their Badu Island release point. The five non-migrating turtles quickly returned to their capture sites. So did the three migrating turtles after their nesting migration. Shimada *et al*. (2016) found that 52 of 59 turtles, comprising 44 green turtles, 13 loggerhead turtles, and two olive ridley turtles, displaced up to 117.4 km from their capture locations travelled back to their home areas or nearby (n=4) with no evidence of distance being a limiting factor to homing ability.

Migration

Sea turtle tagging programs typically focus on nesting females as large number of individuals can easily be tagged during nesting events. Consequently, much less is known about the life cycle and movement patterns of male turtles or female turtles on the feeding grounds or about the relationships between feeding, courtship, mating and nesting areas. Thus despite the small sample size, our study provided some important insights. The three breeding female green turtles (T2, T5 and T8) we tracked swam back to their capture location after nesting at Raine Island and Moulter Cay, some 250 km away. We also captured a male green turtle (T3) while it was mating with one of the migrating females (T5). To our knowledge, this is the first occasion for Torres Strait on which: (1) a male green turtle has been satellite tracked and (2) a mating pair of green turtles has been fitted with satellite transmitters and tracked simultaneously. The male green turtle (T3) quickly returned to its capture location after release and remained there during the entire period for which it was tracked. This period covered the green turtle breeding season as defined by the migrating female turtles (October 2015 to February 2016). The fact that this male green turtle did not migrate after courtship and that the migrating females returned to Torres Strait after nesting suggests that these animals use Torres Strait as foraging site as well as a courtship and mating ground. Such behaviour is not unexpected in this region (Mark Hamann pers. comm.) but differs from the behaviour reported from some other green turtle habitats. For example in Hawaii during the breeding season, male green turtles swim between 800 and 1300 km from their feeding grounds in the main Hawaiian Islands to their nesting beaches, primarily at French Frigate Shoals, in the North-western Hawaiian Islands (Balazs *et al*. 2000) and in southern Queensland male turtles migrate each year between foraging and breeding sites (Limpus 1993).

Breeding areas for green turtles occur at variable distances from the nesting rookeries and the distribution of courtship areas associated with the rookeries can be identified by the movement of the females from courtship areas to their nesting beaches (Limpus 1993). The migrating female green turtles we tracked swam 250 km from near Badu Island to Raine Island and Moulter Cay, despite the existence of nesting beaches in Torres Strait e.g., at

Murray Island. This behaviour is typical of green turtles. In addition to being a nesting ground for turtles from Torres Strait, Raine Island and Moulter Cay are also nesting grounds for turtles that have migrated from eastern and northern Australia, Indonesia, New Guinea, Vanuatu and New Caledonia. Because green turtles have strong fidelity to nesting areas, it is likely that the female turtles we tracked will return to the same nesting grounds during future nesting seasons.

Marine turtles typically migrate in a direct route between nesting and foraging areas. One unexpected result of our tracking was for turtle T8. This female turtle was in the Raine Island region for approximately 3.5 months and had likely laid two clutches of eggs on Raine Island. She then migrated back to Torres Strait in early February only to reach the eastern edge of the Torres Strait region and then turn around and swam back to Raine Island. She then laid a third clutch of eggs and migrated back to Torres Strait. As far as we know, this is the first time a near double migration has been recorded for a marine turtle in one nesting season.

4.1.3 Both species

Spatial relationships

Our results show that dugongs and green turtles captured in the same general area had overlapping home ranges, even though the non-migrating green turtles used smaller areas than dugongs. For example, the range of the dugongs captured south of Badu Island overlapped with that of the green turtles captured at the same location. These results are similar to those for the dugongs and green turtles tracked around Mabuyag Island in 2010 (Gredzens *et al*. 2014). However, dugongs and green turtles tracked from around Badu Island shared little space with the dugongs and green turtles tracked from around Mabuyag Island. These results suggest that individual dugongs and green turtles spend long periods in the Sea Country of specific Torres Strait communities.

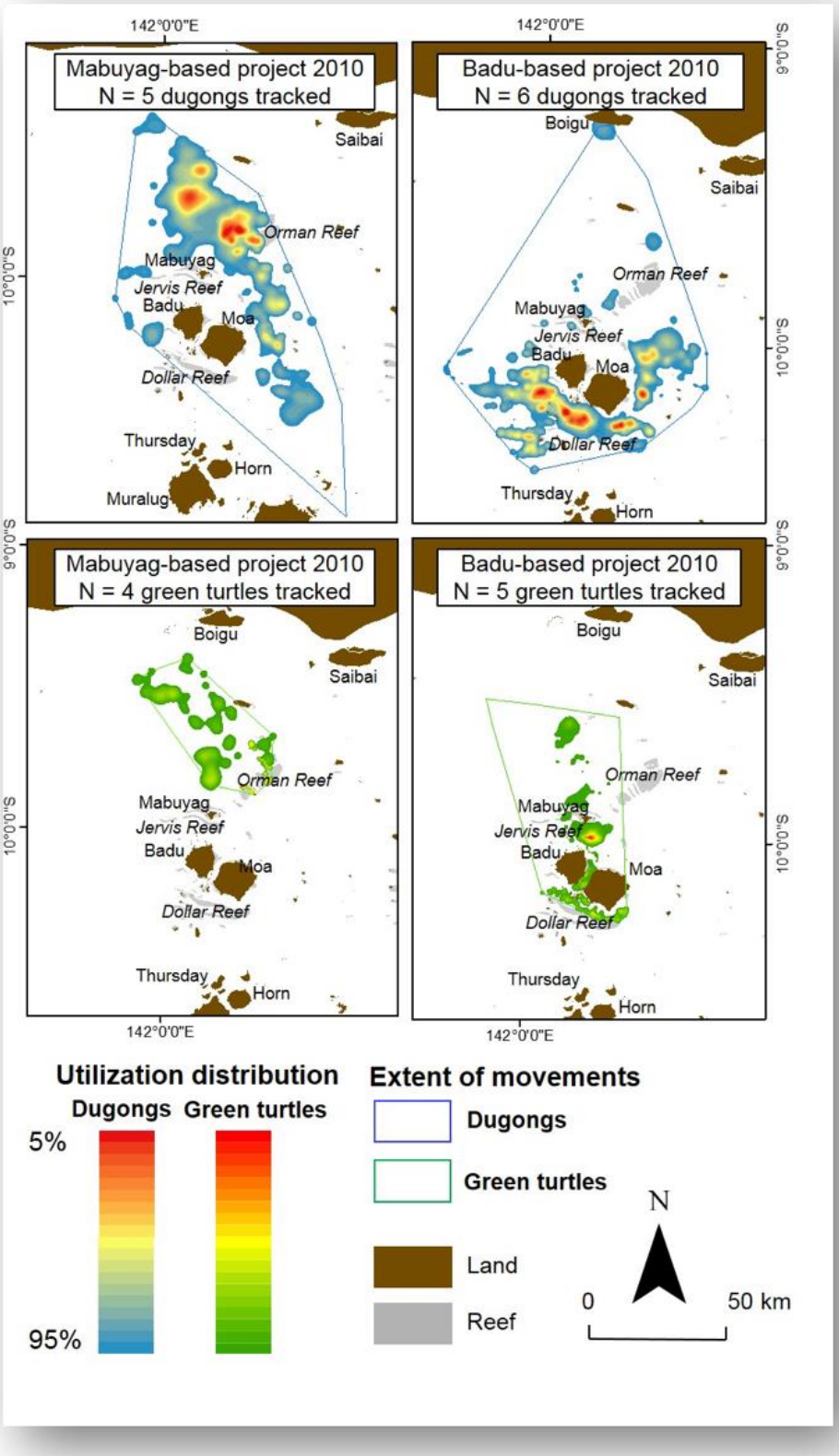


Figure 12: Visual comparison of the use of space by dugongs and green turtles tracked from two study regions within Torres Strait: Mabuyag (Gredzens *et al*. 2014) and Badu Islands (this study). These results suggest that individual dugongs and green turtles spend long periods in the sea country of specific Torres Strait communities.

4.2 Management Implications

Our results provide further evidence that the management of dugongs and green turtles needs to be implemented at several spatial scales appropriate to the ecology of the two species. The relatively sedentary behaviour of some of the tracked dugongs and turtles during both this study and that of Gredzens *et al*. (2014) highlights the importance of the community-based management plans currently developed at the scale of the Sea Country of individual communities. Effective management at this scale should assist in the maintenance of local populations, although recruitment failure at the nesting sites of green turtles will remain a long-term threat as discussed in our parallel report (Hagihara *et al*. 2016).

The tracked dugongs and non-migrating green turtles spent most of their time within areas where Traditional hunting is likely to occur (Marsh *et al*. 2015) and very little time within the boundaries of the Dugong Sanctuary where dugong hunting is banned. These results support the recommendations in the parallel report by Hagihara *et al*. (2016), that the TSRA continue to give high priority to further discussions with the Prescribed Bodies Corporate of the Top Western and Near Western Islands and the Protected Zone Joint Authority (PZJA) about the desirability of: (1) declaring some of the high density dugong areas as a no-hunting areas for an agreed period; and (2) determining how the Dugong Sanctuary might be extended.

Dugongs and green turtles also undertake large-scale movements across jurisdictional boundaries (e.g., green turtles migrate from Torres Strait to the Northern Great Barrier Reef during the nesting season as demonstrated by our study). Thus, the management arrangements for these two species also requires collaboration among the Torres Strait communities and with neighbouring regions including the Great Barrier Reef World Heritage Area and PNG as discussed further in our parallel report (Hagihara *et al*. 2016).

Three of the eight female green turtles we tracked were absent from Central and Western Torres Strait region between mid-October and late February. The proportion of females undertaking such migrations is influenced by the El Niño phenomenon (Limpus and Nicholls 2000). Thus the estimates of the number of large juvenile and adult females in Central and Western Torres Strait obtained from the aerial surveys in November 2006 and 2011 are underestimates by variable and unknown amounts and caution is required in interpreting inter-year differences. These matters are discussed in Hagihara *et al*. (2016).

4.3 Future directions

Satellite tracking of dugongs and green turtles has considerable potential to inform the management of the Torres Strait Dugong and Turtle Fisheries by enhancing collaborations between Traditional Owners and JCU researchers to increase the evidence base for community-based management of these cultural keystone species and build understanding of and trust in western science in the local communities.

This evidence base would be strengthened by increasing the number of dugongs and green turtles caught in Torres Strait, fitted with satellite transmitters and tracked. A systematically-designed, multi-year program in which animals are captured in in different locations with the

help of different communities at different times of year and in different years could yield valuable insights.

4.4 Recommendations

That a systematic multi-year further satellite tracking of dugongs and sea turtles be designed and implemented jointly by Torres Strait communities and JCU researchers to enhance collaboration, increase the evidence base for community-based management of these cultural keystone species and build trust in and knowledge of western science in the local communities.

5. REFERENCES

BALAZS, G. H., RICE, M., MURAKAWA, S. K. & WATSON, G. 2000. Growth rates and residency of immature green turtles at Kiholo Bay, Hawaii. Proceedings of the 18th International Sea Turtle Symposium, Mazatlán, México, US Department of Commerce, Miami, Florida, 2000. 283-285.

BAUER, G. B., COLBERT, D. E., GASPARD III, J. C., LITTLEFIELD, B. & FELLNER, W. 2003. Underwater visual acuity of Florida manatees (Trichechus manatus latirostris). *International Journal of Comparative Psychology,* 16.

BEYER, H. L. 2012. Geospatial Modelling Environment (Version 0.6.0.0). . Available: http://www.spatialecology.com/gme.

CLEGUER, C. 2010. Le dugong (Dugong dugon), monographie de l'espèce, état des lieux des connaissances et des méthodologies d'études. Propositions d'actions en vue d'améliorer les connaissances relatives au dugong en Nouvelle-Calédonie. *In:* PROTEGEES, A. D. A. M. (ed.).

CLEGUER, C. 2015. Informing dugong conservation at several spatial and temporal scales in New Caledonia*.* Ph.D., James Cook University.

CLEGUER, C., LIMPUS, C., GREDZENS, C., HAMANN, M. & MARSH, H. 2015a. Annual report on dugong tracking and habitat use in Gladstone in 2014. Report produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program.

CLEGUER, C., LIMPUS, C., HAMANN, M. & MARSH, H. 2015b. Annual report on dugong tracking and habitat use in Gladstone in 2015. Report produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program.

COLES, R.G., MCKENZIE, L.J. & CAMPBELL, S.J. 2003. Chapter 11: The seagrasses of eastern Australia. In E.P. Green and F.T. Short (Eds.) *World Atlas of Seagrasses*: pp. 119-128. Berkley, USA: University of California Press.

COPE, R., POLLETT, P., LANYON, J. & SEDDON, J. 2015. Indirect detection of genetic dispersal (movement and breeding events) through pedigree analysis of dugong populations in southern Queensland, Australia. *Biological Conservation,* 181**,** 91-101.

DE IONGH, H. H., LANGEVELD, P. & VAN DER WAL, M. 1998. Movement and Home Ranges of Dugongs Around the Lease Islands, East Indonesia *Marine Ecology,* 19**,** 179-193.

ESRI 2013. ArcGIS Desktop: Release 10.2. Redlands: CA: Environmental Systems Research Institute.

FUENTES, M. M. P. B., CLEGUER, C., LIEBSCH, N., BEDFORD, G., AMBER, D., HANKIN, C., MCCARTHY, P., SHIMADA, T., WHAP, T. & MARSH, H. 2013. Adapting dugong catching techniques to different cultural and environmental settings. *Marine Mammal Science,* 29**,** 159-166.

FUENTES, M., BELL, I., HAGIHARA, R., HAMANN, M., HAZEL, J., HUTH, A., SEMINOFF, J., SOBTZICK, S. & MARSH, H. 2015. Improving in-water estimates of marine turtle abundance by adjusting aerial survey counts for perception and availability biases. *Journal of Experimental Marine Biology and Ecology,* 471**,** 77-83.

GERSTEIN, E. 2002. Manatees, Bioacoustics and Boats Hearing tests, environmental measurements and acoustic phenomena may together explain why boats and animals collide. *American Scientist,* 90**,** 154-163.

GREDZENS, C., MARSH, H., FUENTES, M. M. P. B., LIMPUS, C., SHIMADA, T. & HAMANN, M. 2014. Satellite Tracking of Sympatric Marine Megafauna Can Inform the Biological Basis for Species Co-Management. *Plos One,* 9**,** e98944.

HAGIHARA, R., JONES, R. E., GRECH, A., LANYON, J. M., SHEPPARD, J. K. & MARSH, H. 2014. Improving population estimates by quantifying diving and surfacing patterns: A dugong example. *Marine Mammal Science,* 30, 348-366.

HAGIHARA, R., CLEGUER, C., PRESTON, S., SOBTZICK, S., HAMANN, M., SHIMADA, T. & MARSH, H. 2016. Improving the estimates of abundance of dugongs and large immature and adult-sized green turtles in Western and Central Torres Strait: A project in collaboration with the Mura Badulgal Representative Native Title Bodies. Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns (53pp.).

HARTMAN, D. S. 1979. Ecology and behavior of the manatee (Trichechus manatus) in Florida. *American Society of Mammalogists*, Pittsburgh, Pennsylvania, USA.

HAYS, G., GLEN, F., BRODERICK, A., GODLEY, B. & METCALFE, J. 2002. Behavioural plasticity in a large marine herbivore: contrasting patterns of depth utilisation between two green turtle (Chelonia mydas) populations. *Marine Biology,* 141**,** 985-990.

HAZEL, J. 2009. Evaluation of fast-acquisition GPS in stationary tests and fine-scale tracking of green turtles. *Journal of Experimental Marine Biology and Ecology,* 374**,** 58-68.

HAZEL, J., HAMANN, M. & LAWLER, I. R. 2013. Home range of immature green turtles tracked at an offshore tropical reef using automated passive acoustic technology. *Marine Biology,* 160**,** 617-627.

HOLLEY, D. K. 2006. Movement patterns and habitat usage of Shark Bay dugongs. Master of Science, Edith Cowan University.

IUCN. 2015. IUCN Red List of threatened species: version 2015.2 [Online]. Available at: http://www.iucnredlist.org/. Available: http://www.iucnredlist.org/. Accessed 05 July 2015.

JENSEN, M. P., BELL, I., LIMPUS, C. J., HAMANN, M., AMBAR, S., WHAP, T., DAVID, C. & FITZSIMMONS, N. N. 2016. Spatial and temporal genetic variation among size classes of green turtles (Chelonia mydas) provides information on oceanic dispersal and population dynamics. *Marine Ecology Progress Series,* 543**,** 241-256.

JOHANNES, R. E. & MACFARLANE, J. W. 1991. Traditional fishing in the Torres Strait islands. CSIRO Division of Fisheries, Marine Laboratories.

KWAN, D., MARSH, H. & DELEAN, S. 2006. Factors influencing the sustainability of customary dugong hunting by a remote indigenous community. *Environmental Conservation,* 33**,** 164-171.

LAWLER, I., HAMANN, M., SHEPPARD, J. & MARSH, H. 2005. Working with Torres Strait Islanders to study dugong movements and habitat usage. Report to the Commonwealth Department of Environment and Heritage.

LEVIN, M. & PFEIFFER, C. 2002. Gross and microscopic observations on the lingual structure of the Florida Manatee Trichechus manatus latirostris. *Anatomia, histologia, embryologia,* 31**,** 278-285.

LIMPUS, C. 1978. The reef. *In:* LAVERY, H. J. (ed.) Australia's wildlife from desert to reef Richmond, Victoria: Richmond Hill Press.

LIMPUS, C. 1993. The green turtle, Chelonia mydas, in Queensland: breeding males in the southern Great Barrier Reef. *Wildlife Research,* 20**,** 513-523.

LIMPUS, C. & NICHOLLS, N. 2000. ENSO regulation of Indo-Pacific green turtle populations. *Applications of seasonal climate forecasting in agricultural and natural ecosystems.* Springer.

LIMPUS, C., MILLER, J. D., PARMENTER, C. J. & LIMPUS, D. J. 2003. The green turtle, Chelonia mydas, population of Raine Island and the northern Great Barrier Reef: 1843-2001. *Memoirs-Queensland Museum,* 49**,** 349-440.

MANN, D. A., COLBERT, D. E., GASPARD, J. C., CASPER, B. M., COOK, M. L., REEP, R. L. & BAUER, G. B. 2005. Temporal resolution of the Florida manatee (Trichechus manatus latirostris) auditory system. *Journal of Comparative Physiology A,* 191**,** 903-908.

MARSH, H. & RATHBUN, G. B. 1990. Development and Application of Conventional and Satellite Radio Tracking Techniques for Studying Dugong Movements and Habitat Use. *Australian Wildlife Research,* 17**,** 83-100.

MARSH, H., LAWLER, I. R., KWAN, D., DELEAN, S., POLLOCK, K. & ALLDREDGE, M. 2004. Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. *Animal Conservation,* 7**,** 435-443.

MARSH, H., REYNOLDS III, J. E., O'SHEA, T. J. & REYNOLDS III, J. E. 2011. Ecology and conservation of the sirenia: dugongs and manatees, Cambridge Univ Pr.

MARSH, H., GRAYSON, J., GRECH, A., HAGIHARA, R. & SOBTZICK, S. 2015. Re-evaluation of the sustainability of a marine mammal harvest by indigenous people using several lines of evidence. *Biological Conservation,* 192**,** 324-330.

MCNIVEN, I. J. & BEDINGFIELD, A. C. 2008. Past and present marine mammal hunting rates and abundances: dugong (Dugong dugon) evidence from Dabangai Bone Mound, Torres Strait. *Journal of Archaeological Science,* 35**,** 505-515.

POINER, I.R. & PETERKIN, C. 1996. Seagrasses. In: L. Zann and P. Kailola (Eds.) *The state of the marine environment report for Australia* (Vol. Technical Annex: 1, pp. 40–45). Townsville, Australia: Great Barrier Reef Marine Park Authority.

POPOV, V. & SUPIN, A. 1990. Electrophysiological studies of hearing in some cetaceans and a manatee. *Sensory abilities of cetaceans.* Springer.

REEP, R. & SARKO, D. K. 2009. Tactile hair in Manatees. *Scholarpedia,* 4**,** 6831.

REEP, R., MARSHALL, C. & STOLL, M. 2002. Tactile hairs on the postcranial body in Florida manatees: A mammalian lateral line? *Brain, behavior and evolution,* 59**,** 141-154.

REEP, R. L., GASPARD, J. C., SARKO, D., RICE, F. L., MANN, D. A. & BAUER, G. B. 2011. Manatee vibrissae: evidence for a “lateral line” function. *Annals of the New York Academy of Sciences,* 1225**,** 101-109.

REID, J. P., BONDE, R. K. & O'SHEA, T. J. 1995. Reproduction and mortality of radio-tagged and recognizable manatees on the Atlantic Coast of Florida. *In:* O'SHEA, T. J., ACKERMAN, B. B. & PERCIVAL, H. F. (eds.) *Information and Technology Report.* National Biological Service.

SEMINOFF, J. A., RESENDIZ, A. & NICHOLS, W. J. 2002. Home range of green turtles Chelonia mydas at a coastal foraging area in the Gulf of California, Mexico. *Marine Ecology Progress Series,* 242**,** 253-265.

SHEPPARD, J. K., PREEN, A. R., MARSH, H., LAWLER, I. R., WHITING, S. D. & JONES, R. E. 2006. Movement heterogeneity of dugongs, Dugong dugong (Müller), over large spatial scales. *Journal of Experimental Biology and Ecology,* 334**,** 64-83.

SHIMADA, T., JONES, R., LIMPUS, C. & HAMANN, M. 2012. Improving data retention and home range estimates by data-driven screening. *Marine Ecology Progress Series*.

SHIMADA, T., LIMPUS, C., JONES, R., HAZEL, J., GROOM, R. & HAMANN, M. 2016. Sea turtles return home after intentional displacement from coastal foraging areas. *Marine Biology,* 163**,** 1-14.

TORRES STRAIT FISHERIES MANAGEMENT NOTICE 2003. Torres Strait Dugong Fishery. Prohibitions on the taking of dugongs (are, gear and method restrictions)*. Fisheries Management Notice No. 65* [Online]. Available at: https://www.legislation.gov.au/Details/F2007B00345/Html/Text#_Toc1172467373115 Accessed 22 March 2016.

WEISLER, M., ROWE, C., MCNIVEN, I. J., DAVID, B. & CROUCH, J. 2007. Berberass, marine resource specialisation and environmental change in Torres Strait during the past 4000 years. *Archaeology in Oceania,* 42**,** 49.

WHITING, S. D. & MILLER, J. D. 1998. Short term foraging ranges of adult green turtles (Chelonia mydas). *Journal of Herpetology***,** 330-337.

WRIGHT, D. 2011. Mid Holocene maritime economy in the western Torres Strait. *Archaeology in Oceania,* 46**,** 23.

ZEH, D. R., HEUPEL, M. R., LIMPUS, C. J., HAMANN, M., FUENTES, M. M. P. B., BABCOCK, R. C., PILLANS, R. D., TOWNSEND, K. A. & MARSH, H. 2015. Is acoustic tracking appropriate for air-breathing marine animals? Dugongs as a case study*. Journal of Experimental Marine Biology and Ecology,* 464, 1-10.

ZEH, D. R., HEUPEL, M. R., HAMANN, M., LIMPUS, C. J. & MARSH, H. 2016. Quick Fix GPS technology highlights risk to dugongs moving between protected areas. *Endangered Species Research,* 30, 37-44.

6. APPENDICES

6.1 Appendix I

Research Partnership Agreement between James Cook University, Mura Badulgal Representative Native Title Bodies Corporate, and the Torres Strait Regional Authority Land and Sea Management Unit involved in the following project.

Project title
Improving historical estimates of abundance and distribution of dugongs and large green turtles in western and central Torres Strait.

Benefits of the project for Badu community, especially Mura Badulgal Representative Native Title Bodies Corporate and the Traditional Owners

1. James Cook University scientists believe that current population estimates for dugongs and green turtles in Torres Strait are underestimated. The information received from dive computers attached to captured animals in this project will empower the Badu community to better manage these culturally significant species through their Dugong and Turtle Management Plan. JCU will not use the data for any other purpose without permission.
2. This project will provide additional funding to the community through the hiring of local boats and employment of hunters. Funds will be administered by the Mura Badulgal Representative Native Title Bodies Corporate.
3. This project will strengthen the working relationship between JCU, the Badu traditional owners and community and Torres Strait Regional Authority.
4. This project will also involve the school and community who are invited to name the tracked animals and follow their movements online.

Values and Ethics
This project will be conducted in accordance with the Values and Ethics in the *Aboriginal and Torres Strait Islander Health Research, 2003 guidelines* which provide guidance to researchers in the conception, design and conduct of research involving Torres Strait Islanders and Aboriginal peoples. The research will be conducted in accordance with the six values at the heart of these guidelines as outlined in the JCU Human Ethics Approval for Research Involving Torres Strait Islander and Aboriginal participants. The six values are:

1) **RECIPROCITY:** *This project ensures that research planning and outcomes include equitable involvement in, and benefits from, the findings to the relevant Torres Strait Islander communities or individuals as well as the research agencies.*

2) **RESPECT:** A r*espectful research relationship is expected, where it affirms the rights of people to have different values, norms and aspirations. Those involved in the research processes should show acceptance and tolerance of possible differences of opinion. Also essential to a respectful research relationship is the recognition of the contribution of others and the consequences of research.*

3) **EQUALITY**: *This project affirms Torres Strait Islander People's right to be different. Demonstrated commitment to distributive fairness and justice and to the equal validity of Indigenous Knowledge systems.*

4) **RESPONSIBILITY.** *Recognition of core responsibilities – to do no harm, transparent accountability. Each participant is aware of their roles and has agreed to conduct them to the best of their ability. The roles and responsibility of each participant has been discussed and agreed prior to the trip to ensure that they are recognized and clear. All participants should recognize and conduct their roles to the best of their ability.*

5) **SURVIVAL AND PROTECTION.** *This project recognizes the importance of collective identity. The project will not discriminate against or deride Torres Strait Islander individuals or cultures.*

6) **SPIRIT AND INTEGRITY.** *This project considers community decision making based on shared values. The project has been designed to account for the community's cultural, spiritual and social cohesion, including workable timeframes.*

Permits and Ethics approval

The project will be conducted in accordance with the conditions stipulated in the Animal Ethics Approvals from JCU (**A2072**), Commonwealth Scientific Purpose Permit **E2014/0091** and Queensland Scientific Purpose Permit **WISP15058214** and the **Permit for Scientific Purposes** obtained by **TSRA** under the ***Torres Strait Fisheries Act 1984*****.**

Respecting the rights of Traditional Owners

1. To ensure that cultural protocols are observed this research agreement is based on:
   (1) Discussions between Helene Marsh and Damian Miley (no longer employed by TSRA) leading to TSRA contributing $62,500 (purchase of equipment only) to the project in 2014.
   (2) Discussions between Helene Marsh, Stan Lui and Shaun Barclay in Cairns in May 2015.
   (3) Funding from NESP Tropical Water Quality Hub in June 2015.
   (4) Discussions between JCU personnel Professor Helene Marsh, Dr Mark Hamann, Chris Cleguer and Dr Susan Sobtzick with TSRA personnel Stan Lui (Project Manager, Sea), Tristan Simpson (Senior NRM Officer, Sea), Peter McCulkin (Project manager, Ranger Operations), and Frank Loban (Senior NRM Officer, Senior Ranger Supervisor), on the 23rd June 2015;
   (5) A follow-up discussion and email correspondence between Helene Marsh and Frank Loban; Formal consideration by the Mura Badulgal RNBTC.

2. During these meetings all aspects of the project (from pre-trip planning, dugong catching to data dissemination) were discussed. During these meetings it was agreed that:

   a. The Mura Badulgal RNBTC will have overall control of granting permission for the activity to occur.
   b. The Mura Badulgal RNTBC will provide cultural advice and protocols which must be abided by throughout all aspects of the project.
   c. The Mura Badulgal Rangers will provide advice on the best times and locations for dugong catching activities.
   d. Dugong and turtle catching will be attempted every scheduled day that is safe to go out at agreed times and in accordance with tides, even if the conditions are not 100% optimal for catching activities. (Use of community and TSRA Ranger vessels will be in accordance with the TSRA Vessel Operation Procedures)
   e. Specific protocols be carried out for catching and tagging dugongs and turtles, including:
      i. Catching will be conducted in accordance to Animal Ethics Approvals from JCU (A2072) as described in Appendix A.
      ii. More specifically immature calves (less than 1.5m) and/or adult animals with immature calves must not be tagged; the dermal holdfast heads (if used) must be no longer than 2cm and sterilized using an antibacterial alcohol solution with

70% alcohol (provided by JCU team). Only one dugong is to be caught and tagged at a time.

iii. Turtle catching will be conducted in accordance to Animal Ethics. Large sub adult to adult turtles will be selected.

iv. Catching will not be conducted at times inconvenient to the hunters and only between first light and 6pm on the other days and when the sea state is less than 25 knots.

v. As a general rule, female researchers will not be allowed on the catching boat unless acceptable to all Islander team members & the local RNTBC.

vi. All boats (mothership and catching boats) are to travel together to and from the hunting grounds at all times.

vii. Field participants will not collect material from the Torres Strait marine environment apart from finfish if time permits.

f. Each participant will be assigned a daily role (Appendix C, and below); participants are to conduct their roles to the best of their abilities. Some of the roles will be determined during the debriefing session.

g. A briefing / debriefing session will be conducted prior/after the catching activities each day.

h. All participants are to follow the TSRA Standard Operating Procedure and itinerary provided as well as note the TSRA risk assessment developed in conjunction with Peter McCulkin TSRA (Appendix C, D, E).

3. The information received from dive computers attached to captured animals in this project will empower the Badu community to better manage these culturally significant species through their Dugong and Turtle Management Plan. JCU will not use the data for any other purpose without permission.
4. The research results will be communicated to Torres Strait Islanders as approved by the Mura Badulgal RNTBC via extension materials such as posters, talks to local schools, talking on local Torres Strait radio, articles in Torres News etc.
5. The Mura Badulgal RNTBC and the members of the community directly involved in the project will be consulted and have the opportunity to approve drafts of any manuscripts arising from the project and their assistance will be acknowledged in accordance with the JCU Code of Responsible Research Conduct.
6. The raw data will be stored in the JCU Research repository which is accessible only with the permission of the researchers involved after discussion with the Mura Badulgal RNTBC and the members of the community directly involved in the project.
7. Any changes to this agreement must be approved by all signatory parties in writing.

Increasing the capacity of the Rangers

1. Rangers will be involved in the dugong and turtle capture and transmitter deployment and trained in the associated Western Science techniques. A half-day workshop will be conducted prior to the start of the catching activities.
2. Rangers will be supplied with information materials to assist them to inform their communities about the project and to report the project outcomes to their community.

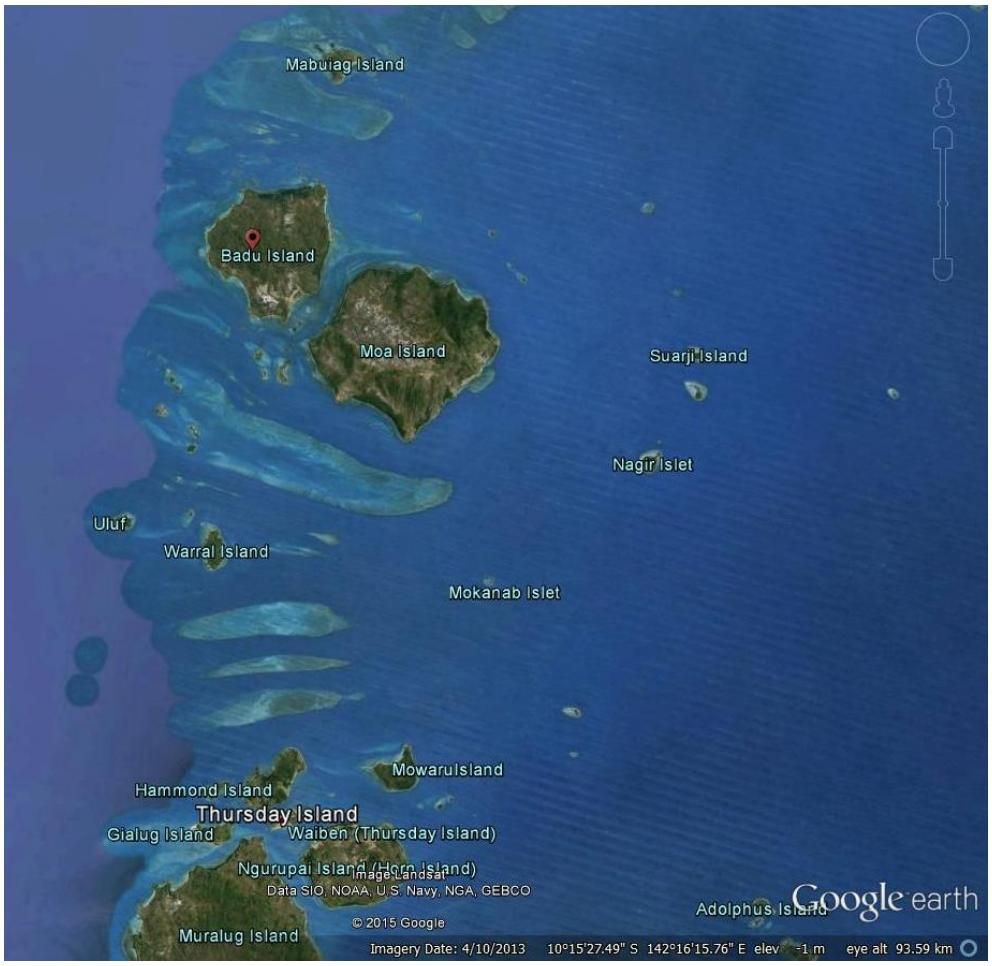
Dates of Field trip:

Gear to arrive ASAP - certainly by Friday September 28 (Friday barge)
JCU crew arrive on Monday October 5th or Tuesday October 6th
Dugong and turtle catching and tagging - 7-30th October 2015 (subject to approval of Mura Badulgal RNTBC and weather)

Project site – Badu Island

Badu Island is an island 60 km north of Thursday Island, Queensland, Australia in the Torres Strait (See Figure 1).

Figure 1. Aerial photograph of central and western Torres Strait showing Badu Island



Badu Island, which occupies a total area of 10 467ha, is formed on continental igneous basement rock. The island is characterised by numerous rocky knolls with Mt. Mulgrave forming the highest peak at 198m. The Island is partly covered with mounds of basaltic rocks, lightly vegetated open areas and fringed with extensive mangrove swamps.

Badu is the only town located on the south-east coast. The language of Badu is Kala Lagaw Ya. The last census (in 2011) recorded 783 people living on Badu Island.

The Badu men were noted seafarers and readily adapted to roles as lugger crews and the collection of pearl shell. They also served in large numbers in the Australian Army in World War II. The Badu economy prospered in the early post-war years, with up to 13 boats and a workforce of 200 engaged in the shell industry. The decline of the industry in the 1960s caused unemployment, some men moving to the mainland but others became engaged in cray fishing.

Badu has preschool and primary education facilities, a hotel, motel, sports and recreation venues and an Assembly of God church. The Badu Arts Centre produces a range of media including printmaking, etching, jewellery, textiles and carving. Badu also has an Indigenous-owned Bronze Casting foundry.

According to recent research conducted in the area, Badu Island is also in close proximity to high density dugong habitat.

Participants and their roles

Participant	Role
Mura Badulgal RNTBC (Chair Laurie Nona)	Have final say as to whether field trip goes ahead and on sharing of data Facilitating payment of local hunters (money provided as bulk sum from JCU) Provide cultural advice to the project participants Approve any outputs from the project.
Project Leaders JCU (Helene Marsh and Mark Hamann)	Project development in collaboration with TSRA and Mura Badulgal RNTBC Securing funding Liaising with TSRA and Mura Badulgal RNTBC about progress of project and outputs Take lead on producing outputs from the projects
Project Manager JCU (role shared by Susan Sobtzick (to September 1), and Chris Cleguer from September 1)	Project management and team leader for JCU Organise required permits and approvals Organize tracking gear and fuel for the project Monitor and control project budget Organize and provide safety gear for local boats Organize the JCU catching team and Arrange for travel and accommodation for JCU team With Frank Loban provide safety advice developed with Peter McCulkin TSRA. Develop the extension materials, with the assistance of the LSMU Sea Team, including developing posters, delivering talks to schools, talking on TSIMA radio
Technical Lead JCU (Chris Cleguer)	Work with Ron Fujiias a cultural broker between members of the field team as required Organise production of dermal holdfasts in collaboration with local hunters Store data according to accepted protocols Conduct a half day training course on tag deployment and catching activities prior to the start of catching Assist with the deployment of the transmitters as required Conducting daily briefs and de-briefs with Ron Fujii Coordinate grocery shopping and food preparation Update project Leaders Helene Marsh and Mark Hamann on progress made during the fieldwork Contact Safety officer Susan Sobtzick every day between 1800 and 2000 (see Appendix C) Assist with data analysis Co-author the outputs from the project, together with all the team members that may wish to collaborate

Ron Fujii	Team Leader for TSRA and Rangers while on project Provide direction to Rangers Catch up on needs bases with Tagging Team and JCU Project Manager to ensure project delivery Coordinate safety calls as per SOP Custodian of smart-phones with cameras of JCU team while on Badu Communication between land and boat via satellite phone or VHF Radio. Provide expert advice on timing of the daily field work Organise and provide details of local, registered boats and hunters and ensure that they will be available for the whole duration of the expedition Report back to Susan Sobtzick regarding the availability of registered boats for the trip Assign daily roles – see Appendix B
JCU Catching team (TBA)	Assist with assembling, testing, checking and testing telemetry gear Assist with the deployment of the transmitters Help Technical Lead to organize daily gear Help with food preparation when necessary Assist Technical Lead in controlling fuel and oil usage
Badu Rangers	Assist with catching activities Assist with the preparations of vessels daily Organise community boats and fuel Receive the fuel and JCU gear from the barge and arrange for it to be stored on Badu
Badu Community members and Traditional Owners	Participate in catching activities Provide cultural advice for project team Provide expert hunting advice Communicate any community concerns or questions to JCU and TSRA Team Leaders
Peter MCulkin	Develop safety advice together with Chris and Shane Receive regular daily safety calls as per SOP Aid the communication between rangers, community members, council and researchers
TSRA TBA	Edit and develop a DVD from footages collected during the trip

Vessels

The vessels that will be used for the project include the following:

1. **Urpi Urui**
   LSRV 2
   Sea prowler
   Aluminium vessel with centre console - 6.05 m in length

Powered by twin 90hp Suzuki 4 stroke outboards.
Vessel is exempt from Commonwealth registration.
Owned and operated by TSRA.

All vessels with be operating within the Satellite Tracking Catching Zone (**Figure Two**). Travel within this zone will always be undertaken only with the approval of both Team Leaders and under adequate weather conditions.

Figure 2.

Data Storage and Access

1. The final protocol with by developed with the Mura Badulgal RNTBC.
2. The name of the community will be recorded in outputs from the project.
3. No names, addresses or any other identifying information of individuals will be recorded without permission
4. No photographs/video clips will be taken or used without written permission. Frank Loban has asked that JCU team provide GoPro camera and shoot video and photos for use by TSRA. Participants will be asked for permission before project.
5. Copies of the data from the dugong and turtle tracking and the outputs of the research will be provided to the Torres Strait Regional Authority Land and Sea Management Unit.

Gaining permissions to use the outputs from the research

1. The researchers will not have access to cameras on Badu, even for personal purposes. Smart phones will be left with Ron Fujii.
2. The research outputs from this study may be used as listed below but only after they have been approved by relevant Traditional Owners as facilitated by Mura Badulgal Rangers with the exception of materials for teaching internal to JCU.
3. Culturally–appropriate extension materials will be developed by the JCU Project Manager with assistance from the LSMU Sea Team in accordance with Mura Badulgal Chair RNTBC to return the information obtained during the project to the people of Torres Strait including: website illustrating movements of tracked dugongs and turtles; articles in local paper *Torres News;* interviews with TSRA staff and researchers on Torres Strait radio.
4. Use of findings at presentations at scientific conferences.
5. Inclusion of findings in scientific publications.

Budget and expenses

TSRA will cover the costs associated with the TSRA staff and TSRA vessels. JCU will cover the remaining costs.

We agree to the terms and conditions outlined in this Research Partnership Agreement

Name	Signature	Date
Laurie Nona		
Helene Marsh		24 September 2015
Mark Hamann		
Shaun Barclay		
Frank Loban		
Tristan Simpson		
Dan Nona		
Chris Cleguer		29 August 2015
Shane Preston		24 September 2015
Susan Sobtzick		24 September 2015

Appendix A - Catching technique to be used.

Prior to the dugong catching activities, a briefing will be conducted by Chris Cleguer, Shane Preston and Frank Loban to ensure that all the participants are aware of their roles and the plan for each day's catching activity.

In addition to the mothership, a minimum of three vessels will be used with a hunter and a skipper in each boat to locate dugongs and insert the dermal holdfast. The JCU team and the gear will be located either on the mothership or on one of the three vessels in accordance to TSRA-local islanders' requirements. Either of the vessels can be used to catch turtles because the turtles will be brought back to the island for attachment of the satellite tags.

All the boats are to travel together at all times, have communication via radio and stay within sighting distance.

Dugongs

Two catching techniques will be trialed:

1. **Rodeo technique (shallow water**): As soon as the dugong is within approximately 2m of the vessel, the catchers will use the rodeo technique to restrain and support the dugong or turtle; or
2. **Dermal holdfast technique** (deeper water, dugongs only): Once the dugong is within about 10m of the catching boat, a skilled traditional dugong hunterwill use a traditional wap (harpoon with a detachable head) to insert a sterile dermal holdfast **(with detachable head not able to penetrate deeper than 2cm)** into the blubber of the dorsal surface of the dugong (well away from the midline and from the head). Once the holdfast is deployed, the catching boats are to contact the JCU team so that the dugong can be followed and slowly approached. A traditional hunter in the bow of the catcher boat will gently pull the tracer-line while giving directions to the skipper. Care will be taken, not to pull too heavily on the tracer-line. The line is not used to haul the dugong close to the boat, but to keep track of the animal when it disappears underwater, and enables the boat to follow and approach it. As soon as the dugong is within approximately 2m of the vessel, the catchers will use the rodeo technique to restrain and support the dugong. After the dugong is secured, a local anaesthetic (1% lignocaine) will be injected into the blubber close to the holdfast to minimise discomfort during removal of the device.

   The satellite tag will then be attached to the dugong, while the length and girth of the animal is measured and a DNA sample taken near the site where the holdfast penetrated. If required, the holdfast will then be removed by cutting the binding holding the three spikes together, and then individually pulling each spike out from the blubber with a pair of pliers. The wound will then be flushed with betadine (10% povidone-iodine in water) and the dugong released.

   The total time for which an animal should be held is approximately 10 – 15 minutes.

Green turtles

The rodeo technique will be used to catch turtles (see description above). Once caught, the turtles will be brought back to the island. They will be housed in one of the vessels and kept cool using damp towels. Satellite tags will be glued onto their carapaces in the early evening and the glue left overnight to dry. Turtles will be released from the island the next morning.

Rodeo Technique SOP

This method has been successfully used since 1987 and is now the preferred method to capture dugongs safely, efficiently and simply.

Catch team: Team will comprise of one primary jumper who will jump and secure a tail rope around the peduncle of the dugong (The rope will have a buoy secured to the end to allow visual contact to be maintained in the event the rope is let go from the vessel). This role will be shared between Chris Cleguer and Shane Preston who are experienced in this method. Any of the experienced hunters are also able to complete this task as they employ the same method in their traditional hunting. This role has the highest potential to cause injury and as such will only be attempted by the aforementioned personnel. To minimise risk, a wetsuit, boots and helmet will be worn by all of the catch team. The dugong will also be allowed to 'run' for 2-4 breaths in order to sufficiently fatigue the animal to allow for easier handling. This generally results in a more successful and safe capture to dugong and catch team. In the event that a dugong is not captured after 10 minutes of pursuit then the chase shall be abandoned.

Secondary jumpers: Any participant who is comfortable in the water and a strong swimmer will be allowed in this role, subject to participating in the trial capture at the start of the trip. Wetsuit/stinger protection, boots and helmet must be worn at all times.

A minimum of four jumpers will be needed to help secure the dugong alongside the vessel. They will be in the ranger support vessel and will follow closely behind the primary catch vessel. As soon as

the primary jumper has secured a tail rope around the dugong, the support vessel needs to quickly place the catch team in close proximity to the dugong. This shall be conducted in a safe and controlled manner by an experienced boat captain. Jumpers do not enter the water until the captain has given the command.

Once in the water, jumpers will secure the pectoral fins from in front of the dugong and attempt to stop the dugong from diving or rolling. Great care must be taken to keep the dugong's head above water so it can breathe. Once the dugong has been brought under control, all jumpers will help move the dugong alongside the vessel, remaining on the outside, not between the dugong and the vessel.

Lookouts: vessels not involved in the capture will remain in motion circling the area. During a pursuit, they should also remain a safe distance from pursuit vessel, keeping in mind the erratic behaviour of a chased dugong.

Appendix B – Daily role for each participant, some of the roles will rotate and will be decided at the debriefing conducted every day after catching activity. This table will be completed after the Research Team arrives on the Island.

Role	Personnel in charge
Catching gear organization (boats, fuel, safety gear, harpoon heads, harpoons, radios, etc)	
Tagging gear organization (PTT, VHF radio, GPS, charge batteries)	JCU team
Daily briefing and debriefing	
Daily safety calls	
Boat 1	
Skipper – re-fuel boat for next day, make sure safety gear is in-order	
Harpooner	
Medical officer and safety adviser	
Boat 2	
Skipper – re-fuel boat for next day, make sure safety gear is in-order	
Jumper 1- Hold dugong	Chris-Shane
Jumper 2- Hold dugong / deploy the tag	Chris-Shane
Harpooner	
Boat 3 JCU	
Skipper – re-fuel boat for next day, make sure safety gear is in-order	
Jumper 3- hold the dugong – in charge of dugong's health	Takahiro
Data recorder- measure	TBD
Medical officer and safety adviser	

Appendix C- Daily Standard Operating Procedures

DUGONG and TURTLE TRACKING PROJECT

(subject to approval of Mura Badulgal RNTBC Laurie Nona)

Task

To improve historical estimates of abundance and distribution of dugongs and large green turtles in western and central Torres Strait by tagging up to 10 adult dugongs and 10 green turtles with GPS satellite transmitters and Minipat tags.

Participants and catchers from JCU will reside on Badu Island for the duration of the project. Dugong catching will occur as directed by the nominated Traditional Hunter, including the best time and location for catching. .

The Rangers and selected community members (led by the nominated Traditional Hunter) will assist with dugong catching for the duration of the project.

The following protocols will be observed during the project:
1) Catching will use the rodeo technique or the dermal holdfast technique only as described in Appendix A;
2) Catching will be conducted only at agreed times and only between first light and 6pm and when the wind is < 25 knots,
3) Female researchers will not enter the catch boat or the water with the dugong,
4) field participants, while hired and conducting the project, will not collect material from the Torres Strait marine environment apart from finfish if time permits, and
5) No dugongs or turtles are to be kept or caught, by project participants on research vessels, for other than scientific purposes during the project.

Permits and cultural protocols

The project will be conducted in accordance with the conditions stipulated in the Indigenous and Animal Ethics Approvals from JCU, permits from QPWS, SEWPaC and research Partnership Agreement described above.

To ensure that cultural protocols are observed a community meeting will be conducted (7th October) prior to the catching activities as well as a half day induction by Frank Loban and Chris Cleguer

Proposed outcomes

Torres Strait Islanders, including traditional owners from the community of Badu will be engaged in western scientific activities by being involved in the dugong capture, transmitter deployment and training sessions on western science techniques. Participants will learn practical research skills, basic dugong biology and ecology as well as record keeping, which will build their capacity to manage dugong stocks.

The research results will be communicated to the Torres Strait community via culturally appropriate extension materials as approved by the Mura Badulgal RNTBC including website, which will illustrate movements of tracked dugongs; articles in local papers (Torres News); interviews with TSRA staff and researchers on Torres Strait radio and talks to schools in Badu and Thursday Island. All of the outputs from this project (with the exception of materials for the teaching internal to JCU) will need to be approved by the Traditional Owners (Mura Badulgal RNTBC) as facilitated by the Badu Rangers.

Activities during the project will be documented using equipment supplied and operated by TSRA. No photographs will be taken or used without written permission of Mura Badulgal RNTBC.

Travel

- Badu 7/10/15- 30/10/15 (except weekends)
- Participants will be undertaking travel from Badu from Wednesday day 07/10/2012 through to 30/10/12 or until 10 dugongs and 10 green turtles are successfully tagged, except on weekends. The exception to this rule is when advised that a culturally sensitive situation has arisen (e.g. a death in the community), or a serious mishap occurs to any participant in the exercise.
- This travel will be done in a convoy of at least 4 vessels (3 local vessels and a mother vessel).
- Dugong catching will only be undertaken when the weather permits based on a decision made by the JCU and TSRA Team Leaders. Daily survey zones will be identified by participants. All dinghies will travel together to these areas, maintaining line of sight and radio contact every hour. All vessels will be operated by suitably qualified drivers. All boat will have all the necessary safety gear.

DAILY STANDARD OPERATING PROCEDURES

CONTACT

TSRA ARRANGEMENTS

Morning between 0800hrs to 0900hrs:
Badu Team Leader (Frank Loban) to contact Peter McCulkin to give an update of program, well-being checks of participants and report any incidents. Who is responsible for end of day Sit Rep? Overdue vessel procedures?

If Peter McCulkin unable to receive the call the alternate contact will be notified as per the LSMU Operations Order. The call should be logged: date, time, person who called, location, all OK

If the TSRA staff do not hear from Frank within the time allocated, then:

Peter McCulkin is to make contact with Frank Loban via TSRA satellite phone (TBA); or if that fails contact JCU satellite phone 0404 099 120. If this fails, Peter will attempt to contact the team, via the TSRA or JCU satellite phone, between the hours of 1800 to 1900. If this fails Peter should contact the Louise Taylor Manager of the RNTBC at Badu Island (074069…..) and if necessary contact the water police and establish an emergency response. Louise is the local land-based contact who is informed of daily operating procedures and aware of vessel return times. If boats do not return, she should be contacting Peter McCulkin as a front line point of action.

JCU ARRANGEMENTS

Chris Cleguer to make contact with Susan Sobtzick between 1800 and 2000. Susan is to log the call as per details above and this information should be available to others in the need of a response should Susan not be available. If Susan should not be available to take the call, she should allocate another responsible person. Should the contact phone number change to contact this person, the field team should be made aware of this change.

Overdue procedures?

Following morning: 0800- 1000 contact is made as per previous agreement if possible.

If no contact is made or after 1100 Susan Sobtzick will establish contact with Peter McCulkin.

1. BRIEFS and DEBRIEFS

Briefs will occur every day prior to catching activities to ensure that all the gear is ready and that all participants are aware of their roles and the daily activity planned.

Debriefing will occur every day after catching activities is finalised. Any issue from the day's catching will be discussed. The role of each participant for the next day will be determined during debriefing. Chris, Frank and XXX are to run the briefs and debriefings.

2. EMERGENCY NUMBERS

1. Land and Sea Management Unit – 0740690700
2. Shaun Barclay – (07) 4069 0809
3. Peter McCulkin- (07) 4069 0700, 0437 498 238
4. Tristian Simpson -40690872, 0448051 065
5. Helene Marsh – 0409872377
6. Mark Hamann - 0415298238
7. Susan Sobtzick 0403921873
8. Louise Taylor 07
9. Community Council – 07 4069
10. State Emergency Services (TBA) – through Badu Council - 074069
11. Emergency – 000
12. Volunteer Marine Rescue (TI / St Paul) – 0428 692 004
13. Frank Loban mobile – 0447178795
14. Shane Preston – 0424 556 553
15. Chris Cleguer - 0413473251
16. TSRA Satellite Phone – TBA
17. JCU Satellite Phone 0404 099 120

COMMUNICATIONS

Two satellite phones will be available for the period of the project; one will be with ……..on land and the other with Chris Cleguer during catching activities.

VHF radios – between ship and shore

Appendix D- Itinerary for dugong tracking project at Badu

ITINERARY Badu DUGONG TRACKING

Monday 6th Oct 2015

- All project participants to fly in on Charter plans or travel by vessel into Badu
- Group to go over SOP and daily safety checks, purchase relevant food stores for dinners and lunches on field days.

Tuesday 7th to Friday 30th Oct 2015 (or until 10 dugongs and 10 turtles are tagged) – Except Weekends

- Dugong and turtle catching will take place when weather permits
- Group to prepare dinghies for travel to dugong catching zone.
- Dinghies fueled up and packed with equipment.
- Group to go over final briefing, to be led by …….
- Catching group (CG) to travel to dugong catching zone at an agreed time in one trip in convoy
- All vessels to stay within line of sight and undertake radio contact on the hour. Team leader to ensure radio contact occurs.
- CG to negotiate time and place to meet to satellite tag, measure, and collect DNA samples from dugong as agreed with Traditional Owners.
- CG to return to Badu at time nominated.
- CG to do de-brief on dugong catching that day and brief for the following days.
- Briefing and preparations for dugong catching the following day
- CG team rests for the night.

Upon completion of project

- Group to prepare dinghies for travel or transport back to their destinations
- Final debrief of project
- JCU staff to leave Badu upon their flights

*** The best time and location for catching activity will be determined by …….. A decision not to go out will rest with the JCU and TSRA Team Leaders.**

Appendix E- Risk Assessment

Description of hazard	Description of risk	Likelihood	Risk Level	Risk Control measures
In boat (not catching)	Sunburn	Unlikely	Medium	Apply high SPF sunscreen (preferably water resistant) to exposed skin when working outdoors. Wear a hat and long clothing.
	Dehydration	Unlikely	Medium	Carry sufficient water and drink as much as appropriate for the environmental conditions (more in hot weather)
	Heat stress	Unlikely	Medium	Wear a hat when working in the sun. Work in the shade when possible. Drink enough water. Rest and cool off if likely to become heat stressed.
	Injured back from lifting	Unlikely	Medium	Apply safe lifting techniques (e.g. use legs not just back)
	Drowning	Highly unlikely	High	Carry life vests in boat. If not a strong swimmer, wear life vest at all times. Maintain awareness of current activities.
In Boat (catching)	Jelly fish stings	Unlikely	High	10 L of vinegar and compression bandages will be carried aboard all boats. Skipper will hold First Aid gear and stinger protection will be used.
	Bruising	Highly unlikely	medium	Safety gear will be used at all time (head guard, diving boots). Wetsuit will be used and padded head gear (Rugby helmet) will be used for protection.
	Boat strike	Highly unlikely	High	Both skipper and catcher will be experienced, a similar method has been used for many years to catch dugongs (see attached JSA at the end of this document). Safety gear will be used by all the jumpers (head guard, diving bots and wetsuit).

	Heat stress	Unlikely	Medium	Full protection from the sun will be worn, adequate fresh water will be on board and the duration of the catching trip will not extend beyond normal working hours
	Sun burn	Unlikely	Medium	Full protection from the sun will be worn, adequate fresh water will be on board and the duration of the catching trip will not extend beyond normal working hours
	Dehydration	Unlikely	Medium	Full protection from the sun will be worn, adequate fresh water will be on board and the duration of the catching trip will not extend normal working hours
Processing animals	Injured back from lifting	Unlikely	Medium	Apply safe lifting techniques (e.g. use legs not just back).
	Sunburn	Unlikely	Medium	Apply high SPF sunscreen (preferably water resistant) to exposed skin when working outdoors.
	Bruising from dugong	Unlikely	Medium	Handle animals with care and using appropriate techniques.
	Shark attack	Unlikely	High	Boats will have engines on at all time and skippers will keep an eye out to warn catchers if a shark is sighted Jumpers will be comfortable in the water and have good swimming ability to potentially escape and swim away from a shark.

Job Safety Assessment

Task:	**Dugong and turtle catching using rodeo method**	
Required Personal Protective Equipment (PPE):		
Wetsuit, padded rugby helmet, mouth guard, gloves		
Required/Recommended Trainings:		
Experience with previous dugong and turtle tagging projects		
TASK	**HAZARDS**	**CONTROLS**
Entering the water	slipping, tripping, falling, drowning, spraining, cuts	PPE, briefing before project start about safe methods of entering the water, strong swimming skills, only enter the water after OK'ed by vessel driver, experienced personnel
Restraining animals	Impact with animals – injury to person and/or animal	Drill of dugong tagging conducted at start of the survey, PPE, vessel kept close, person in water is always monitored by remaining personnel on vessel, experienced personnel
Immobilising animal (dugongs)	Strains, impacts with animal; injury to animal	Briefing at the start of the survey on how best to restrain dugongs (depending on the vessel used), always at least two people in the water, PPE, using ropes to restrain animal, using pool noodles to keep dugong head above water, people remaining on board to monitor animal, experienced personnel
Retrieving animals (turtles)	Strains, impacts with animal; injury to animal	Briefing at the start of the survey on how best to lift turtles into vessel (depending on the vessel used), using safe lifting techniques, PPE, people remaining in boat to assist with lift, securing turtles once on board, experienced personnel
Attaching tags (dugongs)	Injury to personnel from moving dugong, injury to animal	Briefing at the start of the survey on how to attach tags, clear tasks outlined for each person, experienced personnel, dugong secured with ropes
Being in water	Dangerous marine organisms (e.g. stingers, sharks)	PPE, clear communication between in-water and on-vessel personnel, people in water always monitored by vessel skipper, good swimming ability
Being in water	Boat strike	Experienced personnel, vessel skipper to always keep visual on people in water, keep safe distance while location of swimmer is unclear (e.g. when briefly submerged), clear communication

6.2 Appendix II

Figure A1: Frequency distribution of the Argos (Class 3, 2, 1) and GPS (Succeeded, Resolved QFP, Unresolved QFP) location points obtained from the testing phase of the four tags (635862A, 652609A, 638702A, 659774A) that failed to transmit data after they were deployed on dugongs captured in Torres Strait in October 2015.

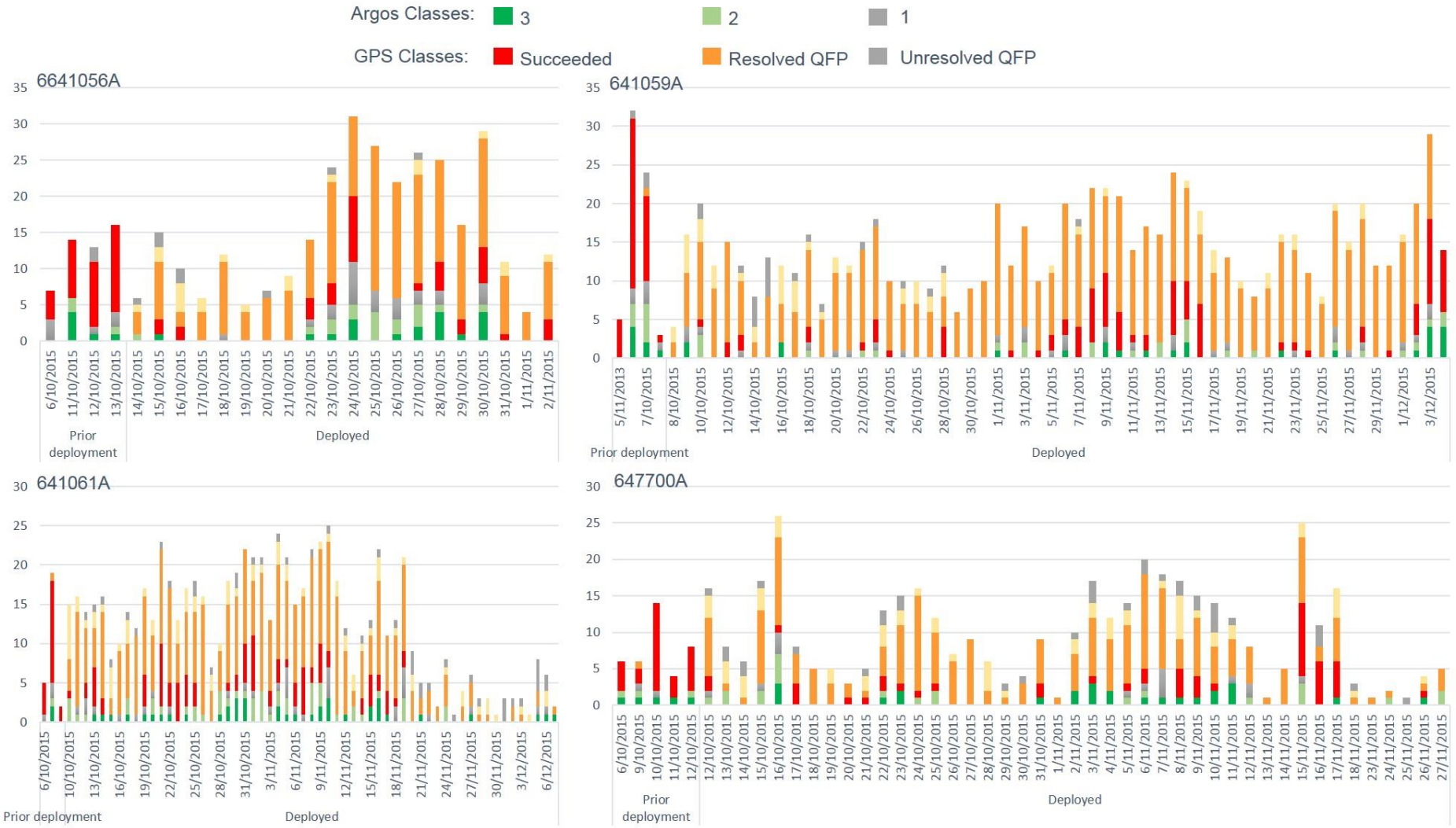


Figure A2: Frequency distribution of the Argos (Class 3, 2, 1) and GPS (Succeeded, Resolved QFP, Unresolved QFP) location points obtained from satellite tags 6641056A, 641059A, 641061A, 647700A prior to and during the tracking of dugongs captured in Torres Strait in October 2015.

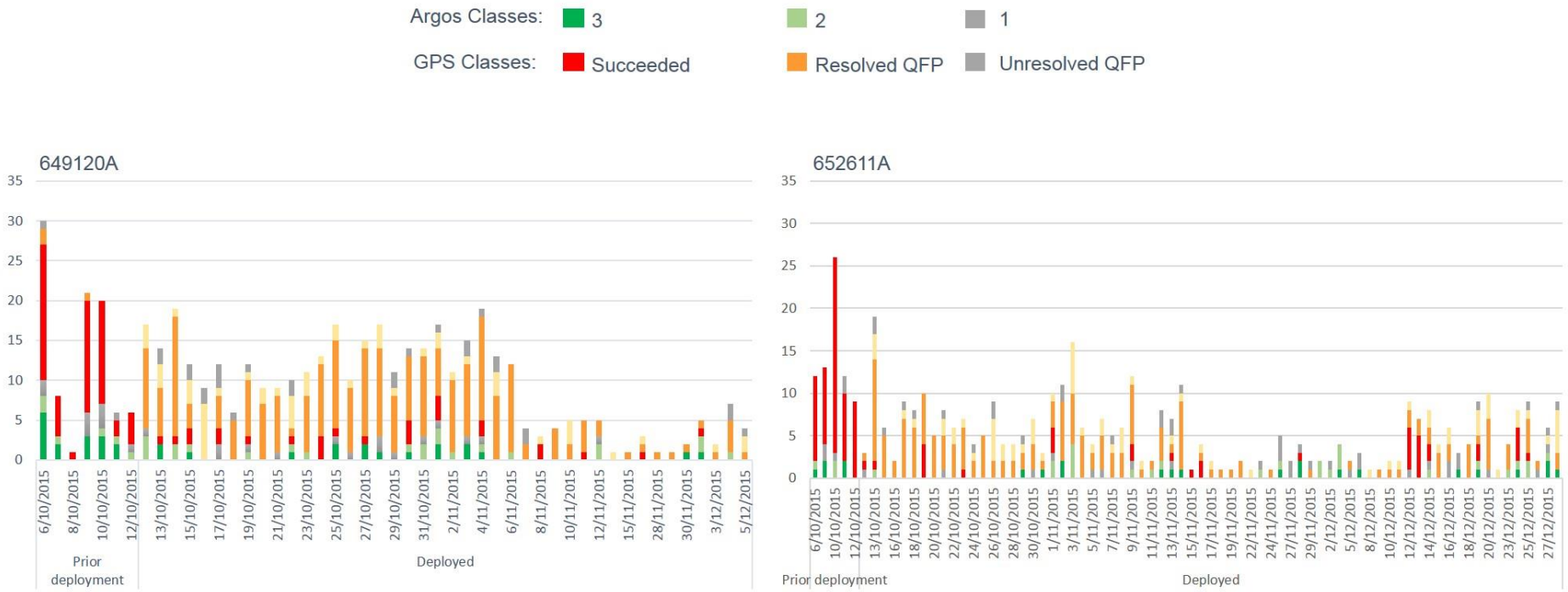


Figure A3: Frequency distribution of the Argos (Class 3, 2, 1) and GPS (Succeeded, Resolved QFP, Unresolved QFP) location points obtained from satellite tags 649120A, 652611A prior and during the tracking of dugongs captured in Torres Strait in 2015.

Table A1: Mean number of Argos (Class 3, 2, 1) and GPS (Succeeded, Resolved QFP, Unresolved QFP) location points obtained prior and during the tracking of dugongs in Torres Strait in 2015.

Tag	Tag status	Mean number of location point transmitted (±SD)						
		3	**2**	**1**	**Succeeded**	**Resolved QFP**	**Resolved QFP (Uncertain)**	**Unresolved QFP**
635862A	Prior deployment	1.4 (1.6)	0.8 (0.9)	1.1 (1.2)	16.4 (10.9)	0.3 (0.5)	0 (0.5)	0.3 (0.5)
659774A	Prior deployment	4.5 (4.9)	1 (1.4)	0 (0.7)	11 (12.7)	0 (0)	0 (0)	0 (0)
652609A	Prior deployment	1.3 (0.6)	0.3 (0.6)	0 (3.5)	6.7 (4)	0 (0)	0 (0)	0 (0)
638702A	Prior deployment	2.4 (1.7)	1.2 (1.1)	1.6 (0.9)	10 (6)	0.6 (0.9)	0 (0)	0 (0)
641056A	Prior deployment	1.5 (1.7)	0.8 (1)	1.5 (1.3)	8.3 (3.3)	0 (0)	0 (0)	0 (1)
	Deployed	0.9 (1.3)	0.9 (1.2)	1.2 (1.6)	1.8 (2.3)	9.5 (5.1)	1 (1.1)	0.4 (0.7)
641059A	Prior deployment	1.8 (1.7)	2 (2.4)	1.5 (1.3)	9.8 (9.1)	0.3 (0.5)	0 (0)	0.8 (1)
	Deployed	0.4 (0.9)	0.4 (0.8)	0.5 (0.7)	1.7 (2.5)	9.9 (3.5)	1.1 (1.3)	0.4 (0.9)
641061A	Prior deployment	1 (0)	0.6 (0.5)	0.4 (0.5)	5.4 (4)	0.2 (0.4)	0 (0)	0 (0)
	Deployed	0.6 (0.9)	0.5 (0.9)	0.3 (0.8)	1.1 (2)	5 (3.6)	1.4 (1.5)	0.8 (1)
647700A	Prior deployment	0.7 (1.2)	0.3 (0.6)	1 (1)	6.3 (5.9)	0.3 (0.6)	0 (0)	0 (0)
	Deployed	0.7 (0.9)	0.8 (1.1)	0.6 (1)	1.5 (2.1)	6.7 (4.5)	1.3 (1.3)	0.8 (0.9)
649120A	Prior deployment	2.3 (2.1)	0.9 (0.7)	1.3 (1.4)	8 (6.5)	0.4 (0.8)	0 (0)	0.3 (0.5)
	Deployed	0.4 (0.7)	0.5 (0.8)	0.4 (0.6)	0.6 (0.9)	5.5 (4.1)	1.3 (1.5)	0.6 (0.9)
652611A	Prior deployment	1 (1)	0.6 (0.9)	0.6 (0.9)	11.8 (6.3)	0 (0)	0 (0)	0.4 (0.9)
	Deployed	0.3 (0.5)	0.4 (0.8)	0.2 (0.5)	0.5 (1.2)	2.5 (2.4)	1 (1.3)	0.5 (0.8)

6.3 Appendix III

Table A2: Distance between the location fixes of the six dugongs and five non-migrating green turtles and their respective capture location in Torres Strait in 2015-2016.

Individual ID	Distance from capture location (km)		
	min	max	mean (± SD)
D2	0.6	43.0	22.3 (5.7)
D4	0.5	31.6	11.5 (6.3)
D5	0.8	54.7	17.7 (11.2)
D6	0.5	112.9	29.3 (34.1)
D7	1.7	38.5	17.9 (7.7)
D9	2.3	50.9	18.1 (9.9)
T1	2.7	22.2	11.5 (5.5)
T3	0.0	18.2	2.1 (3.8)
T4	0.1	66.1	13.6 (16.9)
T6	0.2	31.3	4.2 (6.9)
T7	0.0	19.5	2.0 (2.0)

Table A3: Distance between the location fixes of the six dugongs and five non-migrating green turtles and any land in Torres Strait in 2015-2016.

Individual ID	Distance to any land (km)		
	min	max	mean (± SD)
D2	0.9	15.4	5.5 (1.9)
D4	0.1	17.2	3.4 (3.1)
D5	0.5	14.9	4.2 (2.6)
D6	0.1	16.1	3.6 (3.6)
D7	0.2	19.5	4.9 (3.8)
D9	0.1	38.6	6.6 (7.9)
T1	0.2	5.4	2.8 (1.0)
T3	0.0	4.3	3.4 (0.9)
T4	0.1	35.6	7.6 (8.3)
T6	0.2	21.1	3.1 (2.3)
T7	0.1	4.8	3.2 (0.6)

6.4 Appendix IV

Table A4: Nesting history of green turtles tracked from Torres Strait in 2015-2016.

Dates turtle recorded on Raine Island	Activity
	Turtle T2
11 November	Likely clutch number 1
4 and 6 December	Likely no lay on 4th and 3rd clutch on 6th
16 and 17 December	Likely no lay on 16th and 4rd clutch on 17th
27 and 28 December	Likely no lay on 27th and 5rd clutch on 28th
8 January	Likely clutch number 6
28, 29 and 30 January	Likely no lay on 28&29th and 7th clutch on 30th
9 February	Likely clutch number 8
	Turtle T8
30 October to 25 December	The turtle was in waters to the west of Raine Island, it was not possible to determine if she came ashore on any of the small rubble banks.
25 December	Recorded on the beach at Raine Island – likely clutch 1
26 January	Recorded on the beach at Raine Island – likely clutch 3
9 February	Recorded on the beach at Raine Island – likely clutch 4

6.5 Appendix V

Table A5: Details on the 95% home range and 50% core area sizes of and use of the Dugong Sanctuary and areas where hunting is likely to occur by the six dugongs and five non-migrating green turtles tracked in Torres Strait in 2015-2016.

Individual ID	95% home-range size (km^2)	50% core area size (km^2)	Area of overlap with take areas (km^2)		Area of overlap with Dugong Sanctuary (km^2)	
			95% home range	50% core area	95% home range	50% core area
D2	497.5	60.0	307.5	54.6	0.0	0.0
D4	354.0	43.5	332.1	41.0	91.7	2.3
D5	258.5	37.3	243.7	35.2	26.3	0.0
D6	928.7	99.0	680.9	76.1	0.0	0.0
D7	408.9	88.9	362.4	82.5	119.2	21.2
D9	732.6	130.3	603.0	122.6	299.5	34.0
T1	96.6	14.5	96.6	14.5	0.0	0.0
T4	752.5	36.2	545.3	28.8	0.0	0.0
T7	29.6	5.4	29.6	5.4	0.0	0.0
T3	11.4	1.4	11.4	1.4	0.0	0.0
T6	75.7	6.1	75.7	6.1	0.0	0.0

6.6 Appendix VI

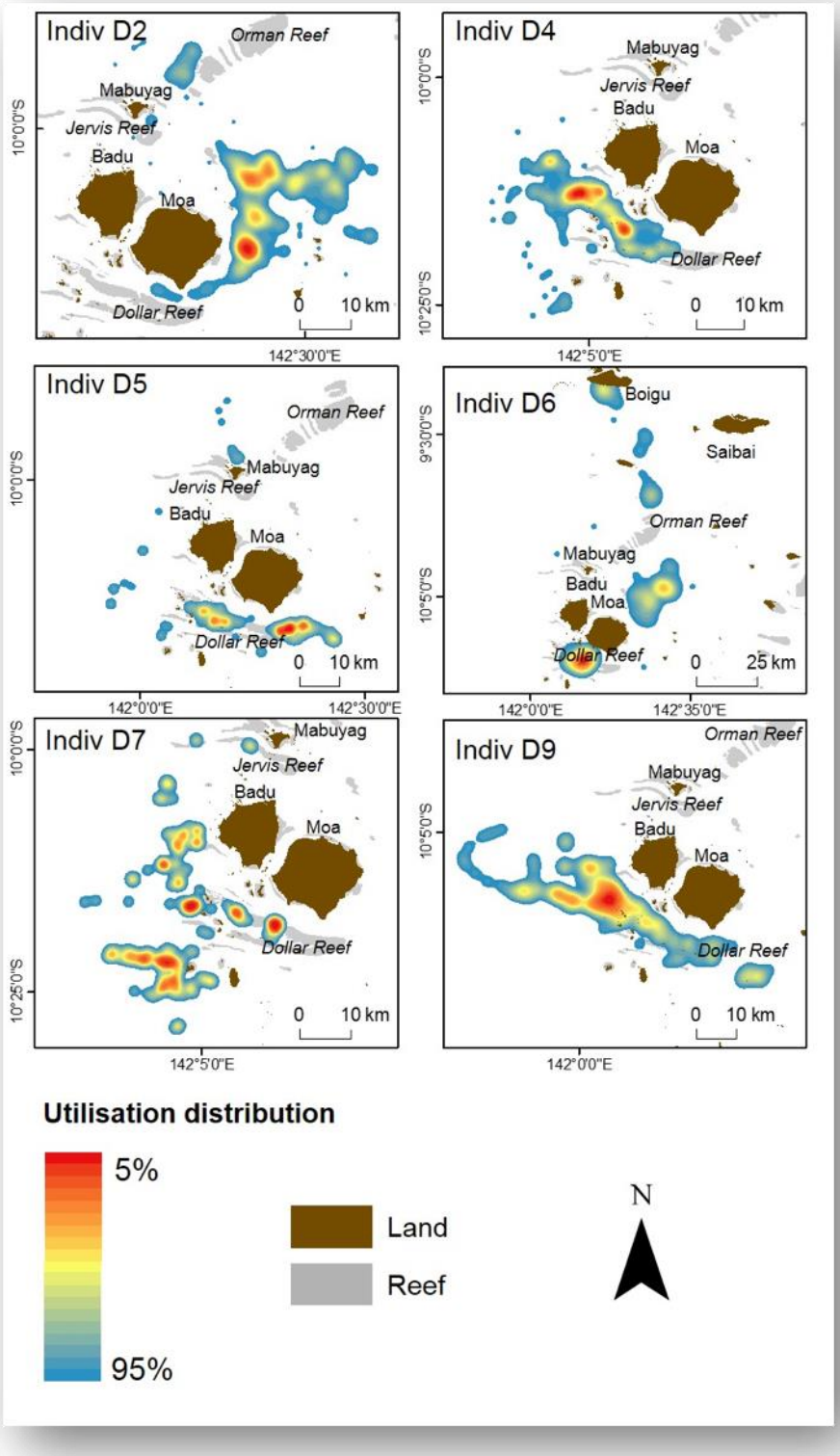


Figure A4: Utilisation distribution (UD) of each dugong caught in Torres Strait in October 2015. Density ranged from high (red) to low (blue).

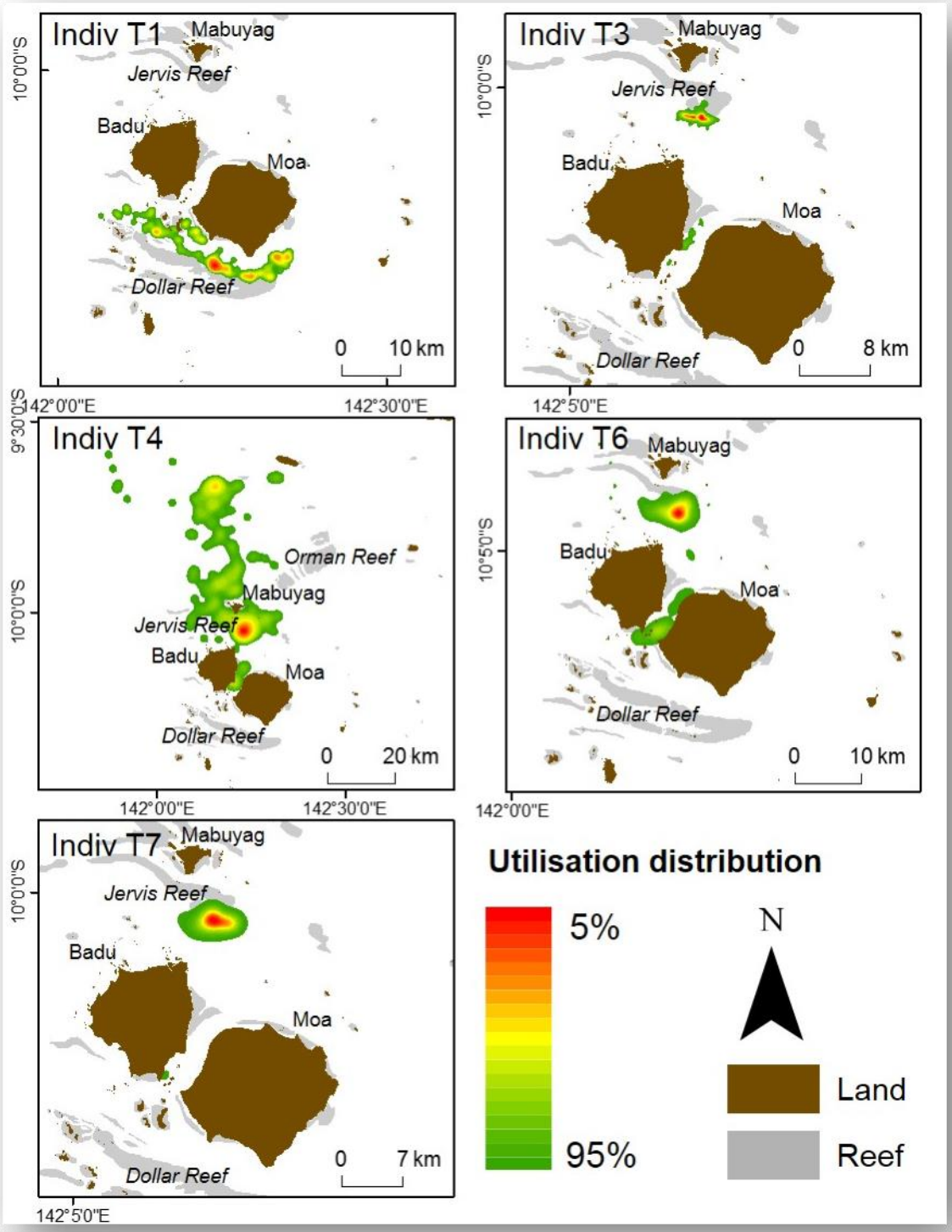


Figure A5: Utilisation distribution (UD) each non-migrating green turtle caught in Torres Strait in October 2015. Density ranged from high (red) to low (green).

Reef & Rainforest
RESEARCH CENTRE

www.nesptropical.edu.au