

**LOGGERHEAD TURTLE, *Caretta caretta*
K33061**

**46 YR OLD TURTLE: ORIGINALLY TAGGED AS A HATCHLING
IN FEBRUARY 1975**



PREMIERE
IS
BACK
AT
MON REPOS



**OUR 1ST TURTLE TAGGED AS A HATCHLING
THAT RETURNED AS A BREEDING ADULT**

PREMIERE'S HISTORY:

LOGGERHEAD TURTLE, *Caretta caretta*
K33061

TAGGED AS A HATCHLING: FEB 1975

COMMENCED BREEDING: 24 NOV 2003 – 29 YR OLD

21 NOV 2020 BREEDING STATUS: 46 YR OLD

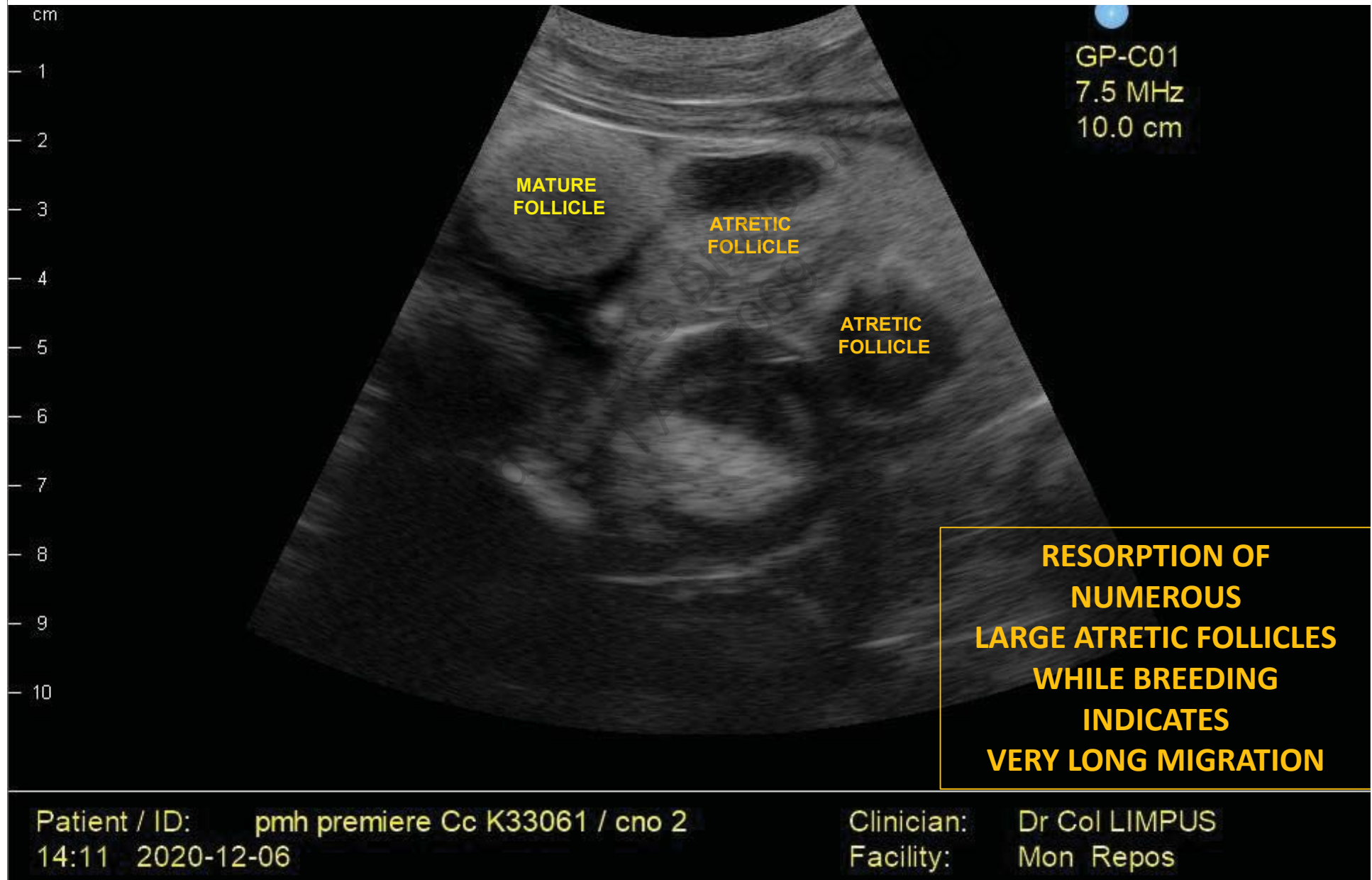
- **5TH BREEDING SEASON**
- **18 YEARS AS BREEDING ADULT**



Season	Beach	Breeding season	CCL (cm)	Clutches per year	Remigration interval (Yr)
1974-75	MR	HATCHED	-	-	-
2003-04	MR x5 OK x1	1 st	96.5	4	-
2004: TRACKED TO FORAGING –NTH GBR HOWICK REEFS					
2010-11	MR x4	3 rd	97.4	3	3
2013-14	MR x5 OK x1	4 th	97.5	3	3
2020-21	MR x?	5 th	98.0	3	7
2020: TRACKED TO FORAGING –will she change her home?					

K33061: LOGGERHEAD TURTLE, *Caretta caretta*

7 Dec 2020: ULTRASOUND SCAN AFTER LAYING 2nd CLUTCH FOR SEASON



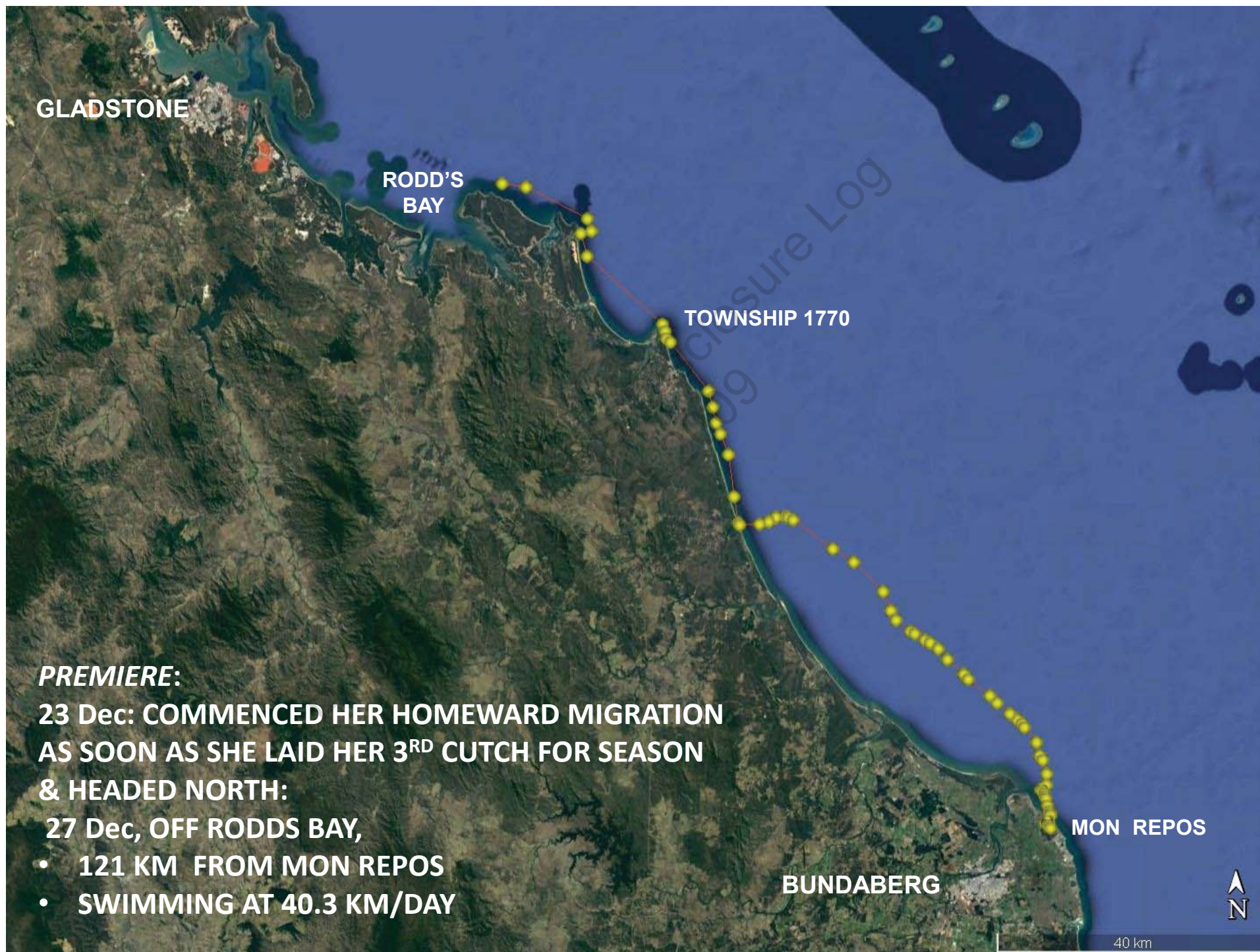
K33061: LOGGERHEAD TURTLE, *Caretta caretta*

46 YR OLD TURTLE: TAGGED AS A HATCHLING, FEBRUARY 1975

**TRACKING BY SATELLITE TELEMETRY
TO IDENTIFY MIGRATION PATH & HOME FORAGING AREA**



**GPS SATELLITE TAG: PTT 197239
WILDLIFE COMPUTERS: SLASH10-BF-385
DEPLOYED ON TURTLE: 23 December 2020**



LOGGERHEAD TURTLE, *Caretta caretta*
K36230

**45 YR OLD TURTLE: ORIGINALLY TAGGED AS A HATCHLING
IN FEBRUARY 1975**



LOGGERHEAD TURTLE,
Caretta caretta
K36230

CTPI 49-Sch

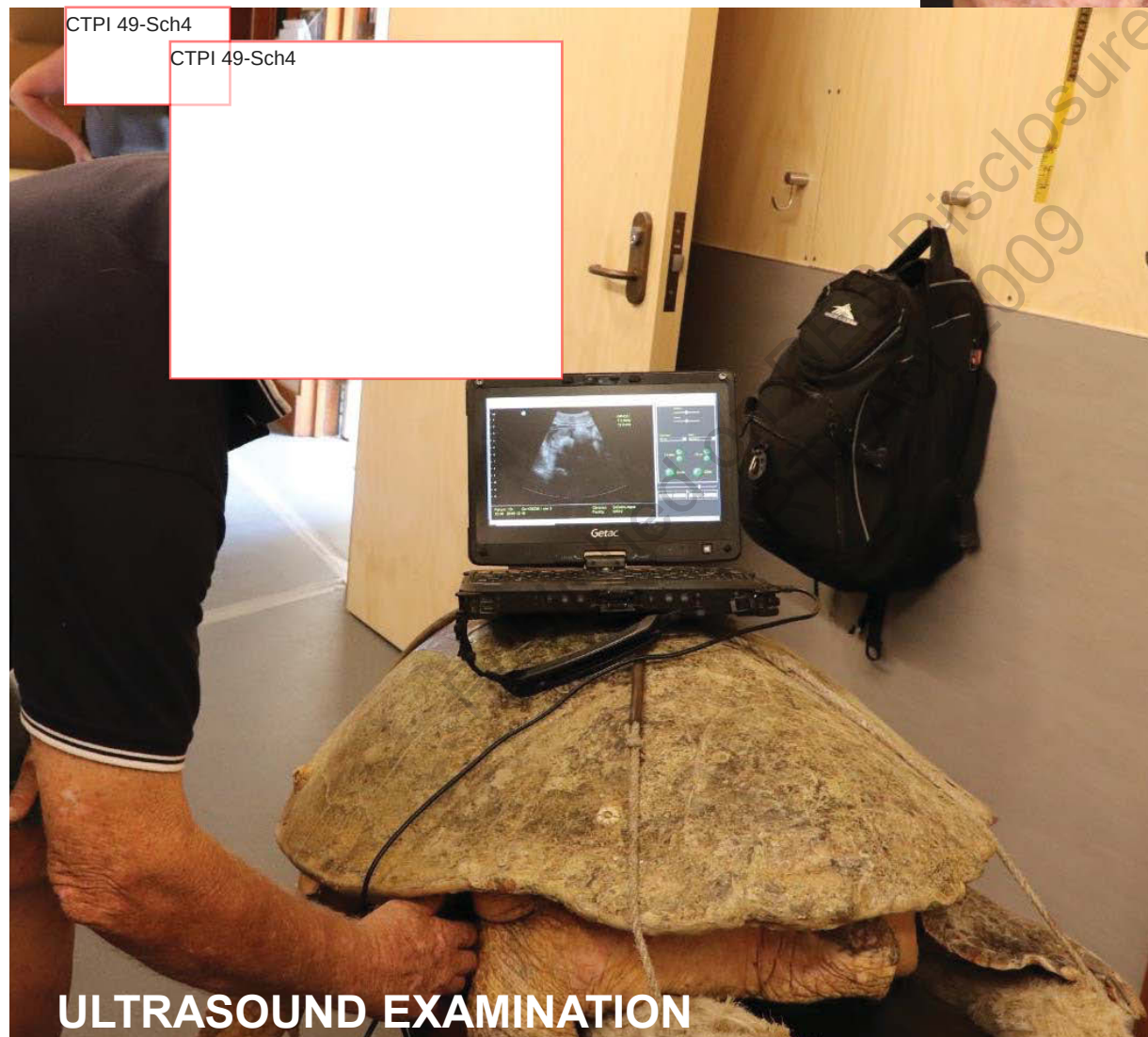
TAGGED AS A HATCHLING: FEB 1975
COMMENCED BREEDING: 12 DEC 2000

CURRENT BREEDING STATUS:

- 19 YEARS AS A BREEDER
- 8TH BREEDING SEASON

Season	Beach	Breeding season	CCL (cm)	Clutches per year	Remigration interval (Yr)
1974/75	MR	HATCHED	-	-	-
2000/01	MR x2 KM x1	1 st	94.1	3	-
2002/03	MR x2 KM x1	2 nd	95.4	-	2
2006/07	MR x1 OK x1	3 rd	97.2	2	4
2009/10	OK x1 KM x3	4 th	-	-	2
2011/12	MR x1 KM x1	5 th	-	-	2
2013/14	NP x2	6 th	97.5	-	2
2018/19	NP x2	7 th	97.5	3	5
2019/20	NP x2	8 th	97.5	4	1

LOGGERHEAD K36230 PREPARATION FOR TRACKING



LOGGERHEAD TURTLE, *Caretta caretta*
K36230

SATELLITE TELEMETRY 2019-2020: PTT 44847
• **Wildlife Computers SPLASH10-F-334A GPS tag**

INTER-NESTING HABITAT

18 Dec – 14 Jan:
Mostly in dredged
channel to Port of
Bundaberg

LOGGERHEAD TURTLE, K36230

18 December:
Released with GPS tag,
MON REPOS

NEILSON PARK

5 December: laid 1st clutch (? eggs)

17 December: laid 2nd clutch (126 eggs)

TAKEN TO MON REPOS TO ATTACH
SATELLITE TAG

NEILSON PARK

30 December: laid 3rd clutch (? eggs)

14 January: laid 4th clutch (113 eggs)

BURNETT RIVER

BARGARA

POST-NESTING MIGRATION

LOGGERHEAD TURTLE,
K36230

14 JANUARY 2019:
COMPLETED HER NESTING SEASON:
COMMENCED HER HOMEWARD
MIGRATION

WOONGARRA
COAST

HERVEY
BAY

MIGRATED 47 KM IN <2 DAYS

16 JANUARY 2020:
COMPLETED HER POST-NESTING
HOMEWARD MIGRATION

BURRUM R

FRASER
ISLAND

SANDY
STRAIT

10 km

HOME FORAGING AREA

LOGGERHEAD TURTLE,
K36230

HOME
FORAGING
AREA

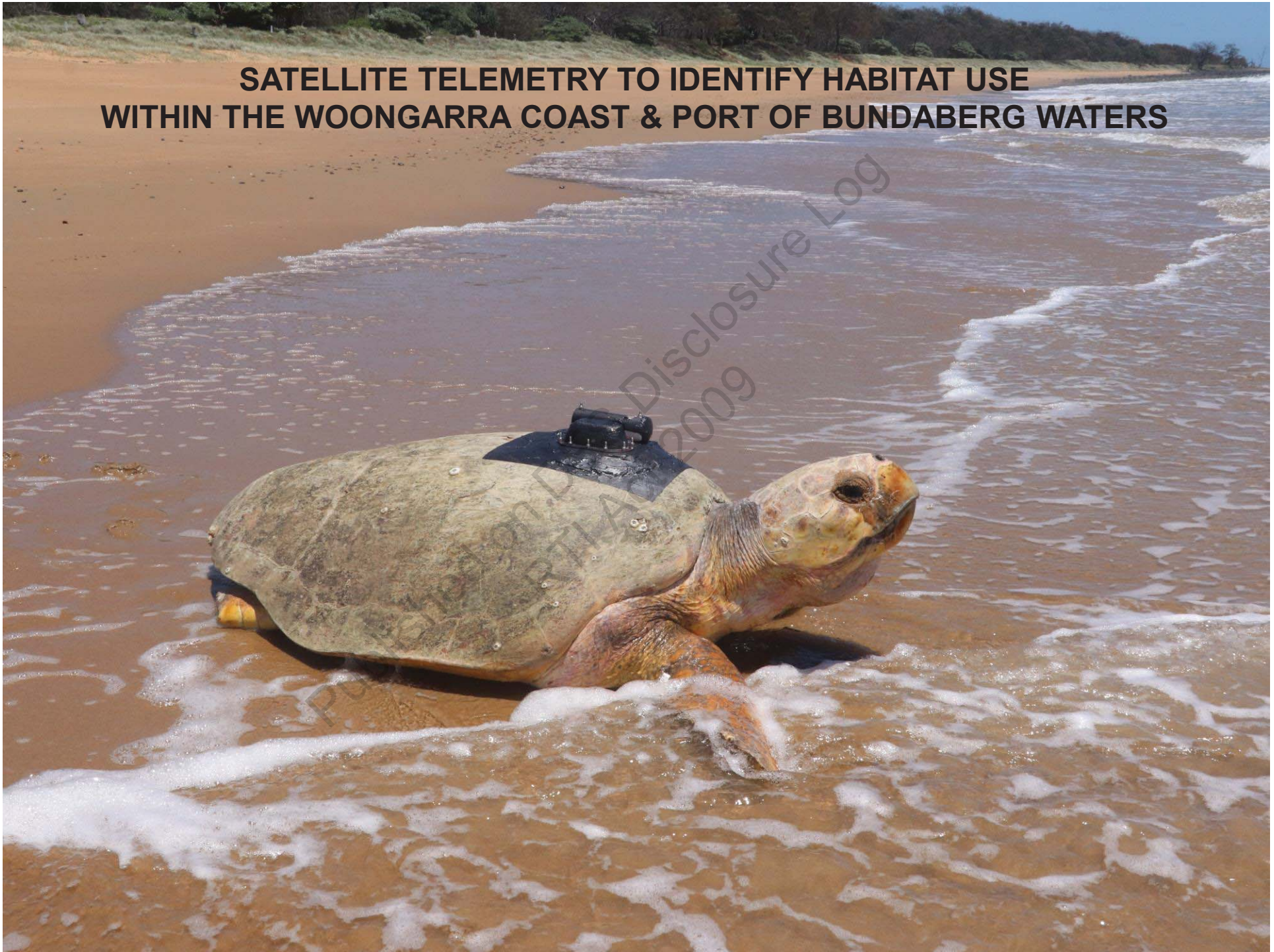
HERVEY
BAY

BURRUM R

FRASER
ISLAND

FORAGING AREA:
CORE: 0.2 KM ACROSS;
REGULAR SHORT TRIPS
INTO
ADJACENT AREAS

**SATELLITE TELEMETRY TO IDENTIFY HABITAT USE
WITHIN THE WOONGARRA COAST & PORT OF BUNDABERG WATERS**



11 December 2021: Tour Group 3 with K97919 LAYING EGGS

CTPI 49-

CTPI 49-Sch4

CTPI 49-Sch4

CTPI 49-S

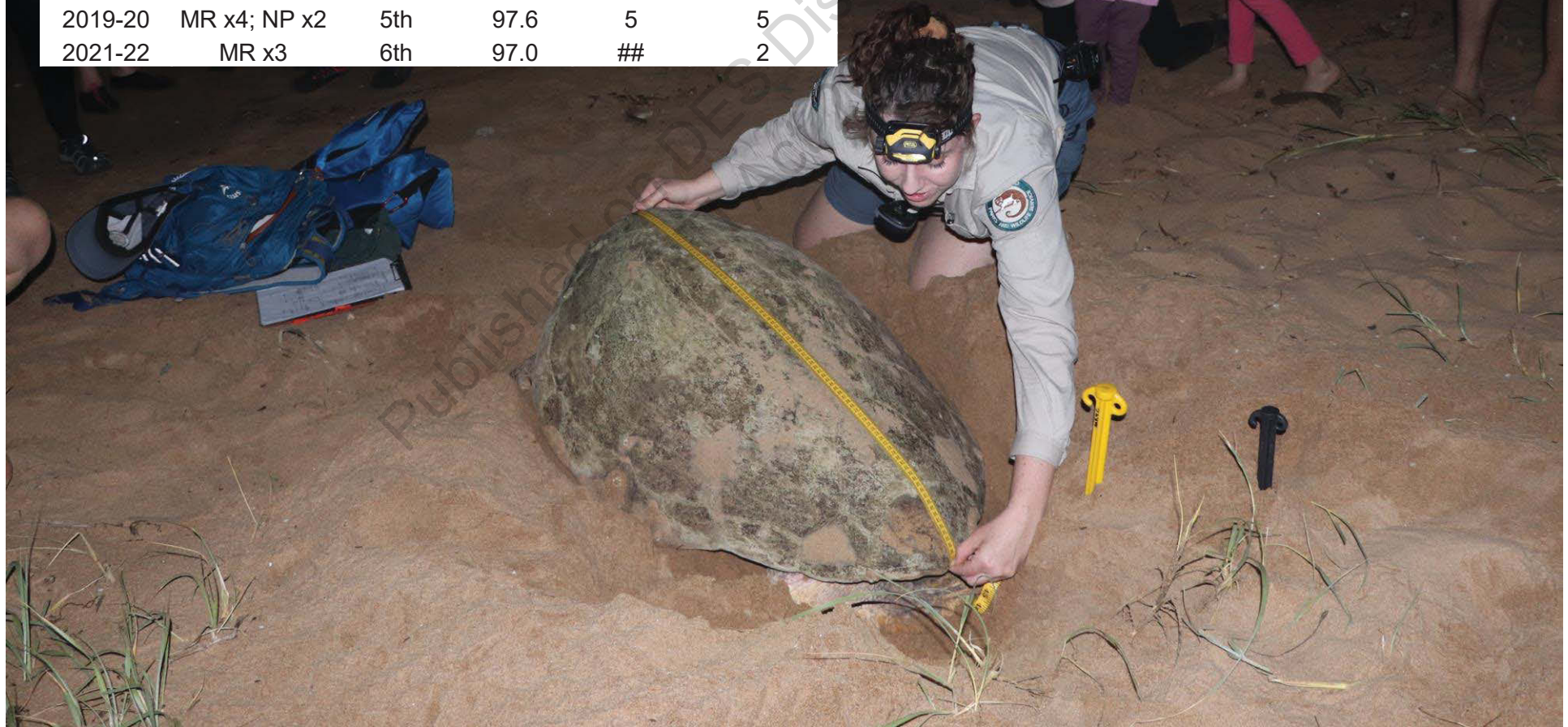
CTPI 49-Sch4

CTPI 49-S



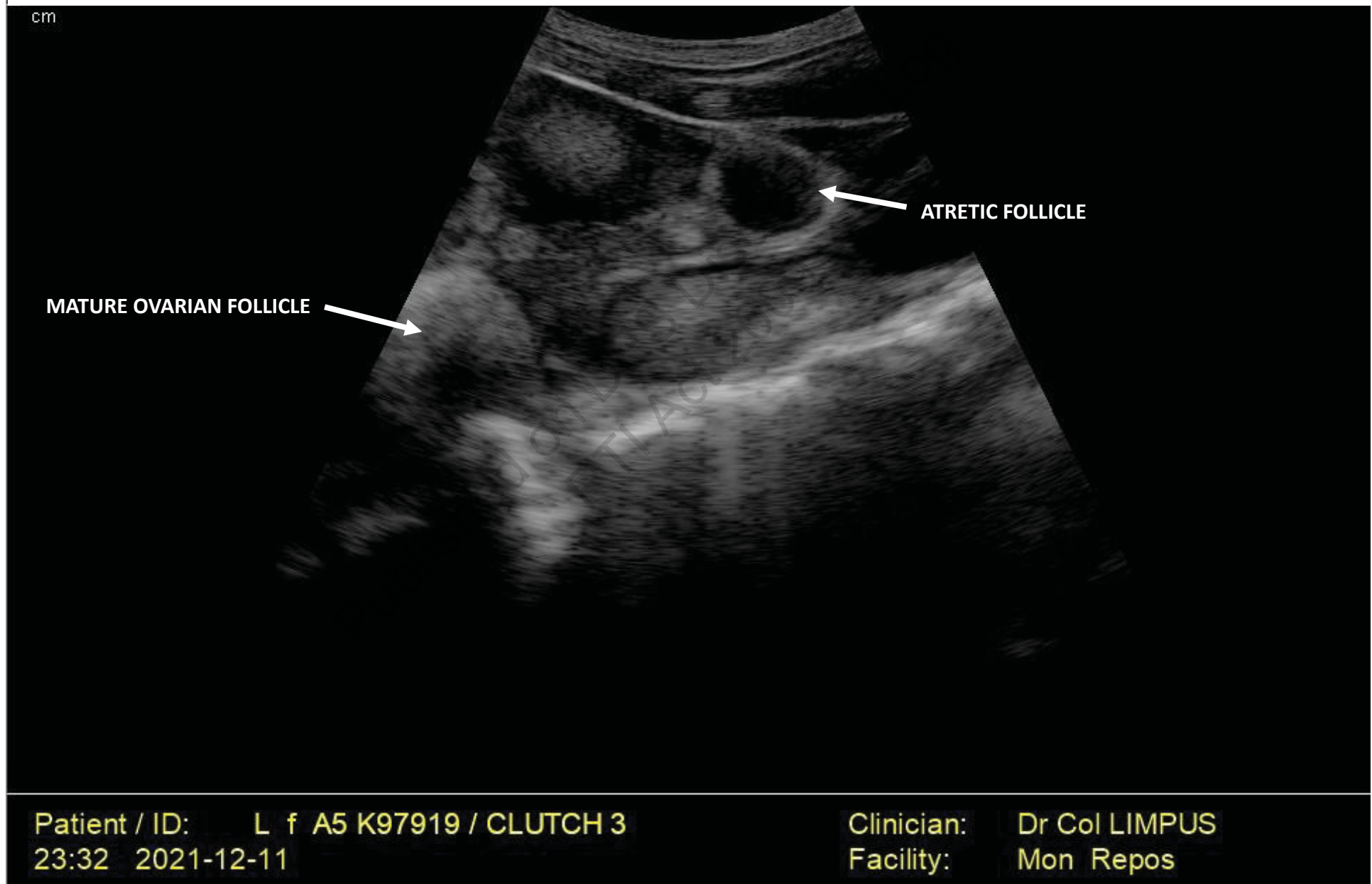
K97919 BREEDING HISTORY

Season	Beach	Breeding season	CCL (cm)	Clutches per year	Remigration interval (yr)
2008-09	MRx3, OK x1	1st	95.8	3	-
2010-11	WR x2	2nd	-	-	2
2012-13	MR x2	3rd	96.6	1	2
2014-15	MR x2; NP x3	4th	97.0	5	2
2019-20	MR x4; NP x2	5th	97.6	5	5
2021-22	MR x3	6th	97.0	##	2



ULTRASOUND IMAGE SHOWING MATURE FOLLICLES IN OVARY:

Indicating that she would return to lay another clutch & be suitable for inter-nesting telemetry study

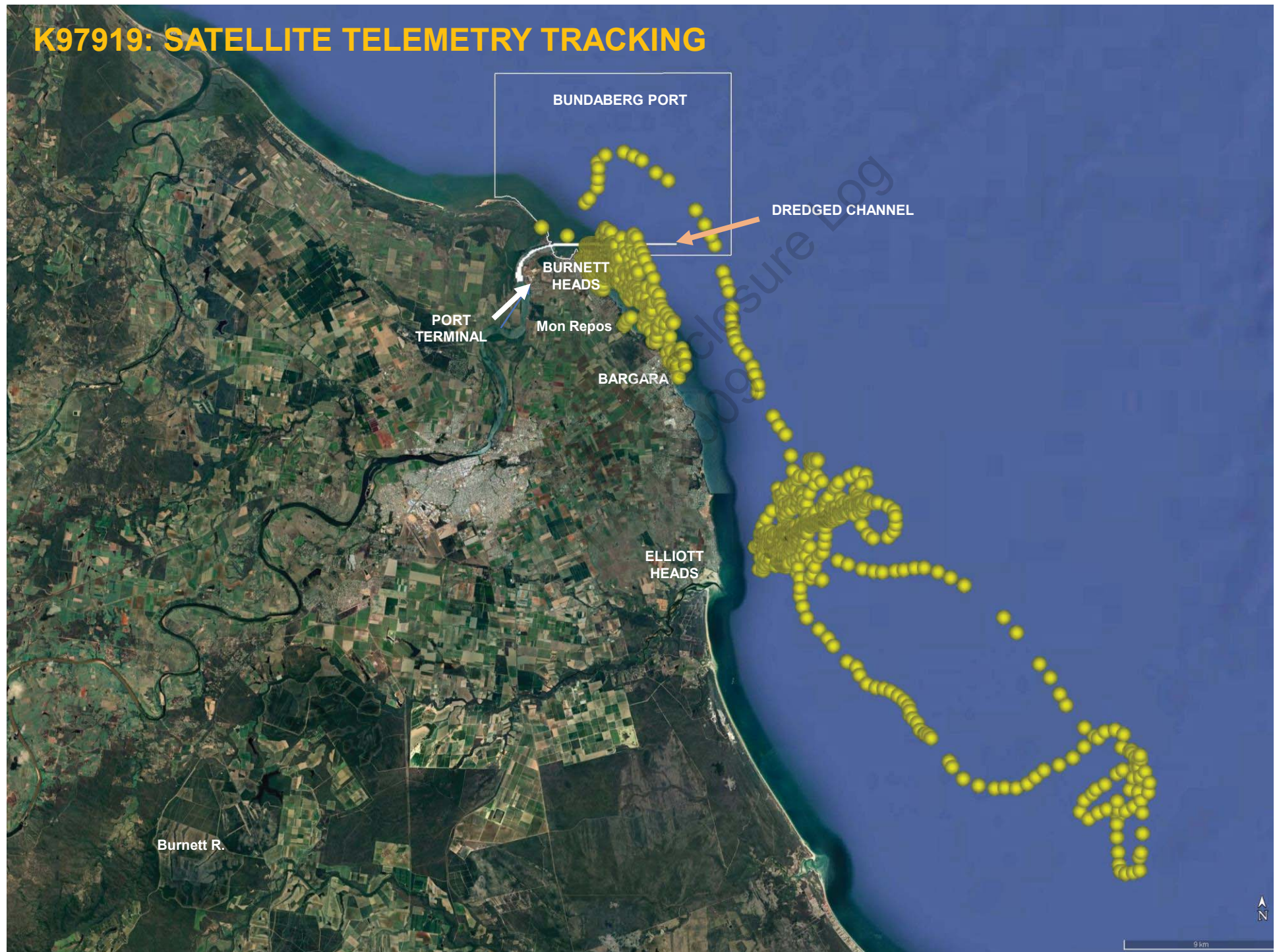


**SATELLITE TELEMETRY TO IDENTIFY HABITAT USE
WITHIN THE WOONGARRA COAST & PORT OF BUNDABERG WATERS
TESTING EFFECTIVENESS OF SATELLITE TRACKING VIA SATELLITE PHONE NETWORKS:
RECORDING GPS LOCATIONS & DEPTH**



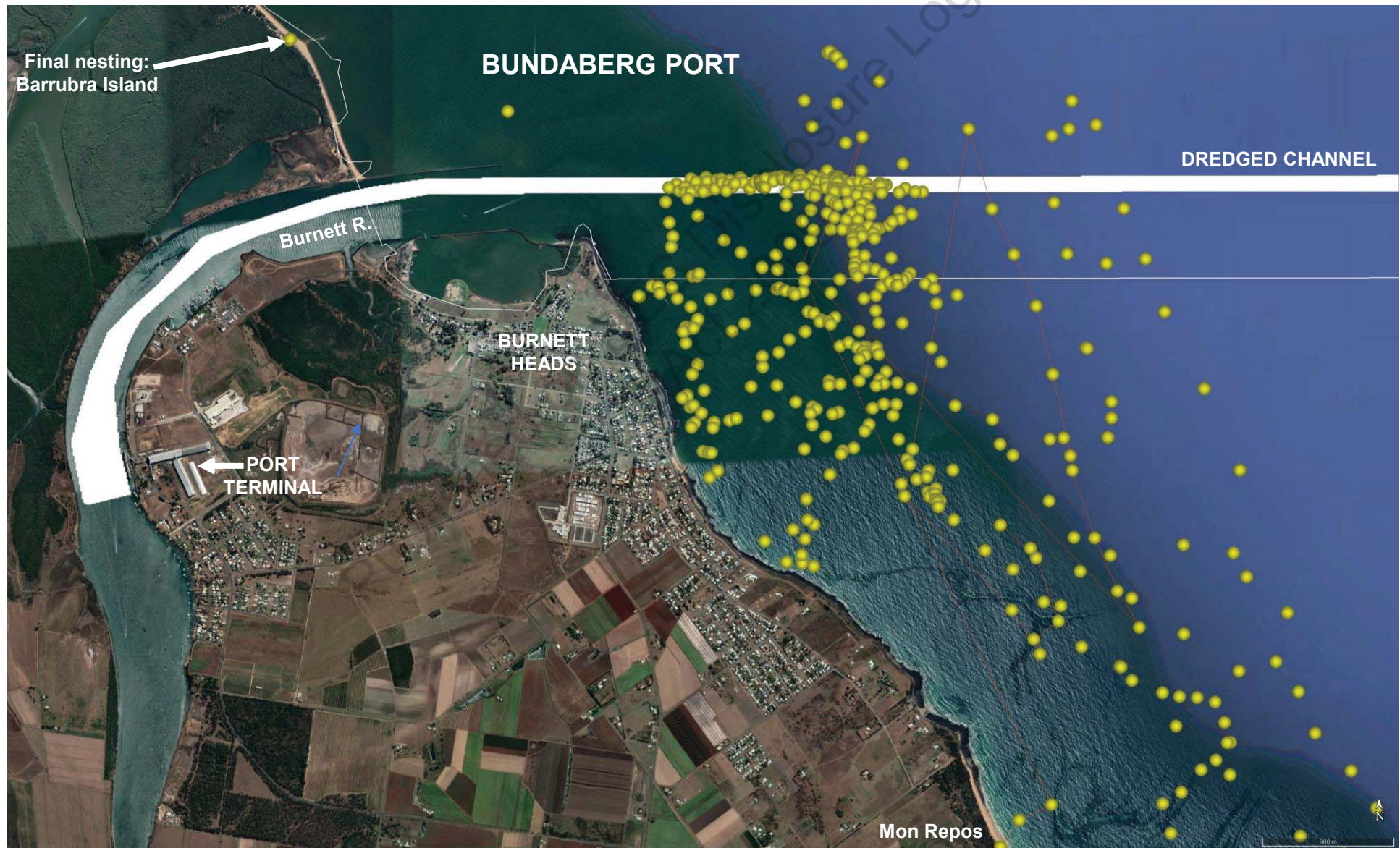
**K97919 RETURNING TO SEA WITH SATELLITE TAGS
12 December 2012**

K97919: SATELLITE TELEMETRY TRACKING

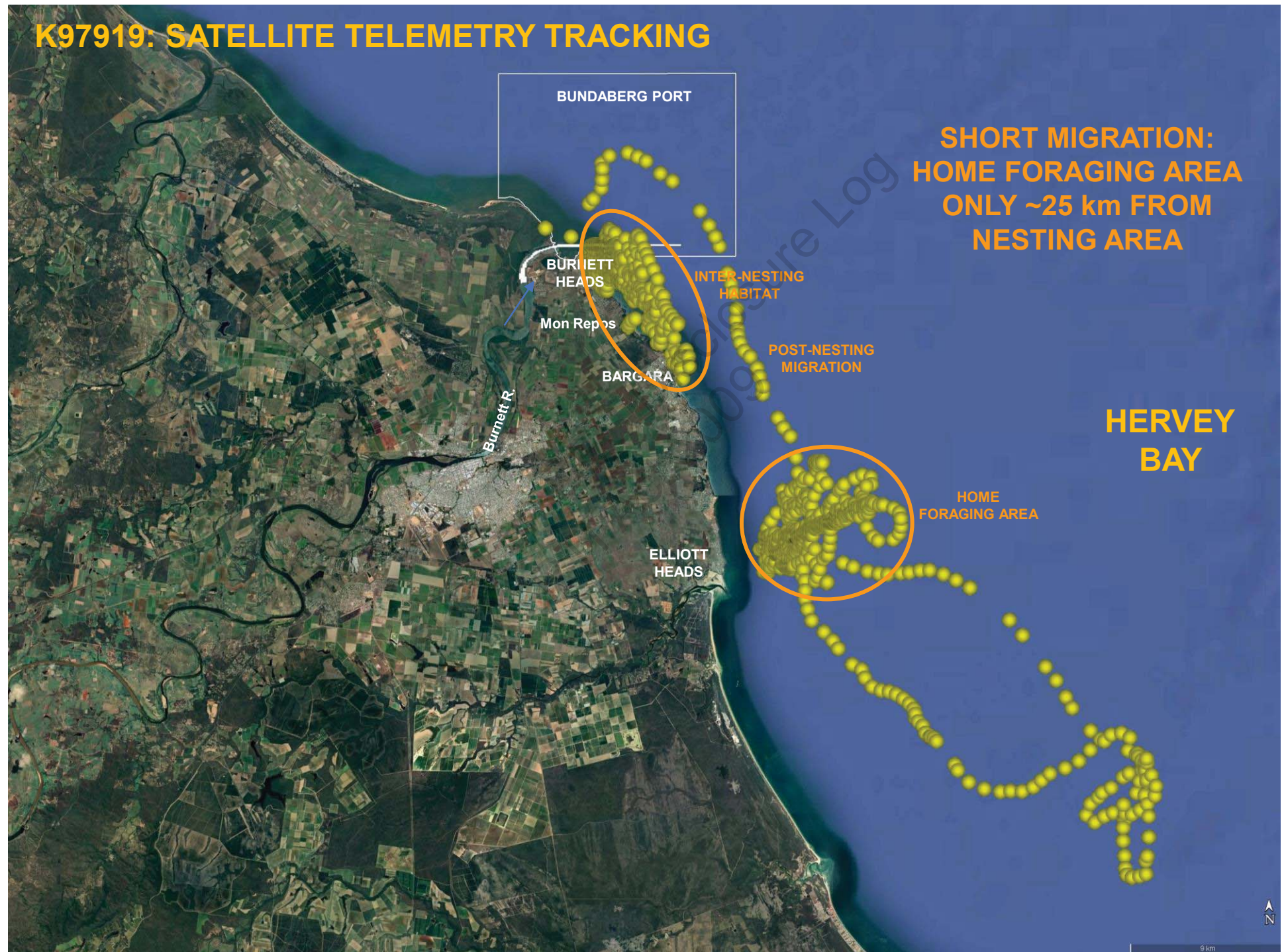


K97919: SATELLITE TELEMETRY TRACKING:

- HABITAT USE WITHIN BUNDABERT PORT



K97919: SATELLITE TELEMETRY TRACKING



MERLIE: LOGGERHEAD TURTLE (*Caretta caretta*), flipper tag K24363



1999 TO 2019:

**ASHORE ON WOONGARRA COAST
FOR NESTING = 24 nesting crawls
SUCCESSFUL NESTING: 16 times**

- **MON REPOS: 21 crawls**
- **BURNETT HDS: 3 crawls**

**Released: Mon Repos 18:24 pm, Saturday 23 November 2019
Wildlife Computers GPS satellite tag
PTT ID: 133765**



LOGGERHEAD TURTLE, *Caretta caretta* MERLIE: FLIPPER TAG K24363

CTPI 49-Sch

CTPI 49-Sch4

CTPI 49-Sch4

CTPI 49-Sch4

CTPI 49-Sch4

2019-2020 BREEDING HISTORY

5TH BREEDING SEASON AT MON REPOS

- 1st CLUTCH: 6 Nov 2019, LAID 147 EGGS
- 2nd CLUTCH: 21 Nov 2019, LAID 126 EGGS
- 3rd CLUTCH: 4 Dec 2019, LAID 118 EGGS
- 4th CLUTCH: 15 Dec 2019, LAID 150 EGGS

PAST HISTORY

First tagged as a nesting turtle in 1999.

1999-2000 1st breeding season: Mon Repos

- CCL = 93.5 cm, laid 3 clutches

2006-2007, 2nd breeding season: Mon Repos

- 7 yr remigration interval, CCL = 93.8 cm, laid 4 clutches

2012-2013 3rd breeding season: Mon Repos

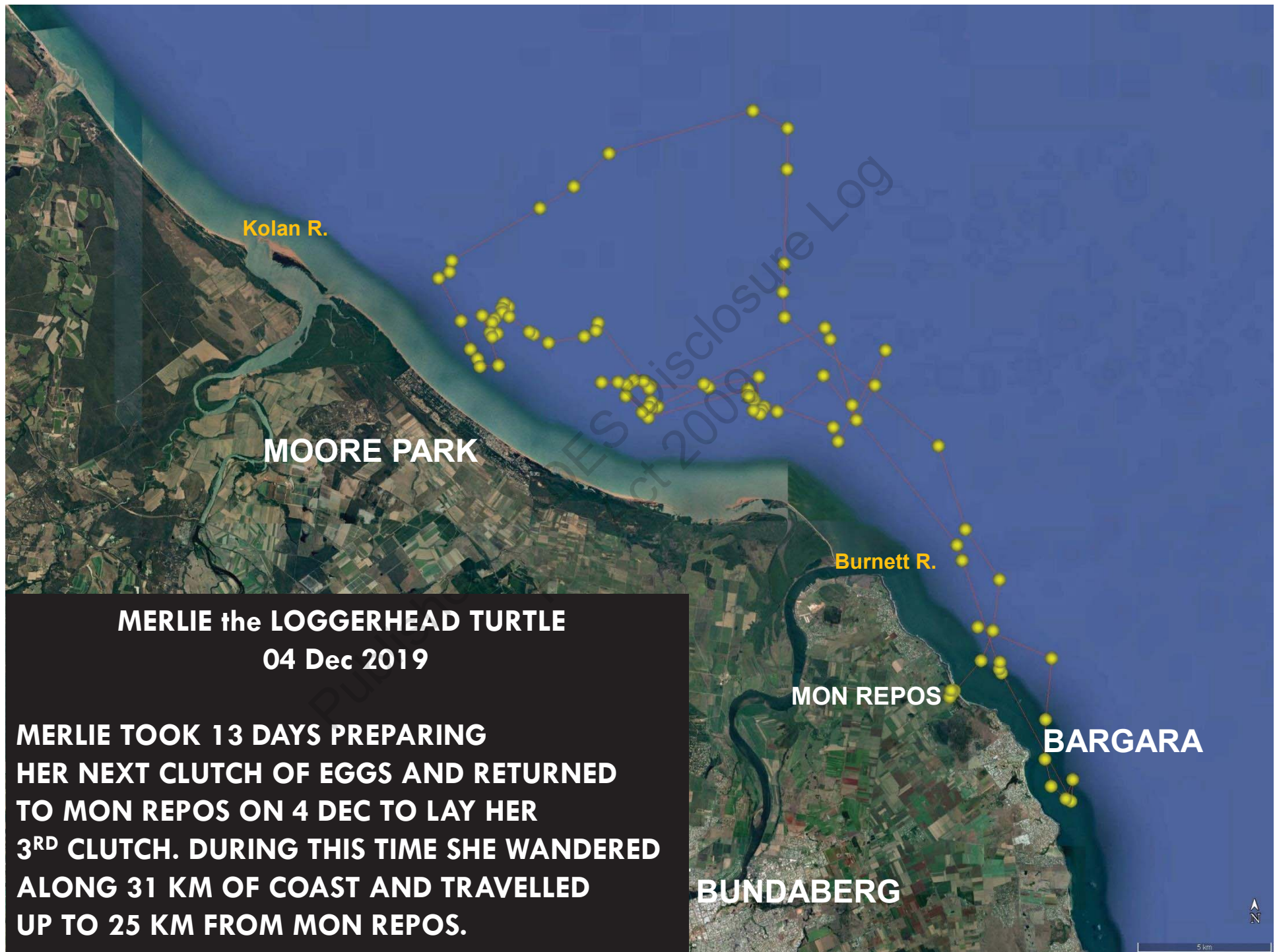
- 6 yr remigration interval, CCL = 94.3 cm, laid 4 clutches

2015-2016, 4th breeding season: Mon Repos

- 3 yr remigration interval, CCL = 94.0 cm, laid 4 clutches

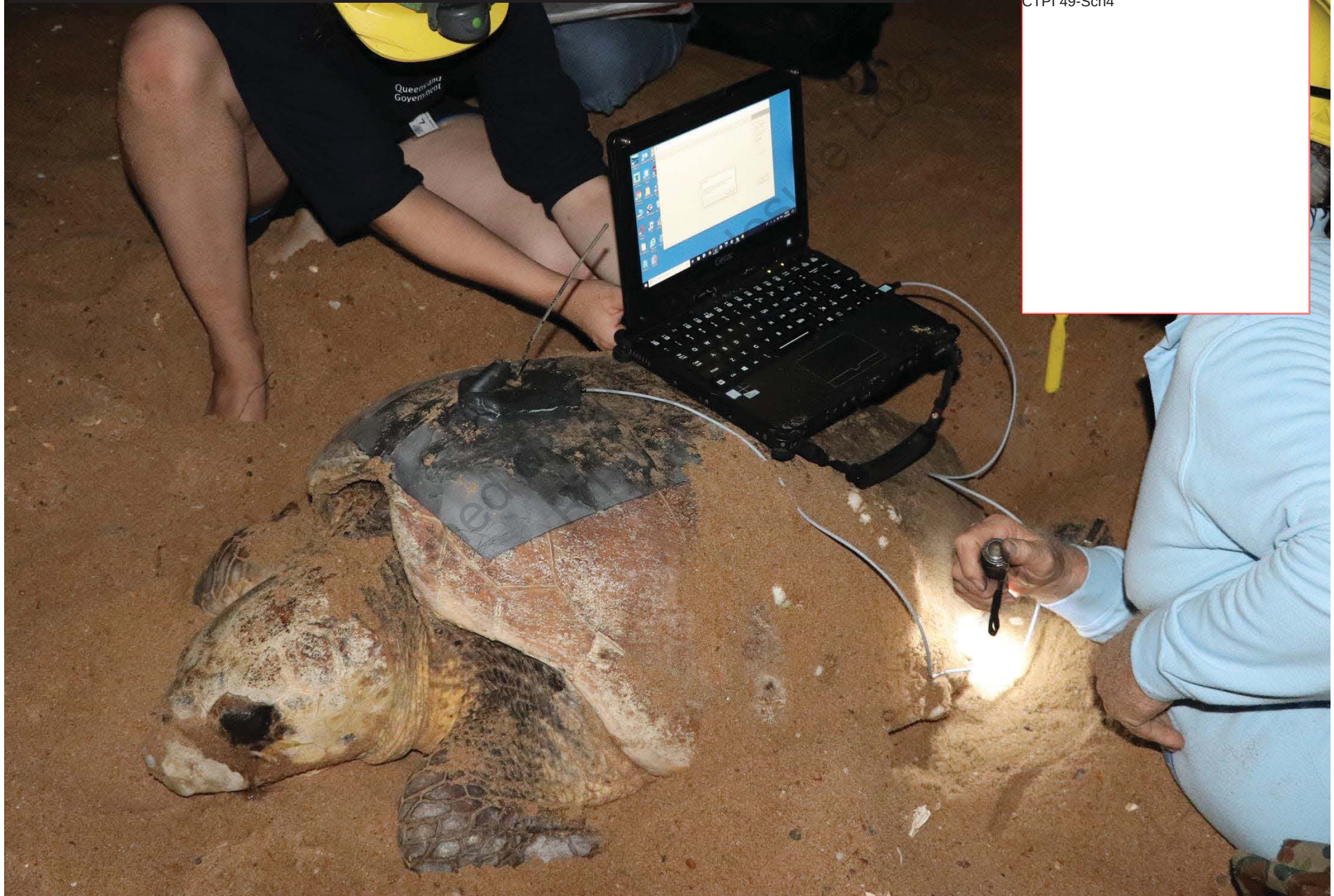
2019-2020, 5th breeding season: Mon Repos

- 4 yr remigration interval, CCL = 94.4 cm, laid 4 clutches

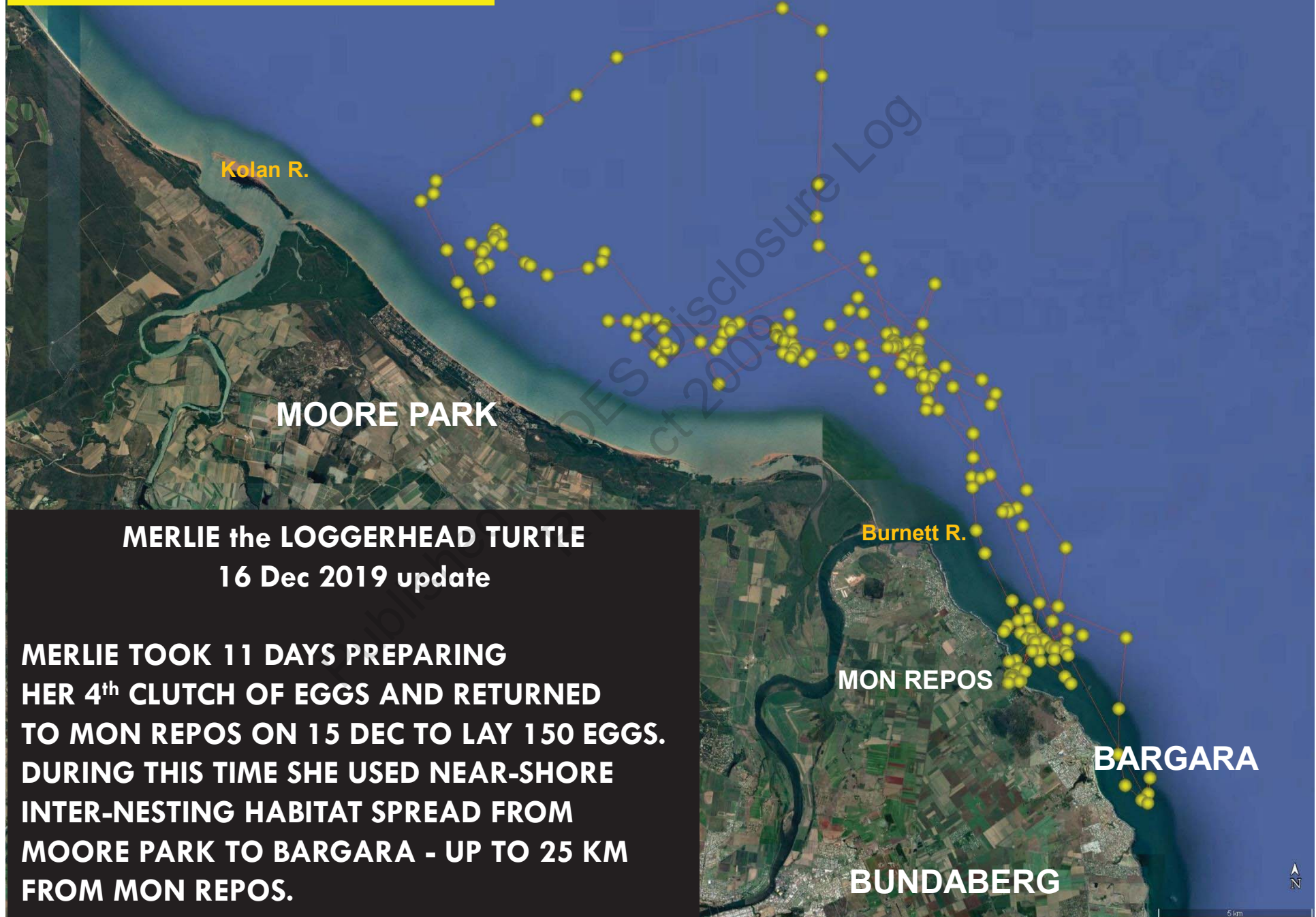


DOWNLOADING EXTRA DATA FROM THE GPS TRACKING TAG WHILE MERLIE WAS ASHORE LAYING EGGS

CTPI 49-Sch4



INTER-NESTING HABITAT



POST-NESTING MIGRATION

TORRES STRAIT

GULF OF
CARPENTARIA

CORAL
SEA

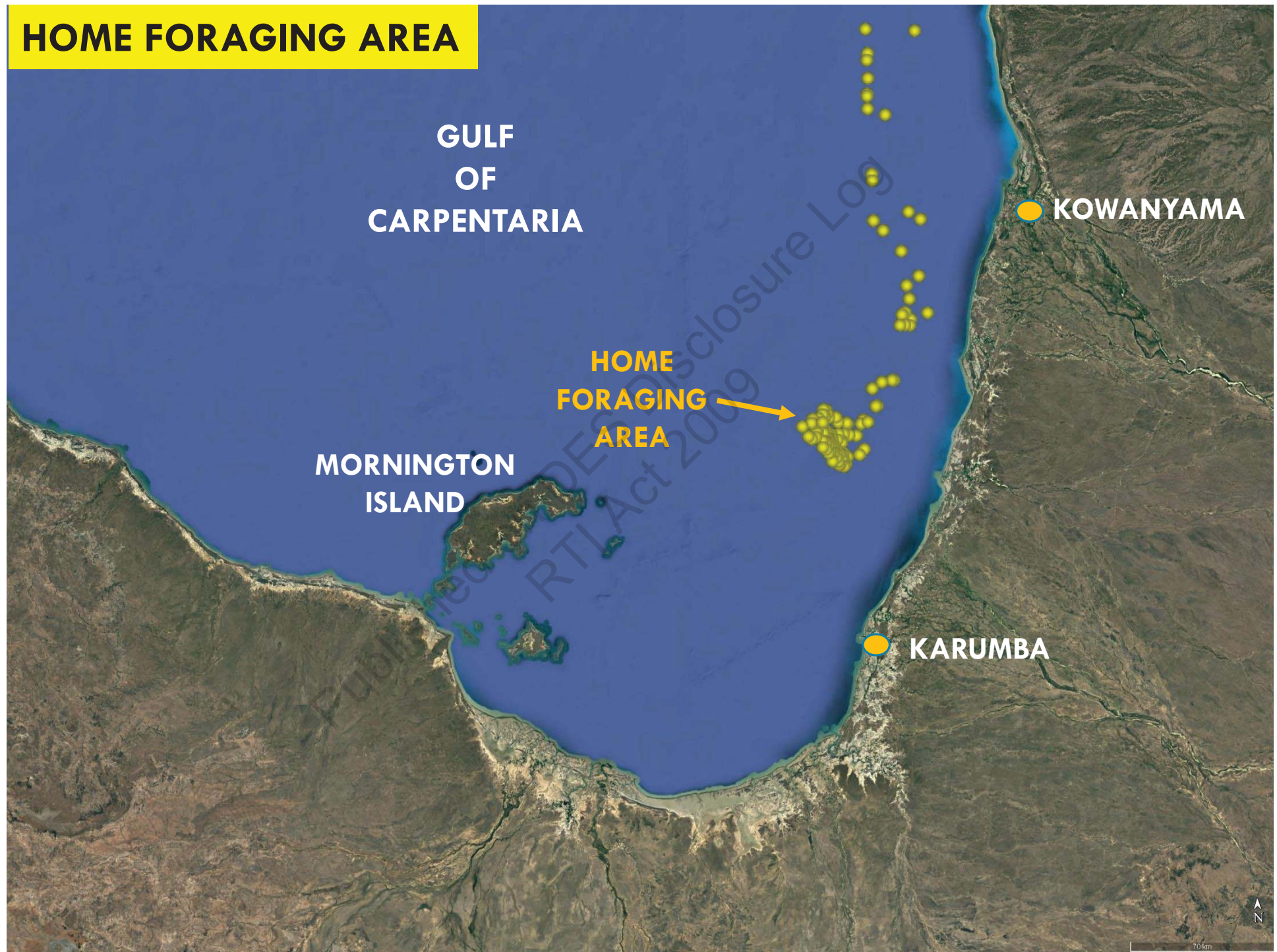
MIGRATED 2,670 KM IN 63 DAYS

27 FEBRUARY 2020:
COMPLETED HER POST-NESTING
HOMEWARD MIGRATION

KARUMBA

16 DECEMBER 2019:
COMPLETED HER NESTING SEASON;
COMMENCED HER NORTHWARD
MIGRATION HOME

HOME FORAGING AREA



**LOGGERHEAD TURTLE, *Caretta caretta*
T93076**

**45 YR OLD TURTLE: ORIGINALLY TAGGED AS A HATCHLING
IN FEBRUARY 1976**



**SATELLITE TELEMETRY FUNDED BY
TOURIST DONATIONS AT MON REPOS CONSERVATION PARK**

**GPS SATELLITE TAG: PTT 133765
WILDLIFE COMPUTERS: SLASH10-BF-385
DEPLOYED ON TURTLE: 2 December 2020**

LOGGERHEAD TURTLE, *Caretta caretta*
T 93076
PAST HISTORY:
HIGH FIDELITY TO MORETON BAY FORAGING AREA
& MON REPOS NESTING BEACH

Season	Beach	Breeding season	CCL (cm)	Clutches per year	Remigration interval (Yr)
1975-76	MR	HATCHED	-	-	-
Apr 1997	FORAGING: MORETON BAY		82.9		
Jul 1998	FORAGING: MORETON BAY		83.3		
Oct 2000	FORAGING: MORETON BAY		84.2		
Mar 2001	FORAGING: MORETON BAY		84.7		
2004-05	MR x3	1 st	88.1	2	-
Apr 2005	FORAGING: MORETON BAY		-		
2014-15	MR x4	2 nd	89.3	3	10
Sep 2015	FORAGING: MORETON BAY		89.3		
2020-21	MR x5	3 rd	89.0	4	6

2020: TRACKED TO FORAGING –will she change her home?

LOGGERHEAD TURTLE, *Caretta caretta*
T 93076

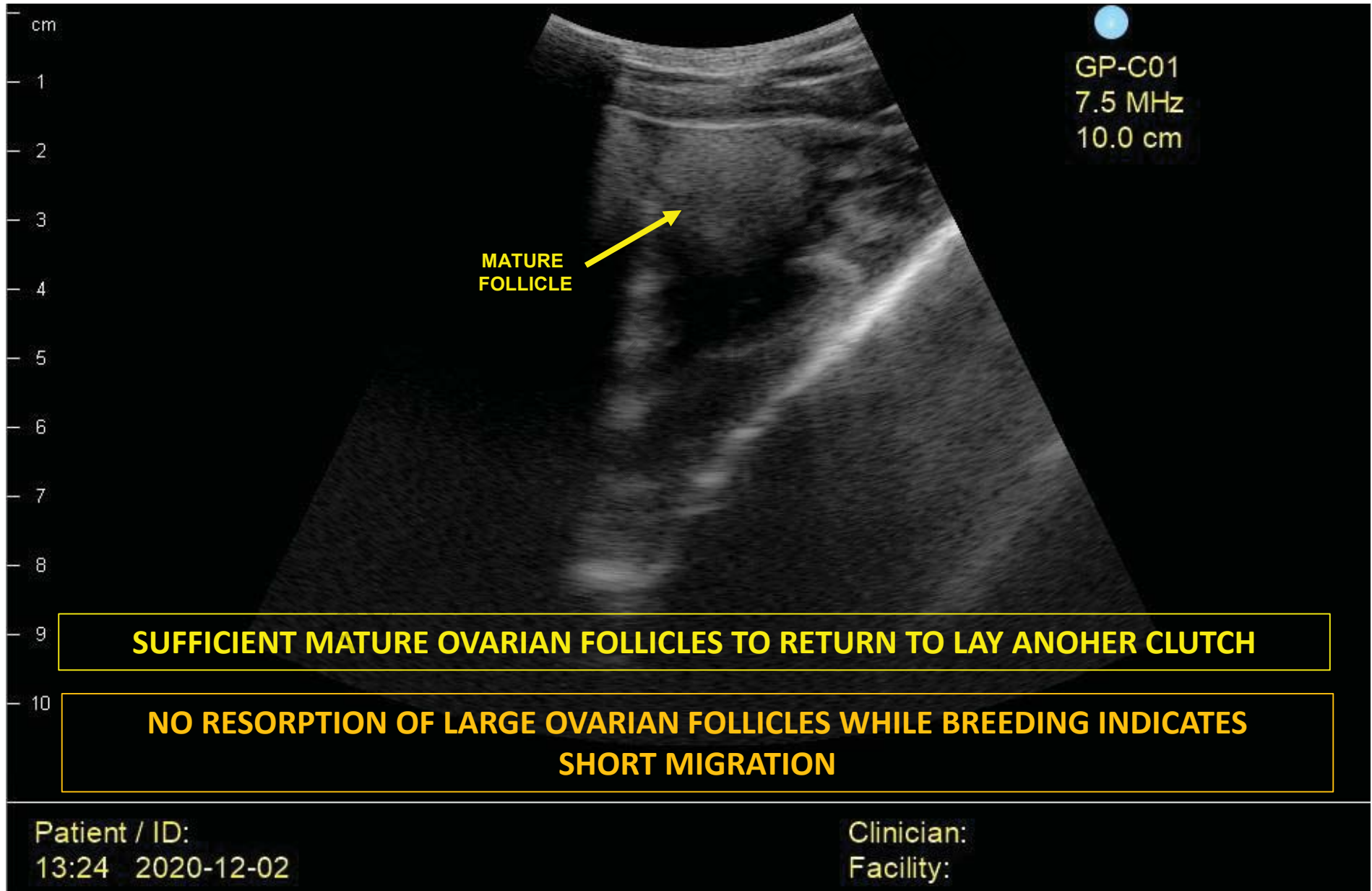
ON THE TURTLE BARROW FOR

- **ULTRASOUND EXAMINATION**
- **DOWNLOAD OF TELEMETRY DATA**



T93076: LOGGERHEAD TURTLE, *Caretta caretta*

1 Dec 2020: ULTRASOUND SCAN AFTER LAYING 2nd CLUTCH FOR SEASON



LOGGERHEAD TURTLE, *Caretta caretta* T 93076

TELEMETRY TRACKING:
INTER-NESTING HABITAT USED FOR PREPARING EGGS FOR LAYING 3RD & 4TH CLUTCHES
2-28 DECEMBER 2020







LOGGERHEAD TURTLE, *Caretta caretta*
X-8400

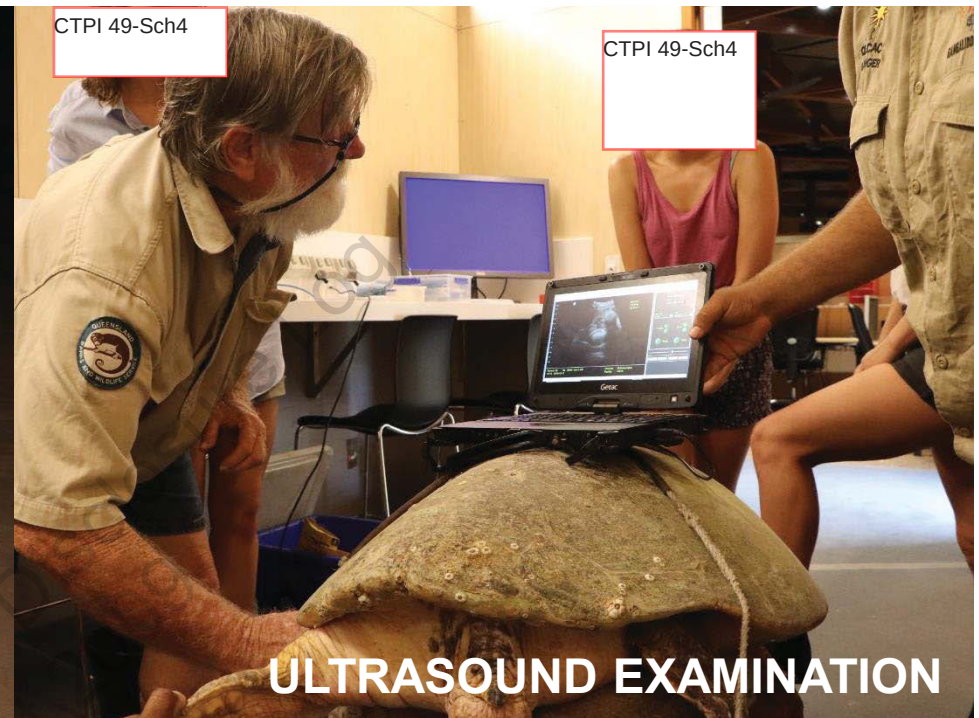
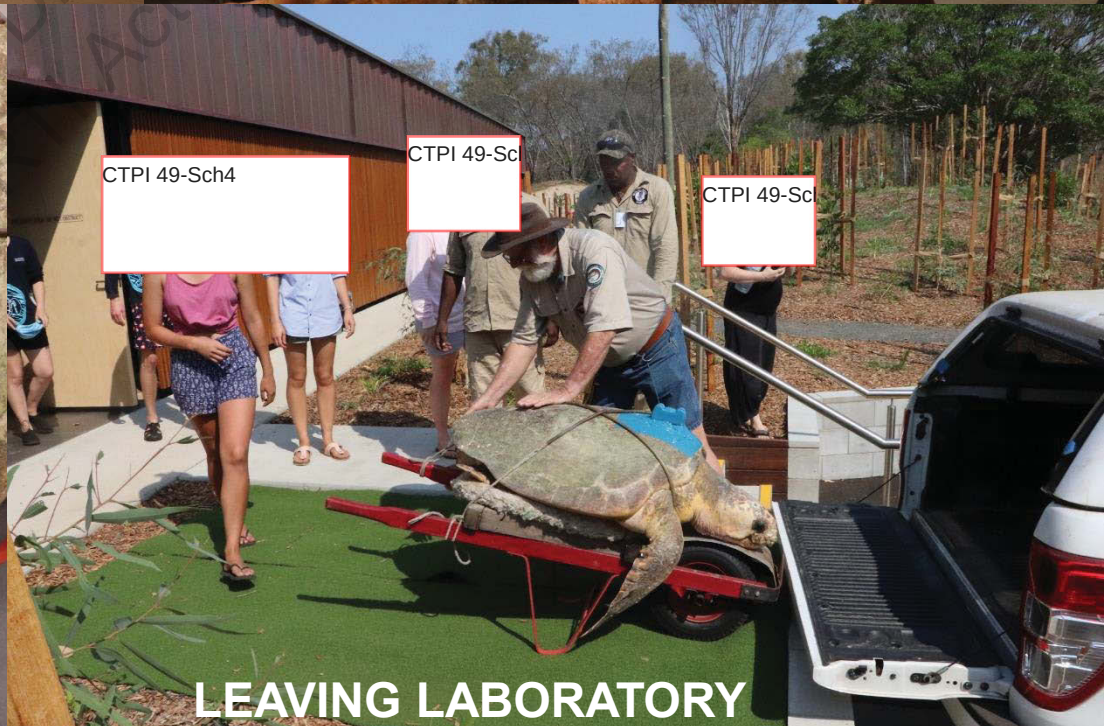


LOGGERHEAD TURTLE,
Caretta caretta
X-8400

**BREEDING LIFE
AT WOONGARRA COAST (WC):**

- 42 YEARS
- 15 SEASONS

Season	Beach	Breeding season	CCL (cm)	Clutches per year	Remigration interval (Yr)
1977/78	WC x3	1 st	94.5	3	-
1979/80	WC x3	2 nd	95.0	3	2
1981/82	WC x2	3 rd	95.0	-	2
1982/83	WC x2	4 th	95.0	-	1
1984/85	WC x1	5 th	95.5	-	2
1985/86	WC x2	6 th	-	-	1
1986/87	WC x2	7 th	94.5	-	1
1988/89	WC x2	8 th	95.0	-	2
1989/90	WC x2	9 th	96.6	-	1
1990/91	WC x1	10 th	-	-	1
1994/95	WC x5	11 th	96.2	3	4
2000/01	WC x2	12 th	-	-	6
2003/04	WC x2	13 th	96.4	-	3
2010/11	WC x4	14 th	97.0	-	7
2019/20	WC x?	15 th	96.3	#	9



LOGGERHEAD TURTLE, *Caretta caretta*
X-8400



SATELLITE TELEMETRY 2019-2020:

- Wildlife Computers SPLASH10-F-334A GPS tag
- PTT: 62090

LOGGERHEAD TURTLE, *Caretta caretta* X-8400

2019-2020 BREEDING SEASON:

9 yr since her last recorded breeding season

Carapace length = 96.3 cm

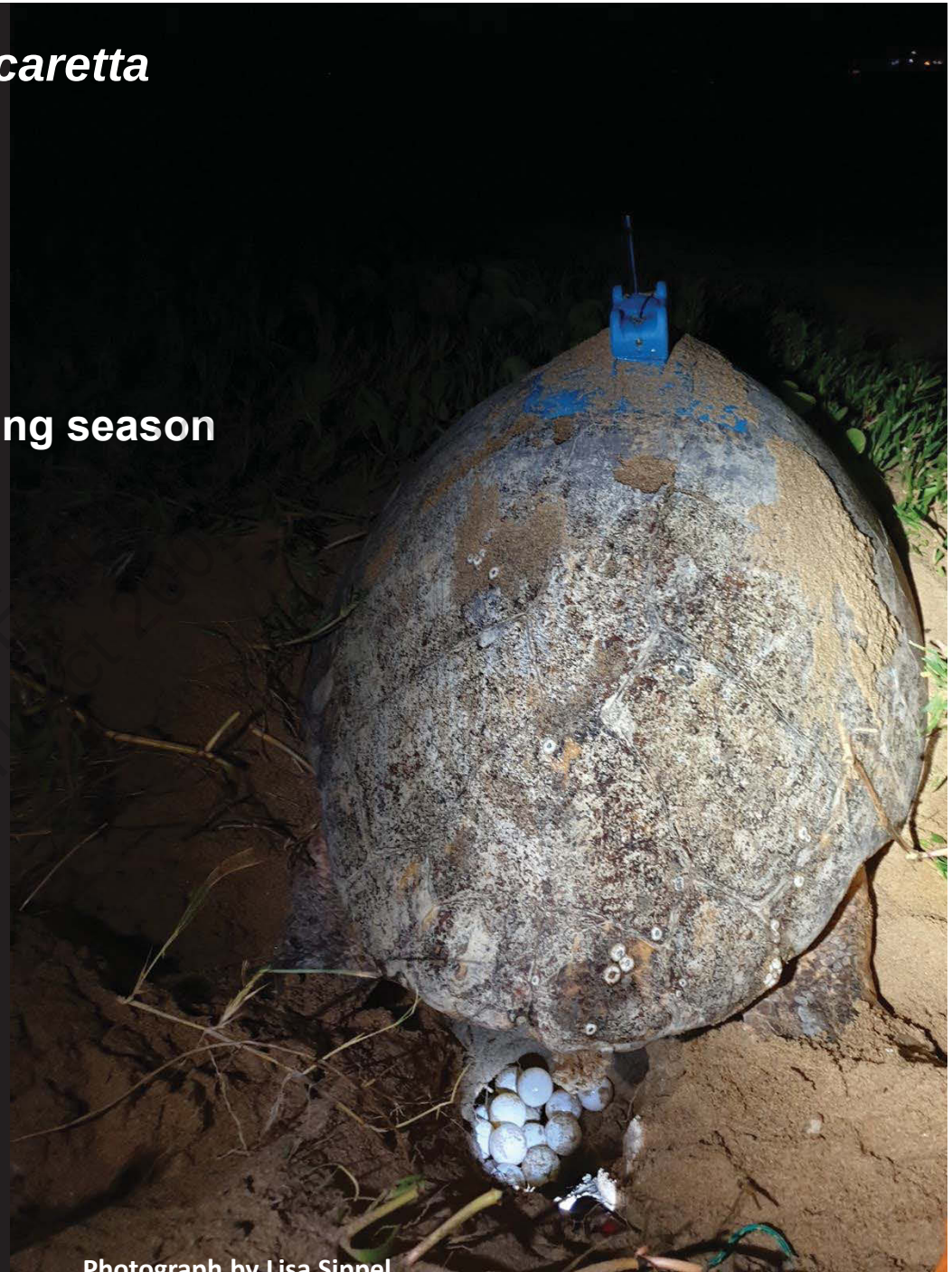
Archie's Beach

29 November: laid 116 eggs

15 December: laid 105 eggs

27 December: laid 129 eggs

09 January: laid 137 eggs



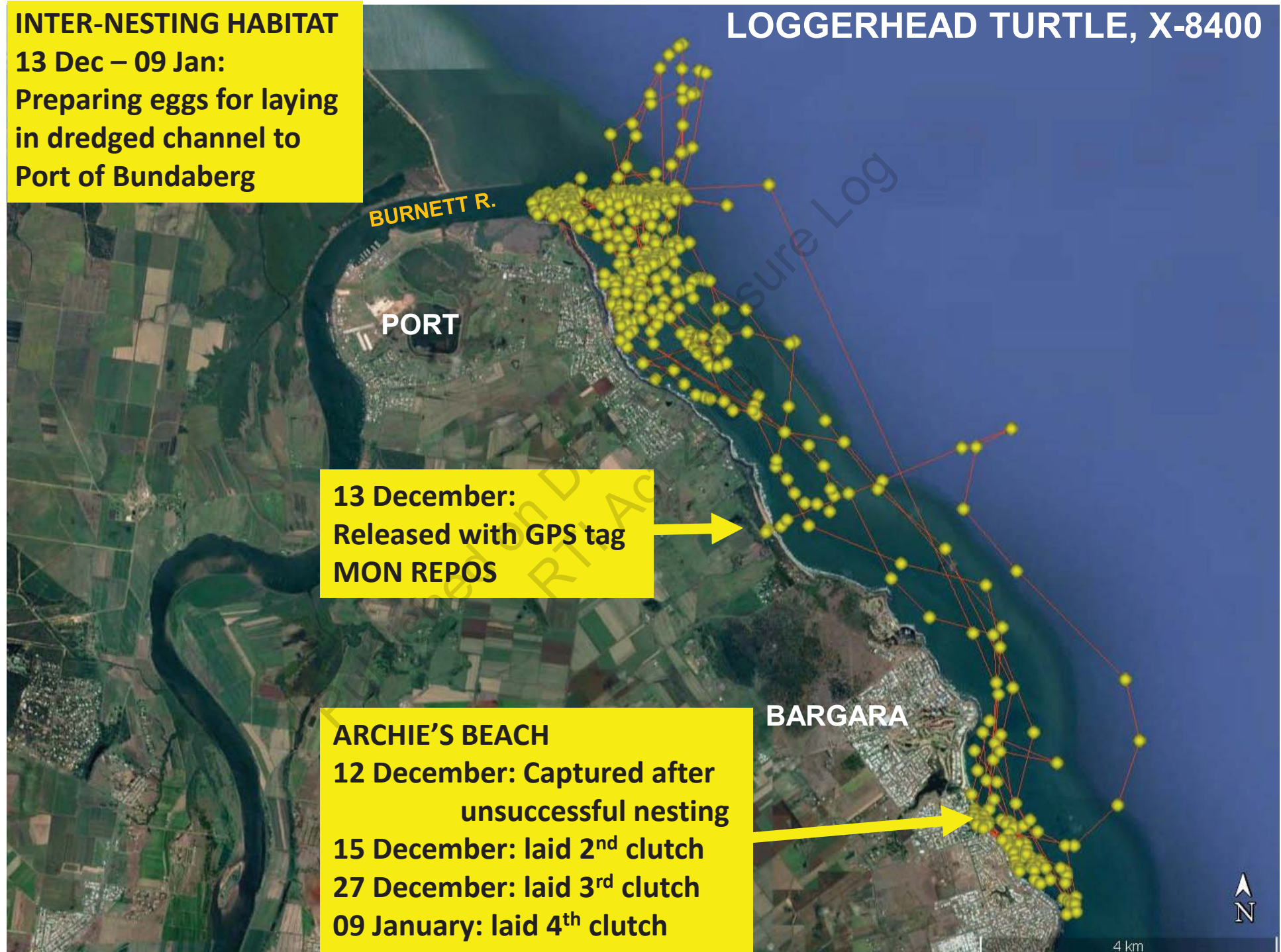
Photograph by Lisa Sippel

INTER-NESTING HABITAT

13 Dec – 09 Jan:

Preparing eggs for laying
in dredged channel to
Port of Bundaberg

LOGGERHEAD TURTLE, X-8400



POST-NESTING MIGRATION

**10 JANUARY 2019:
COMPLETED HER NESTING SEASON;
COMMENCED HER SOUTHWARD
MIGRATION HOME**

MON REPOS

FRASER
ISLAND

MIGRATED 505 KM IN 12 DAYS

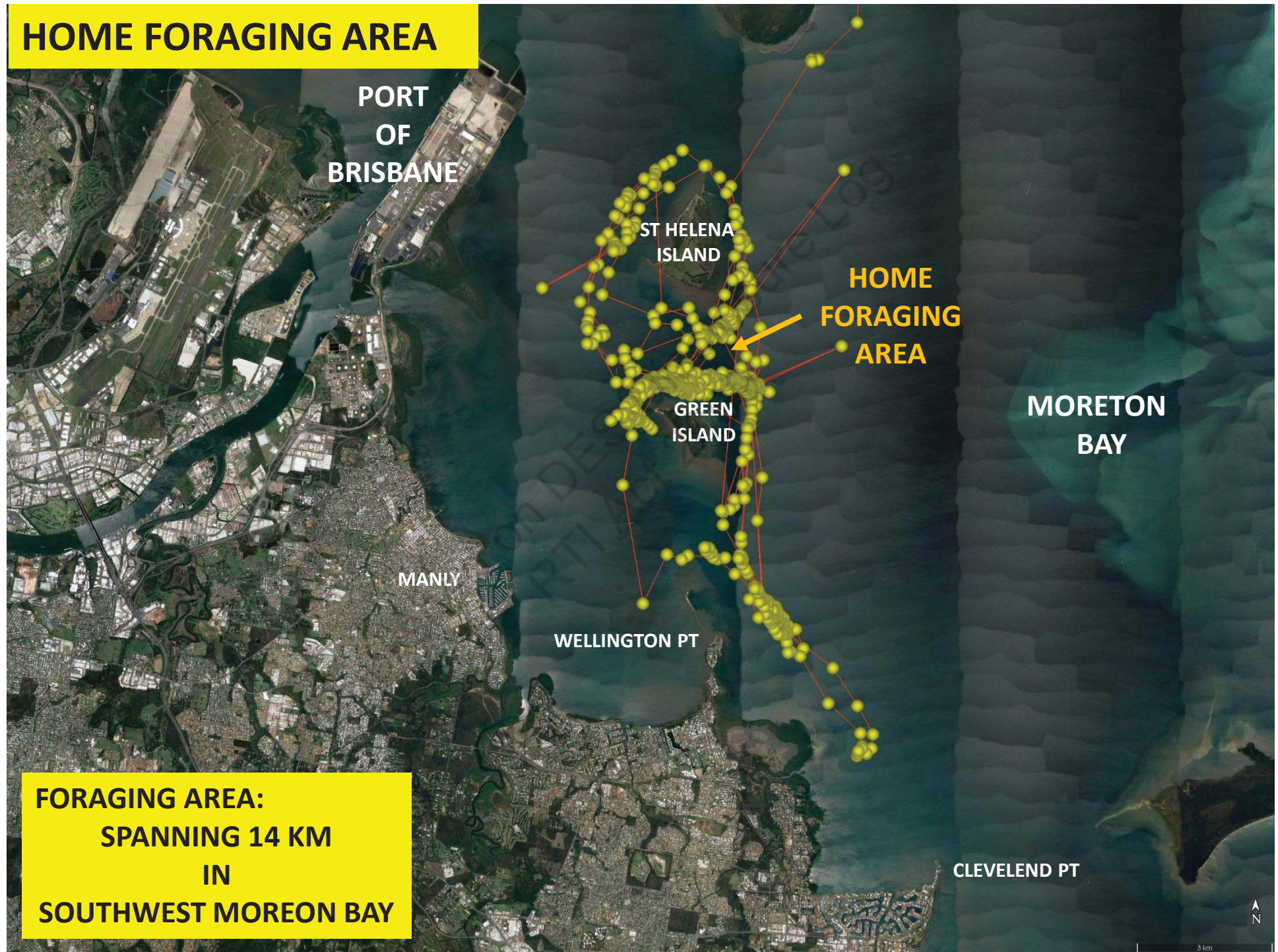
**22 JANUARY 2020:
COMPLETED HER POST-NESTING
HOMEWARD MIGRATION**

BRISBANE

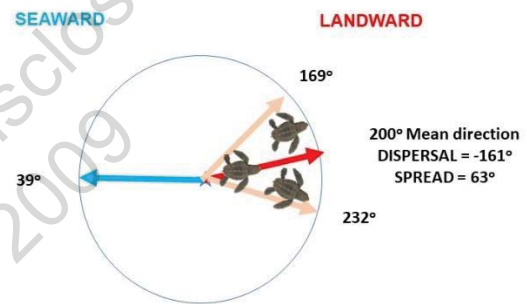
MORETON
BAY

60 km

HOME FORAGING AREA



**QUEENSLAND TURTLE CONSERVATION PROJECT: MONITORING MARINE TURTLE
HATCHING BEHAVIOUR IN RESPONSE TO COASTAL LIGHTING ON THE
WOONGARRA COAST: 2019-2020 BREEDING SEASON**



BARGARA BOAT PASSAGE BEACH, 19 February 2020, ~21.00 hr.

Colin J. Limpus
Threatened Species Operations

Department of Environment and Science



Cover photos, clockwise from the top left:

Light spill from playground lighting, street lights and Caravan Park at Neilson Park Beach

Recording compass bearing at a hatchling track fan.

Pictorial representation of hatchling orientation where hatchlings have headed inland to coastal lighting.

Loggerhead hatchlings crossing the beach

This report should be cited as:

Colin J. Limpus (2020). Queensland Turtle Conservation Project: Monitoring marine turtle hatching behaviour in response to coastal lighting on the Woongarra Coast, 2019-2020 breeding season. Brisbane: Department of Environment and Science, Queensland Government. (29 pp.)

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Peer Reviewers:

Dr Karen Arthur, Biodiversity Conservation Division, Department of Agriculture, Water, and the Environment

Dr CTPI 49-Sch4 Pendoley Environmental Pty Ltd

The study was undertaken under Agreements between the Queensland Department of Environment and Science and the Bundaberg Regional Council to monitor the response of the turtle nesting population to sky glow on the Woongarra Coast.

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EXECUTIVE SUMMARY

This monitoring of lighting impacts on marine turtle ocean finding behaviour on the Woongarra Coast was conducted as part of the Department of Environment and Science's contribution to support the Bundaberg Regional Council's *Low Glow Program*.

The study results are summarised below.

- Opportunistic observations of disrupted marine turtle ocean-finding behaviour by coastal lighting provided an unquantified identification of conservation issues relating to lighting management on the Woongarra Coast:
 - hatchlings were recorded heading inland to directly visible light sources behind the nesting areas at Oaks Beach, Mon Repos (Turtle Sands Caravan Park), Neilson Park, and Bargara Beaches with associated increased mortality of hatchlings.
 - hatchlings that had entered the sea were drawn back to shore to crawl inland towards the sky glow from Bargara, Bundaberg, and Burnett Heads and/or the direct light from street lights and other coastal lighting at Oaks, Mon Repos, and Bargara Beaches.
- Quantified observations of Loggerhead turtle hatchling ocean-finding behaviour following natural emergence from nests on Mon Repos showed:
 - while the differences are not statistically significant, hatchlings from sampled naturally emerging clutches on Mon Repos Beach, while heading seaward, dispersed more southward towards the sky glow over Bargara on nights when the moon was not visible compared to nights when the moon phase was greater than a half moon.
- Quantified observations of Loggerhead turtle hatchling ocean-finding behaviour following releases over five separate nights when no moon was visible showed:
 - 100% of hatchlings released at standardised release sites on the brightly illuminated beaches at Neilson Park, Bargara Playground, Bargara Boat Passage and Kellys Beach headed inland away from the sea.
 - Hatchlings on the darker Archies Beach:
 - headed seaward but with indications of partial disruption of ocean finding behaviour as indicated by increased spread of the hatchling track fan angles relative to those measured at Mon Repos
 - dispersed towards bright light sources away from a more direct path to the sea
- Collectively these observations indicate that the Woongarra Coast is excessively impacted by coastal lighting that is disrupting hatchling turtle ocean-finding behaviour.
- In particular, Neilson Park, Bargara and Kellys Beaches can no longer be considered safe beaches for successful marine turtle hatchling production.
- The current study does not quantify:
 - the negative impacts of coastal lighting on hatchlings that have left the beach and are dispersing out to the open ocean where there can be a resulting elevated depredation by fish and sharks if hatchlings spend longer time in inshore waters.
 - the reduced nesting success of adult turtles coming ashore for nesting on illuminated beaches.
 - the reduction in the number of turtles choosing to come ashore for nesting on illuminated beaches.

QUEENSLAND TURTLE CONSERVATION PROJECT: MONITORING MARINE TURTLE HATCHLING BEHAVIOUR IN RESPONSE TO COASTAL LIGHTING ON THE WOONGARRA COAST: 2019-2020 BREEDING SEASON

1. INTRODUCTION

Marine turtles when ashore, do not instinctively know which way leads to the ocean. During ocean finding, marine turtles respond to cues that lead them towards the horizon at the lowest angle of elevation from their view point and away from elevated dark horizons (Limpus and Kamrowski, 2013). With increasing coastal development there is associated increased levels of light pollution in coastal areas such as the Woongarra Coast (Kamrowski *et al.* 2012, 2014). With increasing illumination of the Woongarra Coast, via directly visible light sources and sky glow, it is expected that there will be an increased incidence of disrupted ocean finding behaviour and resulting increased hatchling mortality (Wood *et al.* 2014).

The Department of Environment and Science (DES) is collaborating with the Bundaberg Regional Council (BRC) *Low Glow Project* to monitor the impact of coastal lighting on marine turtle breeding success on the Woongarra Coast. This particular monitoring by DES focusses on two phases of the turtle life history that are reported separately:

- Monitoring ocean finding behaviour of loggerhead hatchlings in response to coastal lighting on six beaches of the Woongarra Coast.
- Monitoring of the nesting turtles and hatchling production on all beaches of the Woongarra Coast with emphasis on adult selection of nesting beaches and the associated nesting success when ashore for laying eggs (Already reported by Limpus *et al.* 2020).

2. WOONGARRA COAST STUDY AREA

The nesting beaches of the Woongarra Coast ([Figure 1](#)) are described in part within the report on marine turtle nesting and hatchling production for the Woongarra Coast during the 2019-2020 breeding season (Limpus *et al.* 2020). The intertidal areas and a substantial portion of the adjacent marine turtle nesting habitat of the Woongarra Coast are within the Great Sandy Marine Park. In this report, the land tenure of the remaining areas of turtle nesting habitat on the Woongarra Coast beaches are summarised and the general sources of direct coastal lighting impacting the individual beaches are described.



Figure 1: Map of the locations of the marine turtle nesting beaches on the Woongarra Coast.

2.1 Mon Repos Beach

While the majority of the turtle nesting habitat of Mon Repos Beach lies within the Mon Repos Conservation Park (MRCP), approximately 200m of the southern part of the beach is immediately adjacent to the Turtle Sands Caravan Park. Since 1982, the land within MRCP has been revegetated to provide a forested visual barrier to direct light originating from Bundaberg and Qunaba. With expanding coastal development, sky glow from Bargara, Bundaberg and Burnett Heads is now a prominent part of the night sky at Mon Repos. Since 2003, the intensity of sky glow visible to the turtles at Mon Repos, on nights with no moon and on very overcast nights, has frequently resulted in hatchlings heading along the beach towards Bargara. On a number of nights, hatchlings have been recorded leaving the sea to crawl inland towards the glow over Bargara. Directly visible light from the Turtle Sands Caravan Park and buildings within MRCP can also disrupt ocean finding behaviour of hatchlings on nights with no visible moon.

2.2 Neilson Park

The entire beach at Neilson Park is backed by BRC park land with an illuminated children's playground, toilet block and a Surf Lifesaving Clubhouse ([Figure 2](#)). The BRC park land is backed by a road with street lighting and an illuminated Caravan Park.



2.A. 28 December 2019, 21:19 hr: playground lighting, Street lights and Caravan Park lighting.



2.B. Surf lifesaving clubhouse, Neilson Park, 11 February 2020. (Photograph by CTPI 49-Sch4)

Figure 2. Direct light sources visible from mid-beach, Neilson Park.

2.3 Bargara

There are two nesting beaches at the Bargara CBD separated by a rock groin.

2.3.1 Bargara Playground Beach

This is a small, artificially created beach formed following the construction of the adjacent groin on the southern side several decades in the past. The beach is flanked by a BRC esplanade with illuminated children's playground, barbeque picnic areas, toilets, walking track and the adjacent esplanade road with street lighting. On the landward side of the road is a continuous line of illuminated apartment blocks, motels, and homes ([Figure 3](#)).



Figure 3. Aerial view of lighting immediately inland of the Bargara Playground Beach in the bottom right corner of the photograph, Bargara CBD (Photograph by CTPI 49-Sch4 Pendoley Environmental).

2.3.2 Bargara Boat Passage Beach

This beach fronts the illuminated CBD of Bargara with illuminated shop fronts, street lights, barbeque picnic areas, toilets, and a walking track. Lighting at the barbeque areas is automated to switch off at 8 pm and the toilet blocks have motion detectors to switch on lighting within the toilet cubicles when a person is present. ([Figure 4](#))



Figure 4. Aerial view of light spill onto nesting beach (foreground) at Boat Passage, Bargara CBD (Photograph by CTPI 49-Sch4 Pendoley Environmental).

2.4 Kellys Beach

The majority of the beach front on Kellys Beach is freehold land down to the high tide mark. Consequently, the majority of the turtles are nesting within privately owned land on this beach. Light from motels, apartment block and homes, from street lights and vehicle parking areas and from two BRC Parks with toilet blocks and barbeque picnic areas are directly visible from the turtle nesting habitat ([Figure 5](#)).



5A. Looking south across the creek to Crawford Park



5B. Looking north along Kellys Beach to Christen Park



5C. Looking west towards life savers' base

Figure 5. Direct light sources visible from mid-beach, Kellys Beach, 28 December 2019, 21:00 hr; adjacent to life saver's base, Park lighting, street lights, motel & house lighting.

2.5 Archies Beach

The northern half of Archies Beach is backed by a forested esplanade providing a partial barrier to light from adjacent street lights and residential accommodation.

The southern half of the beach does not have an esplanade separating the turtle nesting habitat from the adjoining freehold residential land. Direct light spill from the freehold properties is visible from the adjacent turtle nesting habitat ([Figure 6](#)).



Figure 6. Light spill from private homes on Woongarra Scenic Drive that backed onto turtle nesting habitat at Archies Beach, 11 February 2020.

3. METHODS

Within this project, DES operates under Department of Agriculture and Fisheries Animal Research Ethics Approvals: SA 2018-11-660, 661; 2020-02-733. This study has not been resourced by BRC.

Ideally, when monitoring the response of hatchlings to coastal lighting on natural nesting beaches, every clutch would be monitored and the orientation of the hatchlings or the tracks they leave in the sand recorded. However, it is not possible to collect these data for every nest on the Woongarra Coast due to:

- Resource limitations for the labour intensive monitoring of every beach, all night for every night of more than three months of the hatchling emergence season.
- Pedestrian traffic at night erases the hatchling tracks; and
- Clutches emerging among dune vegetation making it difficult to find and follow hatchling tracks.

However, during the annual nightly monitoring of hatchling emergence on the Woongarra Coast during December to March, whenever adult turtles or hatchlings were recorded heading in a direction other than seaward, field notes were recorded opportunistically to summarise the events.

It was not logistically practicable to close a section within each of the public beaches of the Woongarra Coast or on Mon Repos Beach to prevent public disturbance of hatchling behaviour within constructed pit-fall beach arenas at night. Therefore, no attempt was made to quantify the orientation of individual hatchlings recorded in night-time orientation trials.

The ocean finding orientation of hatchlings was measured based on hatchling track fan measures designed by Pendoley (2005) and Kamrowski *et al.* (2015). The study design was selected to facilitate delivery of quantifiable results under repeatable conditions for hatchling turtle behaviour across numerous nights from multiple beaches that was within the capacity of the existing staffing for the project. For adult turtles, the emphasis was on capture-mark-recapture recording of tagged turtles on a nightly basis on all nesting beaches of the Woongarra Coast (Limpus *et al.* 2020).

Within the Queensland Turtle Conservation Project data recording at nesting beaches, dates are recorded for night commencing at dusk and times after midnight are recorded 24 + standard eastern Australian time for the event, i.e. 1:00 hr am is recorded as 25:00 hr.

3.1 Hatchling track fan data collection

The compass bearings required to define each hatchling track fan that were taken at nest sites at Mon Repos or at each release point at other beaches included:

- Two compass bearings, one along each of the tape measures delineating the straight line from the release point marker (= outer A and outer B bearings) (Figure 7).
- Compass bearing along the high tide line, converted to the compass bearing perpendicular to the tide line towards the sea (= seaward bearing). The compass bearing along the high tide line was taken along a 30 m tape stretched along the high tide line.

These bearings were used to calculate the following parameters:

- **Spread** of hatchling fan = outer A – outer B.
Small values of spread are indicative of strongly oriented hatchlings. If this is seaward, they are orienting normally. If this is anything other than seaward, the hatchlings are mis-oriented, possibly by light. High spread values are indicative of a poorly defined low elevation horizon, or widely dispersed bright light sources.
- **Mean direction** of hatchling fan = (outer A + outer B)/2
- **Dispersal** = minimum angle between seaward bearing and mean direction.
Dispersal provides a measure of the extent to which the hatchlings deviate from the shortest path to the sea.



Figure 7. Taking a compass bearing along a measuring tape

3.2 Natural beach emergences

It was not logistically practicable to close a large section of Mon Repos Beach from tourist visitation to allow effective test releases of hatchlings. At Mon Repos, hatchling track fans were recorded following natural hatchling emergences in the absence of human activity/torch light interference as the hatchlings departed the nest site and for which the presence or absence of the moon in the night sky was known at the time of hatchling emergence.

3.3 Controlled fan studies

Observations in previous years have identified that there is a high risk of hatchlings emerging from clutches of eggs laid at Neilson Park, Bargara and Kellys Beaches heading inland away from the sea and associated increased mortality of hatchlings. In response, the management of marine turtle nesting on the Woongarra Coast includes the relocation of clutches laid on these beaches to darker incubation sites at either Archies Beach or Mon Repos Beach. Relocation of eggs, following standard Queensland Turtle Conservation methods, require the removal of the eggs from nests with the minimum of rotation and on the same night that they were laid. If the eggs were not found on the night that they were laid, then the nest was left in situ for three weeks to allow the embryos to develop beyond the critical fragile stage when rotation of eggs causes near total death of the eggs. These clutches were then relocated to a dark beach. As a consequence of this management during the 2019-2020 breeding season, only isolated clutches of turtle eggs that had not been found when laid remained to hatch on Neilson Park, Bargara, and Kellys Beaches. As a consequence of this management, there were insufficient clutches remaining on these beaches for reliable assessment of hatchling orientation from natural nests.

Standard hatchling release locations were established at mid-beach on each of Neilson Park, Bargara Playground, Bargara Boat Ramp, Kellys and Archies Beaches ([Table 1](#)). Each site was chosen to be at approximately mid-beach on a wide beach during the early evening low tides associated with new moon phases, and to be immediately seaward of areas at each beach with known successful turtle nesting for the breeding season. It is the intention to release hatchlings at these same defined sites under similar moon phase conditions in future years to compare hatching responses at the various beaches to changing lighting management.

The results obtained from hatchling track fans recorded from naturally emerged clutches is examined independently from those recorded in the controlled fan studies.

Table 1. Location of standard hatchling release points on Woongarra Coast for hatchling orientation studies.

BEACH	RELEASE LOCATION	LATITUDE	LONGITUDE
Neilson Park	Opposite playground & beach entrance	-24.8063°	152.4572°
Bargara: Playground Beach	Opposite barbeque shelters	-24.8133°	152.4635°
Bargara: Boat Passage Beach	Opposite boardwalk & barbeque shelter	-24.8144°	152.4646°
Kellys Beach	Opposite lifesaving base	-24.8256°	152.4666°
Archies Beach	Opposite walking entrance & hatchery cage	-24.8293°	152.4680°

Hatchling track fans are mapped for groups of 30 loggerhead hatchlings released from these standard mid-beach release locations. These were recorded using the following protocols:

- Hatchlings were released after dark on nights during the monthly new moon cycles when no moon was visible above the distant horizon.
- Hatchlings were collected from naturally emerging clutches at Mon Repos Beach, usually between 20:00 to 20:30 hr, stored in a dark bucket and transported by road to each beach for the respective trials. All trials were completed within three hours of the hatchlings being collected.
- Once at a study beach, a group of 30 active hatchlings were counted into a second bucket.
- The release point was marked with a plastic peg and the bucket with 30 hatchlings was up-ended over the peg ([Figure 8](#)).
- With all torches turned off, the bucket was removed, and the hatchlings allowed to run for 2 to 3 minutes, responding to the surrounding light horizons. The recorders waited stationary in the dark at least 5m laterally along the beach from the release point.
- After 2 minutes, torches were turned on and recorders moved quickly to locate the outer most hatchlings as they fanned out from the release point. A plastic peg was placed to mark the location of each outermost hatchling.
- Measuring tapes were laid on the ground from the release point to each outer markers and compass bearings from the release point recorded.
- At the same time, a recorder collected and counted the hatchlings and returned them to the bucket.
- Only one release of hatchlings was made at each beach on any one night.

At the completion of all releases of hatchlings for the controlled fan studies for the night, the hatchlings were released on Archies Beach to allow their dispersal to the sea.



Figure 8. Preparing to release a group of 30 hatchling loggerhead turtles for ocean finding trials on nights with no moon from a defined location at each beach.

4. RESULTS

4.1 Opportunistic records of disrupted ocean finding behaviour

Field notes summarising disrupted ocean finding behaviour recorded on the Wongarra Coast during the 2019-2020 turtle breeding season.

4.1.1 Mon Repos Beach in front of Turtle Sands Caravan Park

Hatchling turtles were recorded heading inland towards the lights of the Turtle Sands Caravan Park on five occasions from Flatback nests and on seven occasions from Loggerhead nests.

Flatback turtle, *Natator depressus*

1/01/2020: No moon, scattered cloud; prominent sky glow over Bargara, seaward horizon difficult to distinguish for the human eye:

- Nest on the top of dune in grass, adjacent to trees, adjacent to sector 17 post,
- hatchling found after daylight wandering among the camps behind sector 16-17 area where a Flatback clutch was emerging during the previous night,
- Hatchling released to the surf by camper.

3/01/2020: crescent moon, scattered cloud; lights on at numerous camps

- Hatchlings emerged from nest on the top of dune in grass, adjacent to trees, sector 17/17A,
- 21:45 hr: hatchling crawled into illuminated area of camp,
- 102.4 m from nest to where hatchling found in camp,
- Hatchling measured, tagged, and released.

24 January: Moonless sky with wide cloud cover

- Hatchlings from clutch of female T92631 (3rd clutch at sector 16) emerged into hatchling cage at approximately 19:30 hr,
- Bright lighting from within the Turtle Sands Caravan Park at a camp immediately inland of the cage,
- Hatchlings were drawn to the light of the camp and crowded against the inland side of the cage.

24 January: Moonless sky with wide cloud cover

- Second emergence for night of hatchlings from clutch of female T92631 (3rd clutch at sector 16) released after weighing and measuring .
- 17 hatchlings released on beach in sector 14A.
- 1 hatchling headed south towards Bargara.

25 January: Moonless sky with wide cloud cover

- Hatchlings from clutch of female QA90747 (2nd clutch at sector 16C) emerged at approximately 19:45 hr,
- Bright lighting from within the Turtle Sands Caravan Park at camps immediately inland of the cage,
- Approximately one third of the emerging hatchlings ran towards the lights of the camps. They were attracted back out of the Caravan Park by staff using head spots directed towards the hatchlings, bringing them back to the seaward crest of the dune where they were collected and released at a darker area of the beach.

Loggerhead turtle, *Caretta caretta*

19 January: no moon, scattered cloud, prominent sky glow over Bargara.

- approximately 21:30 hr, Loggerhead hatchling found in camp adjacent to Turtle Sands Toilet Block.

21 January: no moon, scattered cloud, prominent sky glow over Bargara.

- Sector 16B/C,
- early evening: 5 hatchlings found in camp adjacent to Toilet Block.
- at approximately midnight, following the emergence of hatchlings from a different clutch being viewed by a tour group, 4 hatchlings observed walking back to the beach from the Turtle Sands Caravan Park towards the lights of the tour group.

25 January: Moonless sky with approximately 50% cloud cover.

- Natural emergence 16A /16 prior to 2530hr,
- Hatchlings from an emerged clutch located in the front of the dunes were observed going in various directions,
- The tracks in some areas led amongst thick vine. Some were observed heading inland towards the caravan park, but were unable to be followed due to the ground vegetation,
- It appeared that most of the hatchlings did go towards the ocean, but there were tracks "going in all directions" inland as well.
- It was reported that the lights of the caravan park were quite bright during the earlier part of the night, but no lights were on when the event was observed.

26 January: Moonless sky with wide cloud cover

- Hatchlings from nest at sector 16B emerged at approximately 21:40 hr,
- There was bright lighting from within the Turtle Sands Caravan Park at camps immediately inland of the nest.
- Approximately 30 emerged hatchlings were collected from among the illuminated area of the camps. Collected by members of the public and released to the shore line.
- Approximately 30 min later, additional tens of hatchlings were similarly collected within the camp area and released to the beach by the public.

30 January: Crescent moon, sky clear

- Hatchlings from nest on top of the dune at sector 16B/16C emerged prior to 24:00 hr.
- A circle of hatchling tracks emerging from an area which was further encircled by vegetation. Emergence site was located after 25:00hr.
- Tracks milled around the top of the dune, with most of them finally heading towards the ocean. However, there were a number (hard to tell how many) that headed inland towards the caravan park.
 - o 2 hatchlings were discovered in the grass at 30 m towards the caravan park at 24:30hr.
 - o a third hatchling found 40.20m from nest within the caravan park grounds at 25:30hr at compass bearing 204° from the nest.
- Hatchlings had to go up over a rise to enter the caravan park, then the elevation fell away into a swale.
- It was noted that while looking for hatchlings at 25:00hr, no caravan park lights were visible. **Only light was from the Bargara sky glow or from the sky glow from Bundaberg directly behind the nest was obvious.**
- 40 hatchlings were released at 26:05 from an area adjacent to the nest.

2 February: Crescent moon, sky clear.

- 2 Hatchling tracks from nest on top of the dune at sector 17 heading towards cabin light in Turtle Sands Caravan Park,
- Compass bearings of tracks from the nest = 248° and 222° (1 hatchling recovered and released to sea).

11 February: Waning ~full moon, scattered cloud

- Numerous hatchling tracks found at daylight from a nest on top of the dune at sector 17C heading towards a cabin whose lights had been left on during the night within Turtle Sands Caravan Park,
- Dog tracks around the fresh hatchling tracks,
- Hatchling fan compass bearings: 224° and 22°.

4.1.2 Mon Repos Beach

Given the difficulty of monitoring the behaviour of hatchlings emerging from every clutch of hatchlings on Mon Repos Beach, these observations provide an unquantified identification of the disruption of hatchling ocean-finding behaviour on Mon Repos Beach, the “darkest” beach on the Woongarra Coast.

Prior to 2003, there are no field records of naturally emerging hatchlings crossing the beach from the seaward side of the frontal dunes on Mon Repos Beach and heading in a direction other than seaward (Limpus, 1971; Limpus and Kamrowski, 2013). Since 2003, The sky glow from Bargara (2.4 – 3.1 km from the CBD to Mon Repos Beach) with additional sky glow from Bundaberg (10 km from CBD to Mon Repos Beach) on nights when there is no moon visible is disrupting the ocean-finding behaviour of hatchlings along the length of Mon Repos Beach. In the extreme, hatchlings that have already entered the surf, return back out of the water to head inland towards the sky glow over Bargara.

Loggerhead turtle, *Caretta caretta*

19 January: no moon and scattered cloud

- 12 hatchlings released from research at Sector 14 mid beach and led to water with the “tunnel of light” (a tourist activity that guides hatchlings to the water using torch light) at approximately 21:30hr,
- Torches turned off as hatchlings were reaching the wave wash and left in “darkness”,
- Very prominent sky glow over Bargara and the seaward ocean horizon indistinct to human vision.
- After approximately 10 min, the location of the hatchlings was checked with torches,
- Tracks indicated that as soon as the torches had been turned off, 5 hatchlings turned to crawl back across the beach towards Bargara with 1 was crawling up the beach towards the dune.

20 January: Moonless sky with approximately 40% cloud cover

- Cage on clutch for female T92631, 2nd clutch at sector 9C,
- After clutch emerged in cage, ten hatchlings collected and sent to lab for weighing and measuring
- The remaining hatchlings were released by removal of the cage and all lights turned off. After several minutes, lights were turned on so the team members could walk away without walking on hatchlings.
 - o These hatchlings were all heading along the beach towards the sky glow of Bargara – travelled at least 5m. After collection, these hatchlings were led to the surf using a torch.
- The 10 hatchlings on release in sector 14A at 23:45 hr also headed south along the beach towards the sky glow of Bargara.

20 January: Moonless sky with scattered variable cloud cover.

- Tracks from two separate clutches on north beach were recorded heading south towards Bargara instead of seaward across the beach,

- o Sector -1A/B: tracks from an entire emerged clutch veered south along the dune towards Bargara,
- o Sector 8B/9: tracks from an entire emerged clutch veered south along the top of the dune.

25 January: Moonless sky with approximately 50% cloud cover 2600hr

- Cage on clutch for female QA57243, 2nd (Partial) clutch at sector 16,
- After clutch emerged in cage, ten hatchlings collected and sent to lab for weighing and measuring
- The remaining hatchlings (~30) were released by removal of the cage and for a few minutes the hatchlings were directed seaward by torch light. After which the team then left.
- On arrival back at the site ~ 2700hr, it was noted that a vast majority of the hatchlings veered south along the slope of the dune towards the glow of the Bargara lights. However, no hatchlings were recorded still on the beach. Note it was low tide.
- The 10 priority hatchlings on release closer to the water in sector 15 at 26:45 hr showed no disorientation.

27 January: Moonless sky with wide cloud cover

- Hatchlings from nest on top of the dune at sector 18 emerged at approximately 21:00 hr,
- A circle of hatchling tracks around a nest from which hatchlings had emerged; there was no standard fan of hatchling tracks radiating out from the nest.
- At least 3 sets of tracks headed westward towards the DES tourist car park.
- The majority of the tracks eventually headed towards the ocean.

4.1.3 Oaks Beach

On nights when there is no moon visible, the light spill from street lights up to 190 m from the beach is disrupting the ocean-finding behaviour of hatchlings on Oaks Beach. Hatchlings that have already entered the surf are being drawn back to the beach to head inland towards the street lights. The LED streetlights recently installed by ERGON appeared to strongly contribute to the disrupted ocean-finding behaviour of the hatchlings.

Loggerhead turtle, *Caretta caretta*

22/1/2020: No moon, cloud cover to west; falling low tide; prominent light from street lights

- ~23:45 hr: 24 hatchlings released on beach following a nest excavation,
- When released on sand at mid beach, all oriented to crawl landward towards the dune.
- Volunteers used torch light to lead them into the water.
- 24:15 hr: checked the release site & found that most of the hatchlings had returned out of the water and headed back to the dunes. Collected the hatchlings and released them in the water.
- 25:12 hr: Repeated this rescue of the hatchlings from the dune area one more time. Large area of wet reflective sand with light reflected off cloud cover on the western horizon.
- 07:00 am: 6 dead/dying hatchlings at water's edge of the incoming tide. Some tracks seen heading into the dunes.

02/02/2020: half-moon, scattered cloud, low tide rising

- early evening before moon rise: 85 hatchlings emerged from nest at sector 11 on southern side of rock wall:
- nest site found by following back on the few tracks to the sea.

- At 22:30 hr, residents at 81 Sea Esplanade, Burnett Heads (cnr Miller St. & Esplanade) found approximately 20 hatchlings on the grass at the street corner adjacent to a white car illuminated by the yellow street light – **130 m from nest.**
- Hatchlings released at southern dark end of beach.
- ~23:00 hr: volunteers searched the area and found 1 hatchling walking south along Sea Esplanade after the moon had risen.
- ~26:00 hr: 1 hatchling found on road at corner of Scott St & Sea Esplanade under the recently installed “white” street light – **190 m from nest.**
- 26:10 hr: 2 more hatchlings at the same site.
- 27:30 hr: 2 more hatchlings found under the street light.
- Next morning at ~08:30 hr: 3 hatchlings found dead in the middle of the road adjacent to car park at southern end of Oaks Beach.
- **Hatchlings had headed inland and dispersed over 420 m of Sea Esplanade in response to the bright lights from 2 street lights, including one of the newly installed ERGON lights.**

14/2/2020: No moon, cloud cover to west; falling low tide; prominent light from street lights

- ~23:45 hr: 24 hatchlings released on mid beach from nest excavation and the hatchlings headed inland towards the street light.

4.1.4 Neilson Park

Most clutches laid on Neilson Park Beach were relocated to a dark beach on the night that the eggs were laid to minimise the negative impact of coastal development lighting on hatchling ocean-finding behaviour. Only isolated clutches remained to hatch on Neilson Park Beach.

On nights when there is no moon visible, the light spill from playground lighting, street lights and caravan park lights is disrupting the ocean-finding behaviour of hatchlings on Neilson Park Beach. Hatchlings that have already entered the surf can be being drawn back to the beach to head inland towards the lights.

Loggerhead turtle, *Caretta caretta*

22/01/2020: No moon, wide cloud cover; prominent light from roads & caravan park, seaward horizon difficult to distinguish.

- natural nest left on Neilson Park Beach, northern end of beach below slope area; laid 1 Dec 2019
- Observations at 29:00 hr (Sharon P.): Tracks from numerous hatchlings that headed south and zigzagged & circled on the beach in front of southern walkway from beach to the playground,
- Hatchlings appear to have left the beach to the surf – probably at dawn.

4.1.5 Bargara

Most clutches laid on both Bargara beaches were relocated to a dark beach on the night that the eggs were laid to minimise the negative impact of coastal development lighting on hatchling ocean-finding behaviour. Only isolated clutches remained to hatch on the Bargara beaches.

On nights when there is no moon visible, the light spill from the CBD, walking track lights, street lights and parkland lighting is disrupting the ocean-finding behaviour of hatchlings on Bargara.

Loggerhead turtle, *Caretta caretta*

16 Jan 2020, Boat Passage: No moon, light cloud cover; prominent light from Bargara CBD.

- clutch laid on ~24-25 November on open beach area,
- 1 hatchling found wandering on footpath behind the beach and opposite 41 Esplanade.
- When released in the surf, this hatchling kept returning to shore towards the CBD lights; eventually released well out in the water.
- The nest was located later in the night with multiple tracks “going in circles-but leading nowhere”.
- 1 dead hatchling found further down the beach; depredated by crab.

4.1.6 Adult turtle ocean-finding behaviour

Kellys Beach: Loggerhead turtle, *Caretta caretta*

26/01/2020: No moon, seaward horizon difficult to distinguish

- **QA93624**, at completion of nesting the turtle headed along the beach towards the lights of *Don Pancho* Motel.
- Turtle led to water using a torch.

09/02/2020: Full moon, overcast

- **QA86532:** nested at the foot of the ramp into Kellys Beach car park. At completion of nesting at ~20:00 hr turtle headed inland towards the lagoon and the reflection of the street lights off the water surface.
- Turtle led to water using a torch.

4.2 Orientation of hatchlings from natural nests

4.2.1 Mon Repos Beach

The number of sampled clutches was restricted to measurements of tracks from naturally emerged clutches for which there was certainty that the hatchlings had not been disturbed by immediately adjacent human activity and that the hatchlings had emerged while there was no moon visible in the sky. For the sampled clutches, 100% of the hatchlings headed seaward ([Table 2](#), [Figure 9](#)), irrespective of the moon phase.

While the differences are not statistically significant, hatchlings from sampled naturally emerging clutches on Mon Repos Beach, while heading seaward, dispersed more southward towards the sky glow over Bargara on nights when the moon was not visible than on nights when the moon phase was greater than a half moon or when hatchlings emerged during daylight hours ([Table 2](#); [Figure 9](#)).

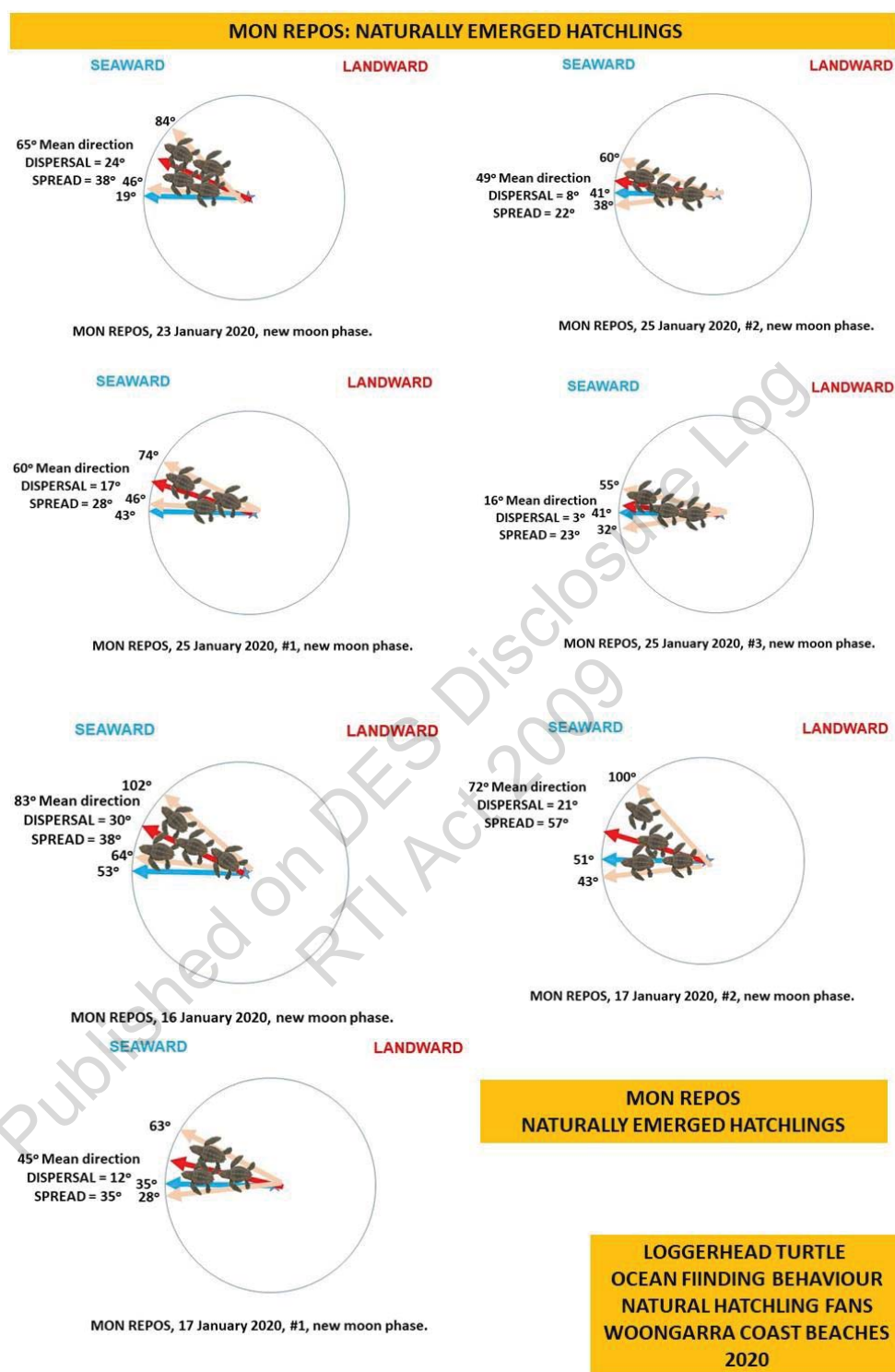


Figure 9. Sample of Loggerhead (*Caretta caretta*) hatchling track fans recorded on Mon Repos Beach during the 2019-2020 breeding season.

Blue arrow denotes the bearing of the most direct line to the ocean (seaward); red arrow denotes mean direction of fan; pink arrows define the outer hatchling fan angles. Magnetic north (0°) is at the bottom of each diagram.

Table 2. Summary of ocean finding behaviour of loggerhead hatchlings that naturally emerged from nests on Mon Repos Beach during January – February 2020.

Parameter	Mean $\pm$ SD (degrees)	Range (degrees)	Sample size
Daylight : when there should be no impact from light horizons			
Spread	47.3 $\pm$ 46.4	7 – 98	3
Dispersal	6.0 $\pm$ 11.1	-6 – 16	3
Night, full moon : conditions when altered light horizons are expected to not impact			
Spread	37.2 $\pm$ 24.2	8 – 132	25
Dispersal	9.0 $\pm$ 19.1	-12 – 93	25
Night, no moon : conditions when altered light horizons are expected to impact			
Spread	40.4 $\pm$ 22.1	12 – 114	38
Dispersal	12.6 $\pm$ 12.1	-9 – 52	38

This sampling of naturally emerging clutches for quantified hatchling track fans from throughout the length of Mon Repos beach, did not include examples of clutches from which hatchlings headed inland as recorded during opportunistic recording of disrupted ocean finding behaviour at Mon Repos Beach (section 4.1 above).

4.3 Orientation of hatchlings released on Woongarra Coast beaches

Neilson Park: 100% of each group of 30 hatchlings released on 5 separate nights headed inland away from the sea ([Figure 10](#)). Hatchling ocean finding behaviour on this illuminated beach was characterised by a wide spread and high dispersal in a landward direction ([Table 3](#), [Figure 10](#)).

Bargara Playground Beach: 100% of each group of 30 hatchlings released on 5 separate nights headed inland away from the sea ([Figure 11](#)). Hatchling ocean finding behaviour on this illuminated beach was characterised by a wide spread and high dispersal in a landward direction ([Table 3](#); [Figure 11](#)).

Bargara Boat Passage Beach: 100% of each group of 30 hatchlings released on 5 separate nights headed inland away from the sea ([Figure 12](#)). Hatchling ocean finding behaviour on this illuminated beach was characterised by a narrow spread but high dispersal in a landward direction ([Table 3](#); [Figure 12](#)).

Kellys Beach: 100% of each group of 30 hatchlings released on 5 separate nights headed inland away from the sea ([Figure 13](#)). Hatchling ocean finding behaviour on this illuminated beach was characterised by a wide spread and high dispersal in a landward direction ([Table 3](#); [Figure 13](#)).

Archies Beach: 100% of each group of 30 hatchlings released on 5 separate nights headed seaward ([Figure 14](#)). Hatchling ocean finding behaviour on this illuminated beach was characterised by a wide spread and very low dispersal in the seaward direction ([Table 3](#); [Figure 14](#)).

Table 3. Summary of Ocean finding behaviour of loggerhead hatchlings released from standard sites on Woongarra Coast Beaches during January – February 2020

Parameter	Mean $\pm$ SD	Range	Sample size
Neilson Park			
Spread	88.4 $\pm$ 26.0	43 – 108	5
Dispersal	152.8 $\pm$ 14.1	133 – 170	5
Bargara, Playground Beach			
Spread	101.6 $\pm$ 20.6	82 – 124	5
Dispersal	146.8 $\pm$ 27.3	107 – 174	5
Bargara, Boat Ramp Beach			
Spread	45.2 $\pm$ 16.9	28 – 63	5
Dispersal	168.0 $\pm$ 13.2	149 – 183	5
Kellys Beach			
Spread	95.8 $\pm$ 25.0	70 – 130	5
Dispersal	160.4 $\pm$ 6.3	154 – 171	5
Archies Beach			
Spread	96.0 $\pm$ 22.7	60 – 121	5
Dispersal	3.8 $\pm$ 9.4	-8 – 13	5

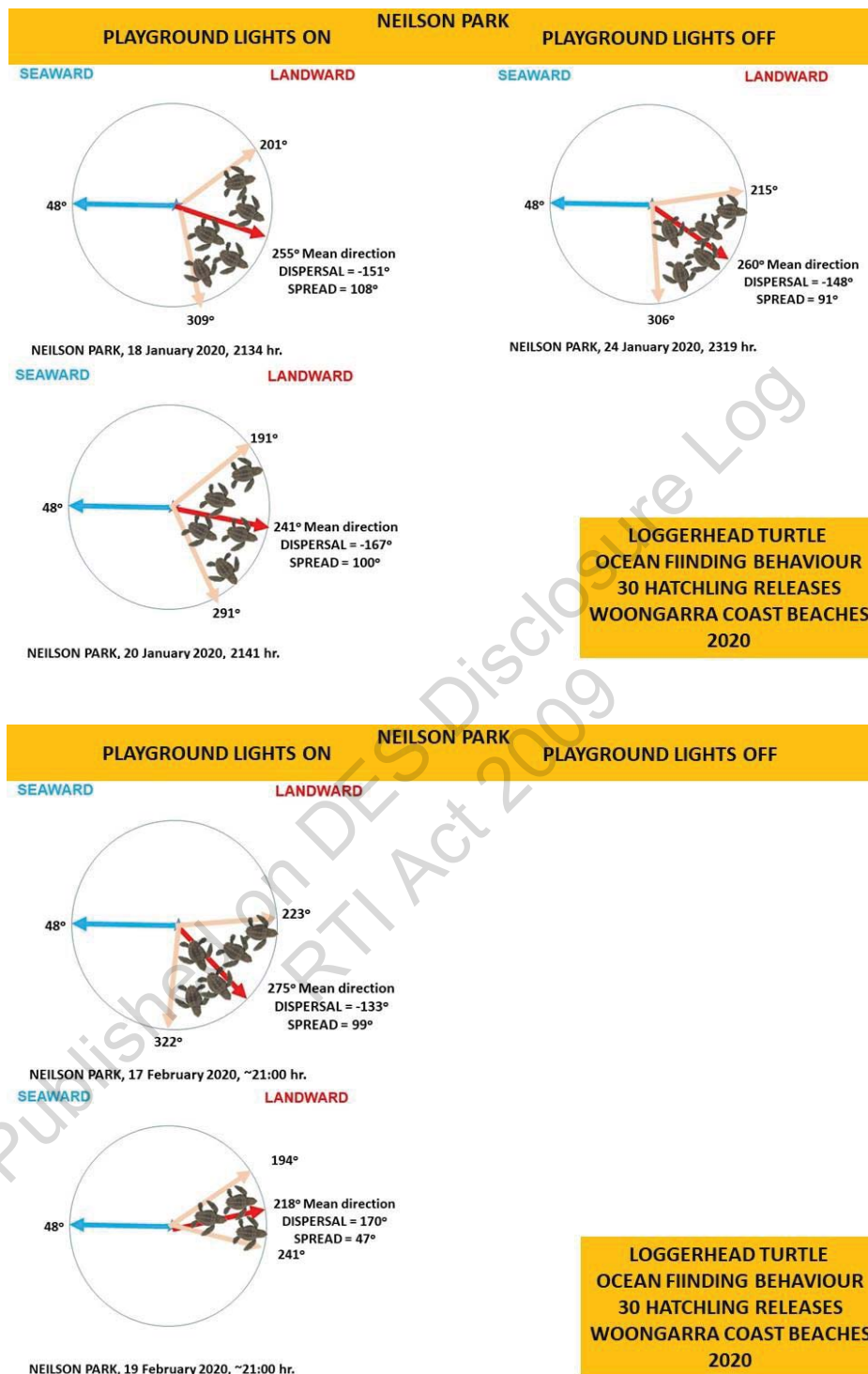


Figure 10. Loggerhead hatchling ocean finding behaviour defined by hatchling track fans at Neilson Park.

Blue arrow denotes the bearing of the most direct line to the ocean (seaward); red arrow denotes mean direction of fan; pink arrows define the outer hatchling fan angles. Magnetic north (0°) is at the bottom of each diagram.

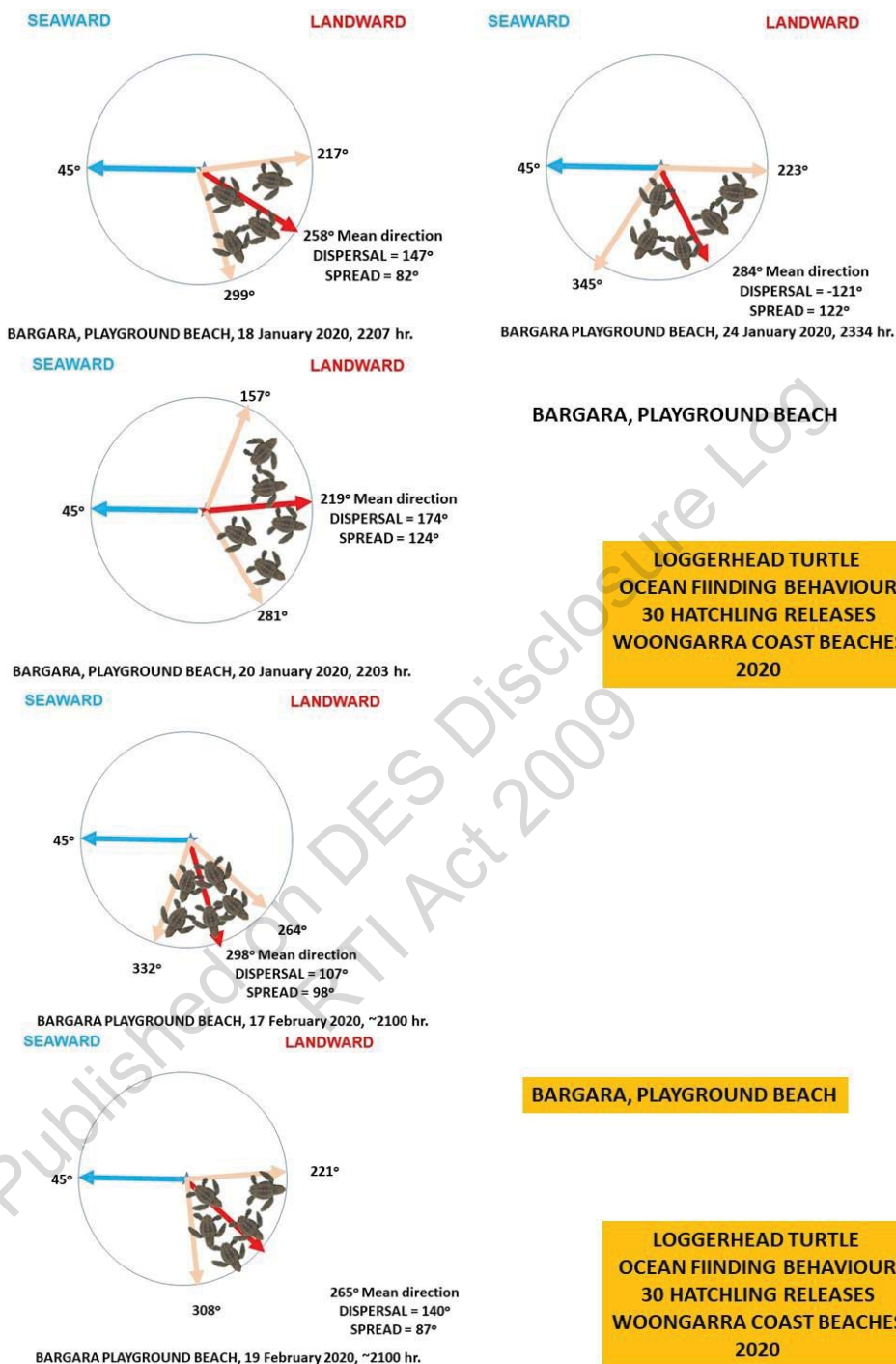


Figure 11. Loggerhead hatchling ocean finding behaviour defined by hatchling track fans at Bargara Playground Beach.

Blue arrow denotes the bearing of the most direct line to the ocean (seaward); red arrow denotes mean direction of fan; pink arrows define the outer hatchling fan angles. Magnetic north (0°) is at the bottom of each diagram.

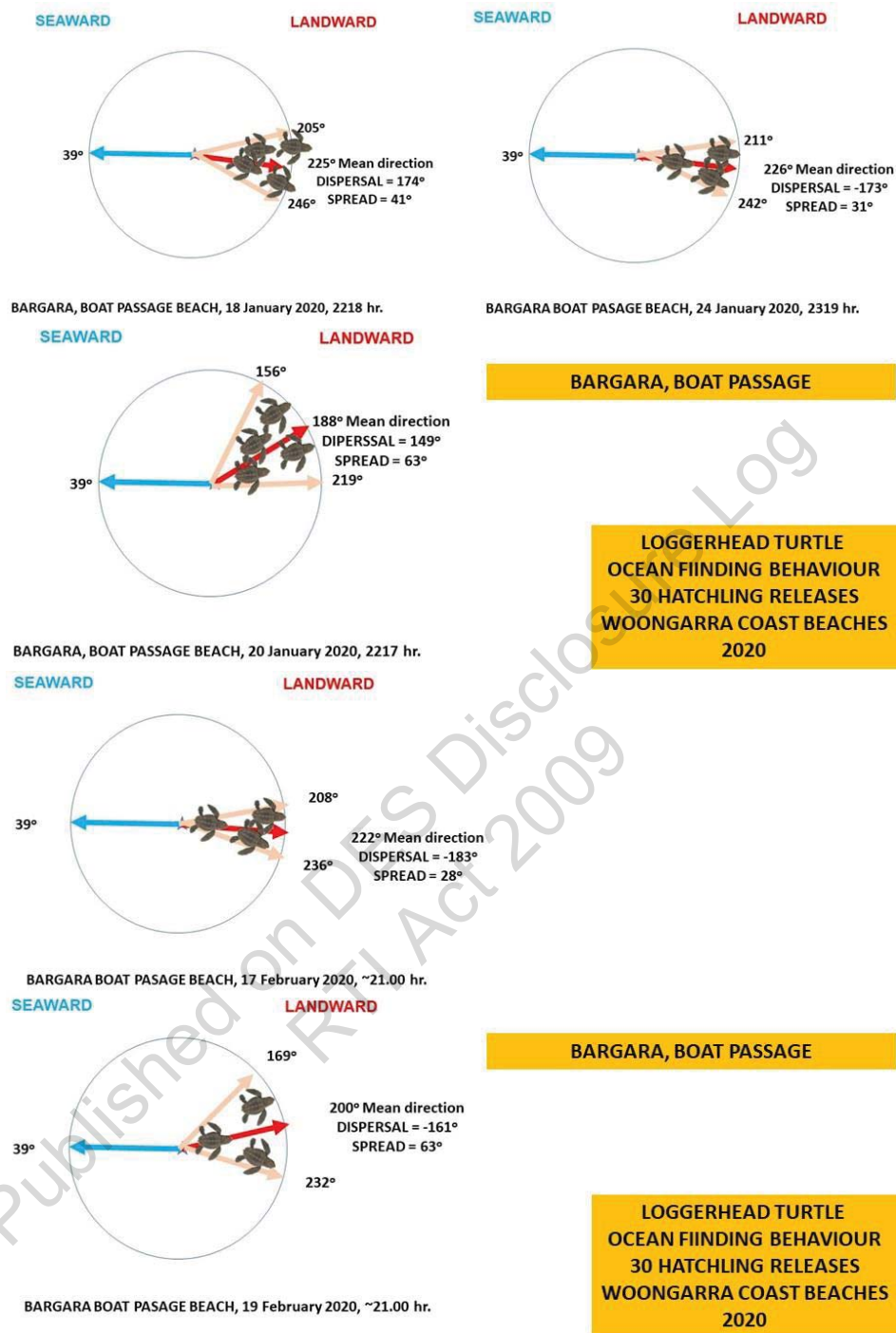


Figure 12. Loggerhead hatchling ocean finding behaviour defined by hatchling track fans at Bargara Boat Passage Beach.

Blue arrow denotes the bearing of the most direct line to the ocean (seaward); red arrow denotes mean direction of fan; pink arrows define the outer hatchling fan angles. Magnetic north (0°) is at the bottom of each diagram.

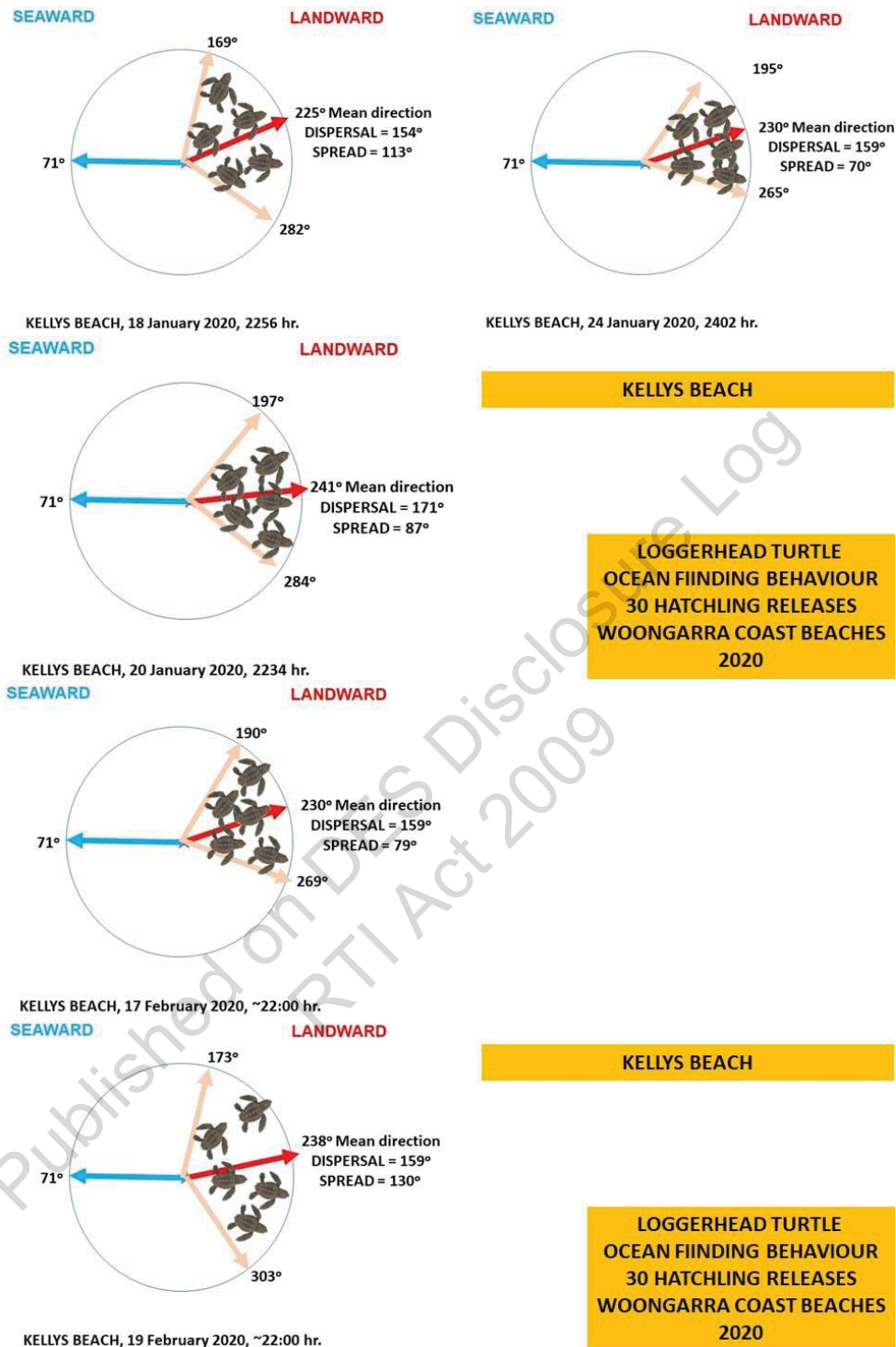


Figure 13. Loggerhead hatchling ocean finding behaviour defined by hatchling track fans at Kellys Beach.

Blue arrow denotes the bearing of the most direct line to the ocean (seaward); red arrow denotes mean direction of fan; pink arrows define the outer hatchling fan angles. Magnetic north (0°) is at the bottom of each diagram.

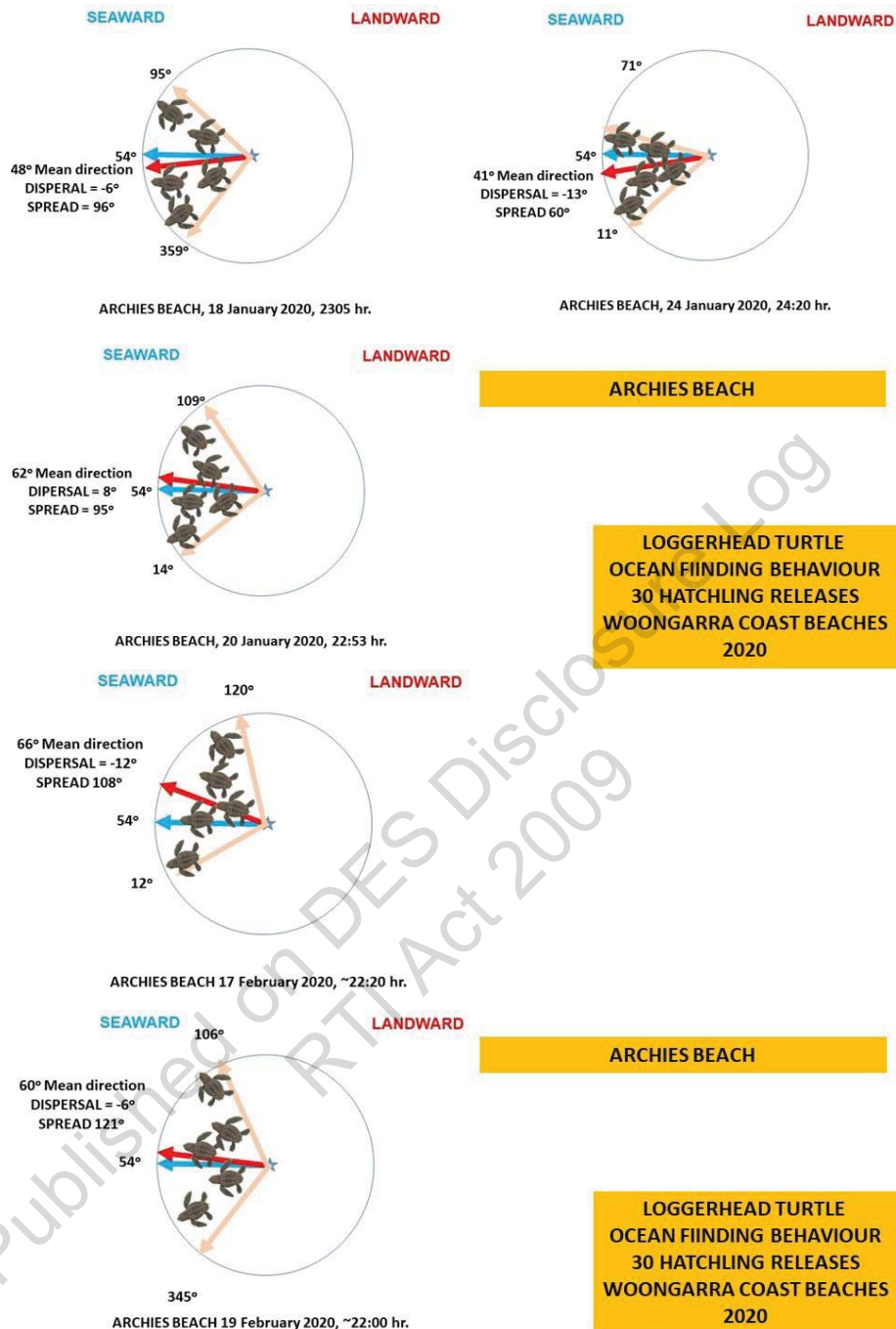


Figure 14. Loggerhead hatchling ocean finding behaviour defined by hatchling track fans at Archies Beach.

Blue arrow denotes the bearing of the most direct line to the ocean (seaward); red arrow denotes mean direction of fan; pink arrows define the outer hatchling fan angles. Magnetic north (0°) is at the bottom of each diagram.

5. CONCLUSIONS

The study has identified that the ocean finding behaviour of hatchling marine turtles on the Woongarra Coast is being negatively impacted by individual light sources directly visible to the hatchlings on the beach and by the cumulative sky glow from coastal development along the Woongarra Coast.

Opportunistic observations of disrupted marine turtle ocean-finding behaviour by coastal lighting provided an unquantified identification of conservation issues relating to lighting management on the Woongarra Coast:

- hatchlings were recorded heading inland to directly visible light sources behind the nesting areas at Oaks Beach, Mon Repos (Turtle Sands Caravan Park), Neilson Park, and Bargara Beaches with associated increased mortality of hatchlings.
- hatchlings that had entered the sea were drawn back to shore to crawl inland towards the sky glow from Bargara, Bundaberg, and Burnett Heads and/or the direct light from street lights and other coastal lighting at Oaks, Mon Repos, and Bargara Beaches.

Quantified observations of Loggerhead turtle hatchling ocean-finding behaviour following natural emergence from nests on Mon Repos showed:

- while the differences are not statistically significant, hatchlings from sampled naturally emerging clutches on Mon Repos Beach, when heading seaward, dispersed more southward towards the sky glow over Bargara on nights when the moon was not visible compared to nights when the moon phase was greater than a half moon.

Quantified observations of Loggerhead turtle hatchling ocean-finding behaviour following releases over five separate nights when no moon was visible showed:

- 100% of hatchlings released at standardised release sites on the brightly illuminated beaches at Neilson Park, Bargara Playground, Bargara Boat Passage and Kellys Beach headed inland away from the sea.
- Hatchlings on the darker Archies Beach:
 - headed seaward but with indications of partial disruption of ocean finding behaviour as indicated by increased spread of the hatchling track fan angles relative to those measured at Mon Repos
 - dispersed towards bright light sources away from a more direct path to the sea

Collectively these observations indicate that the Woongarra Coast is excessively impacted by coastal lighting that is disrupting hatchling turtle ocean-finding behaviour.

In particular, Neilson Park, Bargara and Kellys Beaches can no longer be considered safe beaches for successful marine turtle hatchling production.

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