Marine Turtle Nesting Populations: Curtis Island and Woongarra Coast Flatback Turtles, 2015-2016 breeding season

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Cover photographs:

Scenes from the census of nesting flatback turtles, *Natator depressus*, at Curtis Island and Woongarra Coast, November 2015 - February 2016.

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MARINE TURTLE NESTING POPULATIONS: CURTIS ISLAND AND WOONGARRA COAST FLATBACK TURTLE NESTING STUDY, 2015-2016 breeding season.

Colin J. LIMPUS, Maree McLAREN, George McLAREN, Cathy GATLEY, Duncan LIMPUS, Kelsie O'Leary and Trevor TURNER.

Executive summary

- This report summarises the results of monitoring the eastern Australian flatback turtle nesting population at two representative index beaches during the 2015-2016 breeding season:
    - South End Beach, Curtis Island: a moderate sized flatback population with 44 nesting females and 1 loggerhead turtle recorded during peak nesting from 24 November – 7 December.
    - Woongarra Coast: a small flatback population with 7 nesting females for the entire summer along with 387 loggerhead and 1 green turtles.

- This season's census data continues to indicate that the eastern Australian flatback turtle stock breeding at Curtis Island and Woongarra Coast has had a stable breeding population over recent decades – spanning about one generation for this species.

- Eastern Australian nesting flatback turtles continue to display a high fidelity to specific nesting beaches with most turtles returning to lay successive clutches of eggs at the same beach, both within and between nesting seasons.

- These turtles showed normal demographic features for the eastern Australian flatback turtle stock:
    - At Curtis Island, nesting females had a mean curved carapace length = 94.0 cm (range; 83.6 – 99.4), laid on average 56.8 large eggs per clutch and laid successive clutches at a mean interval of 13.8 days. They returned on average at 2.8 year intervals between breeding seasons.
    - On the Woongarra Coast, nesting females had a mean curved carapace length = 94.1cm (range; 90,2 - 96.3), laid an average of 3.9 clutches of eggs per season and 53.3 eggs per clutch. Turtles laid successive clutches at 14.9 day intervals. They returned on average at 3.2 year intervals between breeding seasons.

- There was variable incubation success and subsequent hatchling emergence from nests:
    - At South End Beach, the season had an overall hatchling emergence success of 86% from clutches laid at mid-season and 84% from across the entire nesting season.

    - At South End Beach, clutches laid during the mid season nesting, 24 November – 7 December, had a hatchling emergence success of 86%, in comparison to 79% from clutches laid across the entire nesting season.
    - On the Woongarra Coast, the hatchling incubation success and emergence success from undisturbed nests, measured across the entire season, was low respectively at 65% and 48.3%.
- The incubation to emergence period for flatback clutches was consistent with generally mild summer temperatures:
    - 48.0 days at South End Beach.
    - 55.1 days on the Woongarra Coast.
    - Existing management at both nesting areas is maintaining flatback turtle clutch loss to predators such as pigs, dogs and foxes at a low level.
- Hatchlings from a number of clutches that emerged from nests on South End Beach, Curtis Island displayed disrupted ocean-finding behaviour and headed away from the sea and towards the inland light horizon associated with Gladstone and Port Curtis.

CURTIS ISLAND AND WOONGARRA COAST FLATBACK TURTLE NESTING STUDY, 2015-2016 breeding season.

INTRODUCTION

This study has been conducted under an agreement between the Gladstone Ports Corporation (GPC) and the Queensland Department of Environment and Heritage Protection (EHP) to continue monitoring of flatback turtle (*Natator depressus*) nesting and hatching at the South End Conservation Park, Curtis Island for the 2015-16 nesting season. The study has been expanded to include the flatback turtle nesting population on the Woongarra Coast adjacent to the Port of Bundaberg.

The biology of the eastern Australian flatback turtle management unit has been reviewed by Limpus (2007) and Limpus *et al*. (2013a). Curtis Island and the Woongarra Coast encompass two of the index nesting areas that are monitored annually for this species.

South End Beach, Curtis Island (23º45'S, 151º18'E), supports a medium density nesting population of the flatback turtle (*Natator depressus*), a turtle found only in Australian continental shelf waters. This large sand island situated off the coast of Gladstone extends for ~100km to the north. The small South End village lies on the south-eastern tip of the island (Figure 1). The majority of the turtle nesting for the island occurs on the adjacent South End Beach which is approximately 5 km in length (Figure 1B). In some years, there is occasional nesting by green turtles (*Chelonia mydas*) and/or loggerhead turtles (*Caretta caretta*). While the rookery has been monitored intermittently since 1969 (Limpus, 1971a), it has been monitored annually since 1994 with support from the Gladstone Ports Corporation (Limpus *et. al*. 2006, 2013a).

Mon Repos (24º48'S, 152º27'E), lying 13 km east of Bundaberg in south Queensland is the largest of eight small sand beaches formed by a series of discontinuous Holocene sand deposits interrupting the 23 km of rocky coastline between the mouths of the Burnett and Elliott Rivers (Limpus *et al.* 2006) (Figure 1B). The Woongarra Coast, encompassing Mon Repos and adjacent beaches, supports a minor nesting population of flatback turtles. This most southerly nesting population for the species in eastern Australia has been monitored annually since the 1968-1969 breeding season (Bustard and Limpus, 1969; Limpus, 1971a,b; Limpus *et al.* 1983b, 1984, 2013a). In addition, these beaches have been the primary site for study of loggerhead turtle nesting biology in eastern Australia since 1968 (Limpus, 1985, Limpus and Limpus 2003; Limpus and Reimer 1994; Limpus *et al*. 2013b). Occasional green turtles also nest on these beaches (Limpus et al. 2013c).

Low density flatback turtle nesting occurs on all beaches along the coast between the Woongarra Coast and Curtis Island. See, for example, Appendix 1 for a summary of flatback turtle breeding at Moore Park Beach during the 2015-2016 breeding season. The Woongarra Coast beaches (supporting a small nesting population) and Curtis Island (supporting a medium density nesting population) have the longest history of monitoring of flatback turtles in Australia.

Together these beaches serve as index beaches for monitoring the long term stability of the eastern Australian *N. depressus* stock (Limpus *et al*. 2013a).

The local Regional Councils are recognising turtle nesting beaches and have erected signs identifying South End Beach and Woongarra Coast beaches as turtle nesting habitat and providing turtle conservation advice to the public (Figure 2).

METHODOLOGY

Standard Queensland Turtle Conservation Project methodologies (Limpus *et al*, 1983a; Limpus, 1992) were followed for the project. These included:

- At Curtis Island, two standard titanium tags (manufactured by Stockbrands Australia) were applied to each turtle on the beach in the left and right axillary tagging positions, generally proximal to the last scute in the flipper closest to the body. At Woongarra Coast, each flatback turtle left the beach carrying four secure titanium tags, one applied to the axillary trailing edge of each flipper.
- PIT (Passive Integrated Transponder) tags (Parmenter, 1993) have been used as a second tagging method for identification of nesting females on the Woongarra Coast since the 1993-1994 breeding season and at Curtis Island since the 1997-1998 breeding season. The PIT tags are injected into the upper left shoulder, below the point of the carapace.
- Curved carapace length (CCL) was measured from the skin/carapace junction at the anterior edge of the nuchal scale, along the midline, to the end of the carapace using a flexible fibreglass tape measure.
- A nest tag (flagging tape ~20 cm long) with the date of laying and a tag number of the turtle (Limpus, 1985) was placed in the nest during oviposition for most clutches. The nest tag assisted in identifying the female that laid the clutch when hatchlings emerged some two months later.
- Clutches of eggs were counted and returned to their nests within two hours of being laid and with minimum rotation to avoid movement induced mortality (Limpus *et al.* 1979).
- A clutch was assessed for incubation success and hatchling emergence success by excavating the nest site, usually 24 hr after the hatchlings have crawled from the nest. A count was made of hatched eggs, unhatched eggs with embryos, unhatched eggs with no signs of embryonic development (= undeveloped egg), eggs showing signs of predation by crabs or other animals (= predated egg), live hatchlings trapped in the nest, and dead hatchlings within the nest.
    - Estimated clutch count = hatched eggs + unhatched eggs + undeveloped eggs + predated eggs'
    - Hatching success = (hatched eggs/estimated clutch count)*100 %;
    - Emergence success = (hatched eggs – [live+dead hatchlings]/estimated clutch count)*100 %.
    - Counting error, the accuracy of counting broken egg shells = estimated clutch count following hatchling emergence - clutch count made when the eggs were laid.
- Vemvo Minilog II temperature data loggers have been deployed for a number of years at turtle nesting beaches in Queensland to measure sand

temperatures at 50 cm depth at 30 minute intervals. These temperature recording instruments can record temperature continuously for up to 10 years.

- Two data loggers have been deployed on South End Beach, Curtis Island (one in the sun and one in shade). These data loggers have not been downloaded during the 2015-2016 breeding season.
- Two data loggers have been deployed on Mon Repos Beach, Woongarra Coast at standard long term recording sites: one on the northern beach at sector marker 9C and one on the southern beach in sector 14, both in open sunny areas. The data logger at sector 14 failed to maintain calibration during 2015 and was replaced in February 2016. These data loggers provide comparative temperature data across seasons measured at these standard sites.
- Four data loggers were installed, one at the front of each of the predator exclusion cages installed to protect late nesting season loggerhead clutches on Mon Repos Beach. These data loggers were installed to commence recording before the beginning of the nesting season and downloaded after the hatchling emergence of the last flatback clutch for the season.

Rescuing doomed eggs

On the Woongarra Coast, EHP in collaboration with the Queensland Department of National Parks, Sport and Racing (NPSR) conducts an annual project to rescue doomed turtle eggs laid that are considered to be at risk of flooding or erosion during incubation (Pfaller *et al.* 2008) or where coastal lighting is likely to disrupt hatchling ocean finding behaviour and cause hatchling to move inland away from the sea. Doomed clutches of eggs were relocated to safer incubation sites either higher up the dunes or to an adjacent dark beach in response to the identified threats. Eggs are relocated to artificial nests that are 55-60 cm deep with a 50 cm radius “body pit” from which surface vegetation has been cleared within 2 hours of oviposition and with the minimum of rotation (Limpus *et al.* 1979). This project to rescue doomed eggs on the Woongarra Coast is directed principally at rescuing eggs of the endangered loggerhead turtle.

Doomed flatback eggs when encountered during routine monitoring of nesting populations are also rescued in a similar manner at other nesting beaches including Curtis Island.

Curtis Island

During census nights for turtle nesting, the beach was monitored for at least two hours before high tide to about four hours after. All turtles encountered were tagged, or checked for tags and measured. Clutches at risk from flooding were relocated further up the dune within one hour of being laid and their eggs counted. The beach was also examined twice daily (at dawn and late afternoon) to count nesting crawls, to locate hatchling emergence and identify daylight nesters. A quad bike and a Polaris Ranger ATV were used to patrol the beach.

During this summer, South End Beach was monitored nightly for turtle nesting during two periods:

- 6 to 10 November 2015. Nightly census of the nesting turtles to assist in capture of 11 turtles for deployment with satellite tags as part of the GPC ERMP funded flatback turtle satellite telemetry project conducted by James Cook University.
- 24 November to 9 December 2015. The standard 2-week mid-season sampling period occurs during the last week of November and first week of December.

Outside the mid-season census period, the beach was intermittently patrolled in the early morning to record nesting crawls and associated nesting success, place nest tags in the nests and assess incubation success of recently emerged clutches.

Fox exclusion devices (FEDs) made from standard plastic garden mesh were laid horizontally at the beach surface over a series of nests to prevent foxes from digging into clutches of turtle eggs. These plastic mesh (100 mm grid size) panels were approximately 1x1 m square. They were placed over clutches of turtle eggs within 2 hours of the eggs being laid. Each mesh panel was held down by 25 x 25 x 400 mm timber pegs, one in each corner of the panel.

For each clutch protected with a FED, a clutch laid on the same or following night was left unprotected as a set of control clutches. All clutches laid during the nesting census period, both those with FEDs and the unprotected clutches, were identified using adjacent markers on the beach surface.

The beach was revisited from 16 to 29 January 2016 to assess the incubation success of clutches and to assess the effectiveness of FEDs in protecting the clutches from fox predation.

Woongarra Coast

Mon Repos beach and adjacent beaches of the Woongarra Coast were examined daily/nightly for flatback turtles during the standard summer total tagging census of loggerhead turtles from mid October 2015 until March 2016 (Limpus, 1985). A full description of the beaches and methodology used at the Woongarra Coast beaches has been described previously (Limpus, 1985; Limpus *et al*. 1983b).

All nesting flatback turtle nesting crawls were recorded on all beaches on the Woongarra coast for this season and hatchling and emergence success was assessed for all clutches.

TAGGING CENSUS RESULTS

Species

Forty-four tagged flatback turtles and one loggerhead turtle were recorded nesting during the 2015-2016 breeding season at South End Beach, Curtis Island.

Seven flatback turtles were recorded nesting along with 387 loggerhead turtles and 1 green turtle on the Woongarra Coast for the 2015-2016 summer.

Table 1 summarises the breeding history of these flatback turtles.

Nesting season

The Woongarra Coast is the only nesting area in eastern Australia where every nesting turtle is tagged for the entire breeding season and each nesting event accounted for. On the Woongarra Coast, nesting commenced on 17 October 2015 and the last nesting occurred on 16 January 2016 while the first clutch of hatchlings emerged on 14 December 2015. Hatchlings from the last clutch to hatch emerged in late March 2016.

On South End Beach, Curtis Island, local residents recorded the first nesting crawl on 22 October 2015 and the last nesting crawl on 13 January 2016. The first flatback clutch to emerge for the season was seen on 15 December 2015.

Nesting density and nesting success

Curtis Island

A total of 67 nesting crawls by *N. depressus* were recorded on South End Beach, Curtis Island during the 24 November – 7 December 2015 census survey (Figure 3). Of these, there were 45 successful beachings that resulted in clutches being laid. This equates to a 73.4% nesting success during the mid-season census period. A nesting success of 91.8% was recorded for the remaining 61 nesting crawls observed outside of the standard census period. When all nesting crawls observed for the season are pooled, the combined nesting success was 82.8%. This is a very satisfactory level of nesting success.

The mean nightly number of nesting crawls during the mid-season census period, 24 November – 7 December 2015 inclusive, was 4.43 (SD = 2.027, range = 0-8, n = 14 nights).

Members of our volunteer team recorded a substantial number of additional nesting and unsuccessful nesting events outside of the mid season nesting census period. The total number of recorded beachings was 123 tracks, but this was not the total for the entire season. Turtles coming ashore to attempt nesting during daylight hours occurred infrequently during this summer (7% of beachings occurred in daylight during the standard census period) and at a considerably lower frequency than in the previous breeding season.

Woongarra Coast

The 7 flatback turtles breeding on the Woongarra Coast made 37 nesting crawls during the entire breeding season. Of these, there were 27 successful beachings that resulted in clutches being laid. This equates to an average nesting success of 73.0% for the season. The mean nightly number of nesting crawls during the mid-season census period, 24 November – 7 December 2015 inclusive, was 0.786 (SD = 1.051, range = 0 - 4, n = 14 nights).

No flatback turtle nesting crawls occurred during daylight in the 2015-2016 breeding season on the Woongarra Coast.

Within the Woongarra Coast, flatback turtles nested only on Mon Repos Beach during this 2015-2016 breeding season.

Size of nesting females

The CCL of nesting female flatback turtles ranged 83.6 to 99.4 cm at Curtis Island and the Woongarra Coast with an overall mean of 94.0 cm at both locations (Table 2 and Figure 4).

Remigration

A total of 37 flatback turtles carrying tags applied in previous breeding seasons were recorded back at Curtis Island this breeding season (Table 1). All these remigrant turtles had been previously tagged at Curtis Island. Similarly the six remigrant flatback turtle nesting on the Woongarra Coast had been previously recording nesting on the Woongarra Coast. The majority of these turtles had returned after a two or three year remigration interval (= interval between breeding seasons) (Table 3; Figure 5).

Clutches and renesting interval

The number of eggs per clutch is summarised in Table 4 and Figure 6. Flatback turtles at Curtis Island have very similar reproductive characteristics to those recorded at the Woongarra Coast.

On the Woongarra Coast where every flatback turtle clutch was recorded for the entire breeding season, on average, the individual females laid 3.9 clutches of eggs each during the 2015-2016 breeding season (Table 4).

There were significant differences in egg diameter and egg weight among clutches at each study site.

The re-nesting interval between a successful nesting and the subsequent return to lay another clutch was 12-17 d at Curtis Island and 13-18 d at Woongarra Coast (Table 4, Figure 7). A turtle that did not lay during a nesting crawl usually returned to attempt another nesting on the same night or on the following night (Table 4, Figure 7).

Health and injuries

No nesting flatback turtles died on the census nesting beaches during the 2015-2016 season.

None of the nesting turtles at either Curtis Island or the Woongarra Coast displayed fresh or recent fractures nor were fibropapilloma tumours observed on any of these turtles. However, flatback K20380 nesting at Mon Repos had

scar tissue resembling that associated with regression of a prior fibropapillomatosis tumour.

SAND TEMPERATURES

Woongarra Coast

The sand temperature profile from the standard monitoring site on the northern end of Mon Repos Beach is summarised in Figure 8. The sand temperatures at this site was mostly below 29.3^{o}C, the pivotal temperature for flatback turtles (Limpus, 2007), throughout most of the 2015-2016 nesting season and generally cooler than recorded in recent nesting seasons. These inter-annual data highlight that with changing beach temperatures across breeding seasons, there should be variable hatchling sex ratios across breeding seasons.

Sand temperatures recorded at nest depth throughout the entire nesting season were variable between sampling sites (Figure 9). It is to be expected that with this level of temperature variability between sites on the one beach and at different times during the breeding season, there will be differences in those aspects of embryonic development that are temperature dependant: incubation period, incubation success, hatchling sex ratio.

INCUBATION SUCCESS AND HATCHLING PRODUCTION

Curtis Island

During the 24 November – 7 December 2015 census period at Curtis Island, nesting *N. depressus* dug into one clutch that had been laid earlier in the breeding season: 0.8% of beachings resulted in disturbance of an existing clutch; 1% of recorded clutches were dug into by a nesting turtle.

At Curtis Island, seven (16%) of the 45 *N. depressus* clutches laid during the census period were laid below the area of potential tidal inundation. These clutches which were at risk of loss through flooding/erosion were relocated to more secure incubation habitat higher up the dune within two hours of the eggs being laid, as part of the project's activities to increase hatchling production.

Twenty-three flatback turtle clutches were covered with FEDs immediately following the respective clutches being laid. There was no evidence of dogs or foxes having attempted to dig for eggs covered by FEDs or any control clutches not protected by a FED. No fox tracks were recorded on this beach during this breeding season. Tracks from a single dog were observed on numerous mornings during the hatchling emergence season. Two flatback clutches were dug into by a dog as the hatchlings were emerging from clutches that had been laid after the completion of the nesting census. Hatchlings were killed from one of these clutches. Dead hatchlings with bitten heads were observed at one of these nests. Trapping and/or shooting of dogs and pigs, and fox baiting by NPSR continued on Curtis Island during 2015 and appears to have been successful.

Mobs of horses and cattle walking and feeding on the dunes were observed stepping on nests. On numerous occasions, tracks from quad bikes and/or ATVs were observed passing over nests, including nests with FEDs. These activities have the potential for killing eggs and reducing hatchling production. NPSR is assessing the management of cattle and horses within the Curtis Island Regional Park and South End Regional Park.

There was good accuracy in assessing incubation success by counting the broken egg shells in the clutches from which hatchlings had emerged: mean counting error = -0.43 eggs per nest (SD = 0.815, range = -3 to +1 eggs, n = 35 clutches). This was equivalent to undercounting eggs by 0.69% per clutch examined.

For the mid-season Curtis Island clutches that successfully incubated, the mean flatback turtle incubation success for eggs was 88% and a hatchling emergence success of 86% with a mean period to emergence of 48 d (Table 5; Figure 10). There was a slightly lower incubation success (84%) and hatchling emergence success (78%) for the total clutch sample across the entire season.

The quantified orientation of hatchlings leaving the nest (hatchling fans) was recorded with only seven clutches. The quantified orientation of nesting adults as they crossed the beach to nest and returned to the sea was recorded for eight females. These data will be analysed in a separate report.

While monitoring incubation success of clutches, hatchlings tracks were recorded leading away from some natural nests and heading inland away from the sea:

- 6 January 2016, sector 3: the tracks from 50 emerged hatchlings from this nest headed inland and westwards towards the “city lights”. Three hatchlings were found dead among the inland dune vegetation the following morning.
- 26 January 2016, sector 12: the majority of the tracks from the 37 hatchlings that emerged from the nest led inland to the top of the dune and towards the “lights of Gladstone”.
- 28 January 2016, sector 7: tracks from at least 15 hatchlings out of 52 that emerged from the nest during the night and went inland. Three hatchlings, still alive but trapped in the lagoon behind the beach the following morning, were rescued and released to the sea.
- 28 January 2016, sector 0: tracks from an unquantified number of the 36 hatchlings that emerged from the nest during the night headed away from the sea towards the sky glow associated with Port Curtis. Some hatchlings travelled at least 200 m within the dune system.

Woongarra Coast

Of the 27 clutches laid by flatback turtles on the Woongarra Coast during the 2015-2016 breeding season:

- 13 flatback turtle clutches (48%) were relocated to safer incubation sites either higher up the dunes as part of the EHP project to rescue doomed eggs.

- No flatback turtle clutches were lost to erosion or flooding by high tides or cyclone storm surge or to dog/fox depredation during the 2015-2016 breeding season.
  - In the absence of management intervention through rescuing doomed eggs, it is estimated that up 13 (48%) of the flatback clutches laid on the Woongarra Coast may have been lost to erosion during the 2015-2016 breeding season.
- No flatback turtle eggs were lost through nesting turtles digging into existing incubating clutches on the beach or from feral predators.

There was acceptable accuracy in assessing incubation success by counting the broken egg shells in the clutches from which hatchlings had emerged: mean counting error = -0.14 eggs per nest (SD = 2.19, range = -7 to +5 eggs, n = 21 clutches). This was equivalent to undercounting eggs by 0.25% per clutch examined.

None of the seven females at Mon Repos produced hybrid hatchlings in any of the 28 clutches examined.

For the Woongarra Coast, 22 clutches were recorded for incubation success (Table 5; Figure 11):

- mean flatback turtle incubation success for eggs was 65% and a hatchling emergence success of 48%;
- mean period to emergence of 55.05 days.

DISCUSSION

This study has examined the flatback turtle at Curtis Island (a moderate sized nesting population) and the Woongarra Coast (including Mon Repos) (a small nesting population at the southern extremity of the breeding range) within the eastern Australian stock. Small numbers of flatback turtles nest on all the beaches between the Woongarra Coast and Curtis Island. A summary of flatback breeding during this 2015-2016 season at one of these beaches, Moore park, is attached (Appendix 1). The numbers of nesting female flatback turtles recorded at these two index sites, Curtis Island (Figure 11a) and Woongarra Coast (Figure 11b) during this 2015-2016 breeding season an seasons past are consistent with the conclusion that the nesting population has been relatively stable at these sites across recent decades (Limpus *et al*. 2013a).

Existing management at both nesting areas is maintaining flatback turtle clutch loss to predators such as pigs, dogs and foxes at a low level.

A comparison of the period from laying to hatchling emergence to the beach surface (Figure 10A) indicates that incubation is generally shorter at Curtis island than at the Woongarra Coast throughout the breeding season. This is expected to be primarily due to the cool beach temperatures at nest depth at Mon Repos (Figures 8, 9). This will be explored further when the temperature data loggers on Curtis Island are downloaded during next turtle breeding season. There is a general trend for shortening of the period to hatchling emergence as the season progresses from mid-October nesting to late

November nesting. The period to hatchling emergence remains low for clutches laid during December before increasing for clutches laid later in the season.

The trend from low hatching success for clutches laid in October to high hatching success during mid breeding season and followed by reduction in hatching success through the latter part of the breeding season is not as pronounced with clutches laid on Curtis Island compared to clutches on the Woongarra coast. It is suspected that there are other as yet undefined factors other than nest temperature that account for the lower hatching success of clutches laid on the Woongarra Coast compared to those on Curtis Island.

The Curtis Island records do not represent a complete inventory of clutches whose hatchlings went inland. These records prove clear evidence of disrupted ocean-finding behaviour by the lights within Gladstone and Port Curtis and the associated sky glow on hatchlings emerging from clutches laid on South End Beach, Curtis Island. These records also do not provide a complete inventory of hatchlings mortality associated with the inland movement of hatchlings at night associated with predation by terrestrial predators, entrapment in vegetation and overheating and desiccation after sunrise. Hatchlings still alive within the dune system after sunrise should respond to the daylight horizons and head seaward unless trapped in vegetation or in the lagoon.

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Table 1. Summary of flatback turtle tagging census at Curtis Island and the Woongarra Coast, Bundaberg during the 2015-2016 breeding season.

	South End, Curtis Island	Woongarra Coast
First time tagged	7	1
Remigrant recaptures		
With tags	35	6
With tag scars only	2	
Total turtles	**44**	**7**

Table 2. Size of nesting female flatback turtles, *Natator depressus*, at Curtis Island and Woongarra Coast during the 2015-2016 breeding season.

	Curved carapace length (cm)			
	Mean	**SD**	**Range**	**N**
Curtis Island				
First time tagged females	92.18	2.160	90.0-95.1	7
Remigrant females	94.59	2.904	83.6-99.4	32
All females for season	93.99	2.988	83.6-99.4	41
Woongarra Coast				
First time tagged females	96.3	-	-	1
Remigrant females	93.78	2.046	90.2-95.8	6
All females for season	94.14	2.096	90.2-96.3	7

Table 3. Remigration interval recorded for flatback turtles, *Natator depressus*, at Curtis Island and Woongarra Coast during the 2015-2016 breeding season.

	Remigration interval (yr)			
	Mean	**SD**	**Range**	**N**
Curtis Island				
	2.80	2.125	2-12	35
Woongarra Coast				
	3.17	1.169	2-5	6

Table 4. Flatback turtle clutches, nest descriptions and within season return intervals, at Curtis Island and Woongarra Coast, 2015-2016 breeding season.

	Mean	SD	Range	N
Curtis Island				
Eggs per clutch	56.84	9.779	31-78	44
Yolkless eggs per clutch	0.09	0.291	0-1	44
Multiyolked eggs per clutch	0.05	0.302	0-2	44
Renesting interval (d), following a successful oviposition	13.8	1.61	12-17	15
Return interval (d), following an unsuccessful nesting attempt	0.7	0.77	0-2	17
Nest depth, top (cm)	42.47	7.127	28-56	38
Nest depth, bottom (cm)	61.78	7.444	43-72	40
Egg diameter (mean) (cm)	5.21	0.157	4.58-5.51	290 (29 clutches)
Egg weight (g)	77.69	4.501	68.29-91.59	290 (29 clutches)
Woongarra Coast				
Clutches/female/season	3.9	0.378	3-4	7
Eggs per clutch	53.32	9.98	30-67	22
Yolkless eggs per clutch	0.18	0.39	0-1	22
Multiyolked eggs per clutch	0.05	0.213	0-1	22
Renesting interval (d), following a successful oviposition	14.9	1.15	13-18	19
Return interval (d), following an unsuccessful nesting attempt	0.5	0.50	0-1	8
Nest depth, top (cm)	35.54	7.90	15-47	19
Nest depth, bottom (cm)	55.33	6.17	43-65	18
Egg diameter (mean) (cm)	5.18	0.124	4.74-5.70	180 (18 clutches)
Egg weight (g)	76.61	4.5156	65.3-86.0	180 (18 clutches)

Table 5. Incubation and hatchling emergence success and incubation period for undisturbed flatback turtle clutches at Curtis Island and Woongarra Coast. These clutches include those protected by fox exclusion devices. An undisturbed clutch is defined as one that was not flooded, eroded, or predated by foxes or dogs.

	Mean	SD	Range	N
Curtis Island				
Incubation period (oviposition to emergence) (d)	48.27	2.762	43-58	96
Clutches laid, 24 Nov-8 Dec				
Incubation success of eggs (%)	87.74	10.382	61.1-100.0	47 clutches
Hatchling emergence success (%)	86.38	10.612	58.1-100.0	47 clutches
All clutches examined for season				
Hatching success of eggs (%)	84.25	15.300	2.6-100.0	138 clutches
Hatchling emergence success (%)	78.82	21.206	0.0-100.0	138 clutches
Woongarra Coast				
Flatback eggs				
Incubation period (oviposition to emergence) (d)	55.05	5.996	48-70	22
Hatching success of eggs (%)	64.61	23.921	13.33-98.18	27 clutches
Hatchling emergence success (%)	48.29	31.094	2.86-96.43	27 clutches

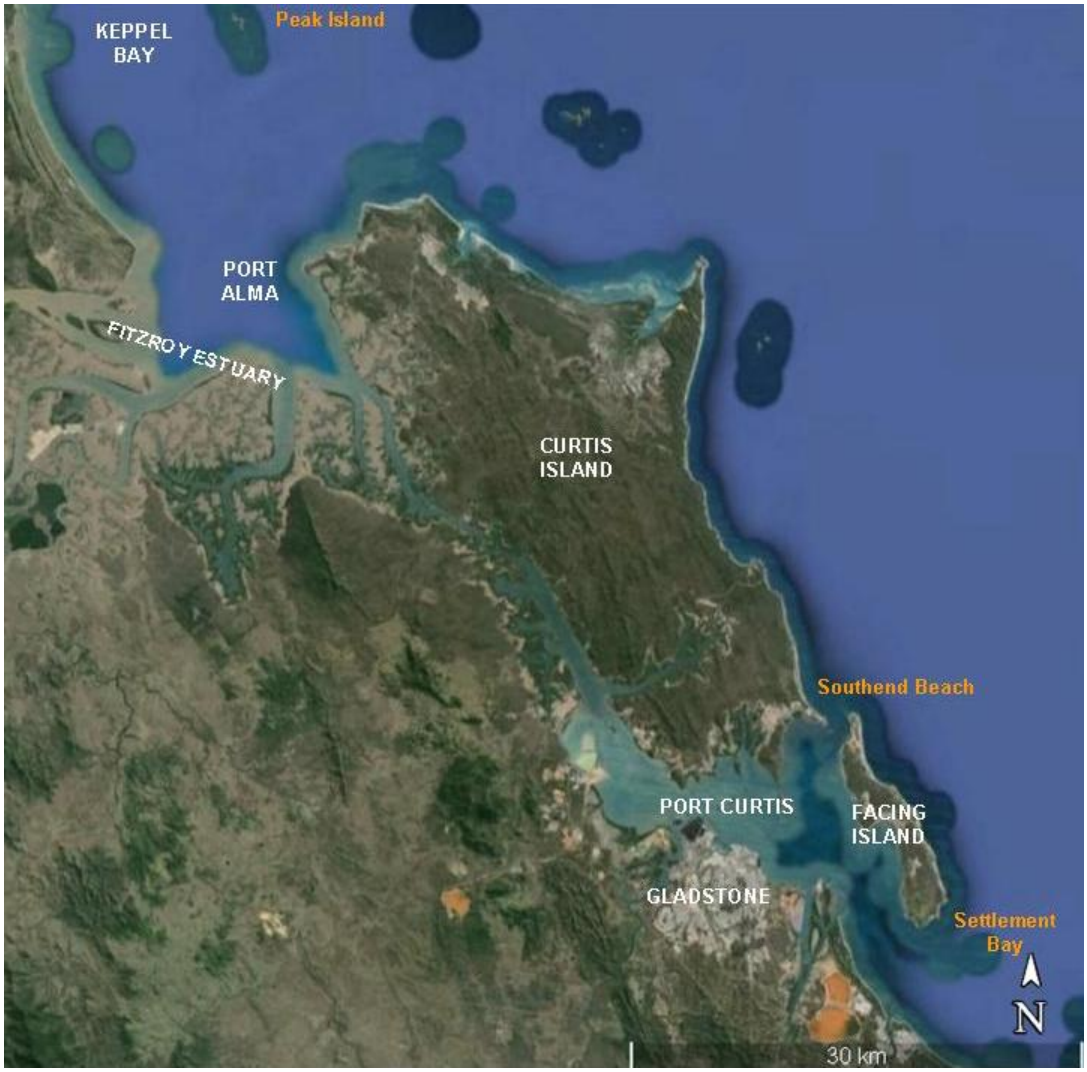
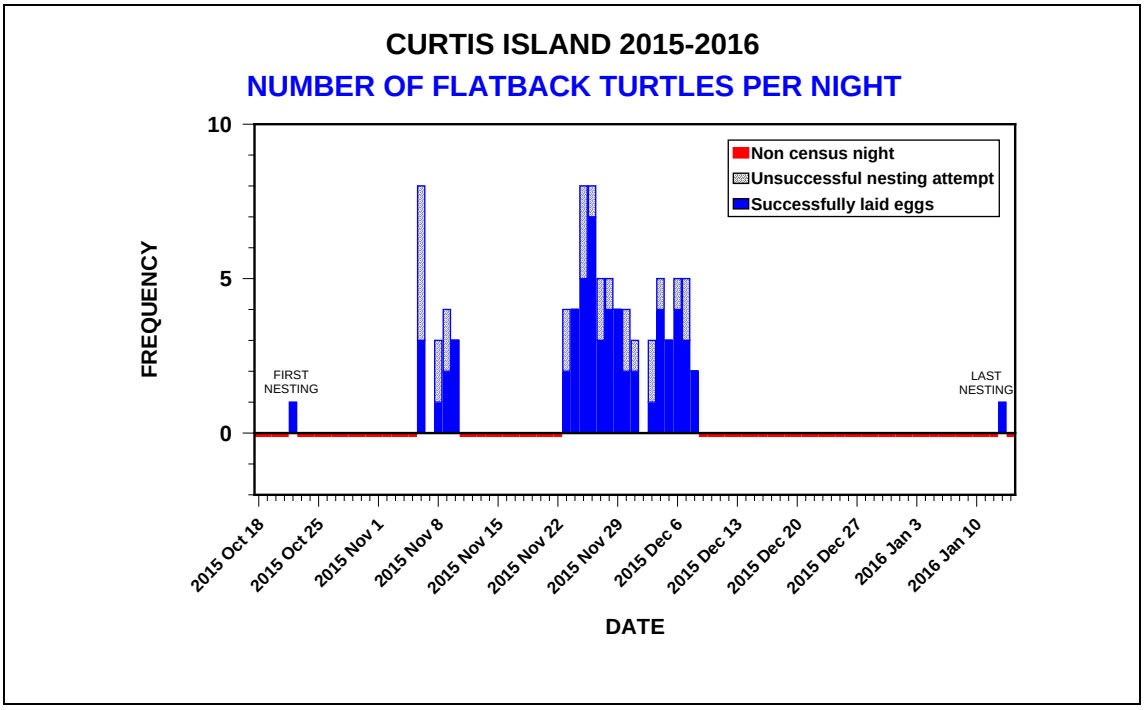


Figure 1. Location of South End Beach, Curtis Island, in relation to Port Curtis and Port Alma.

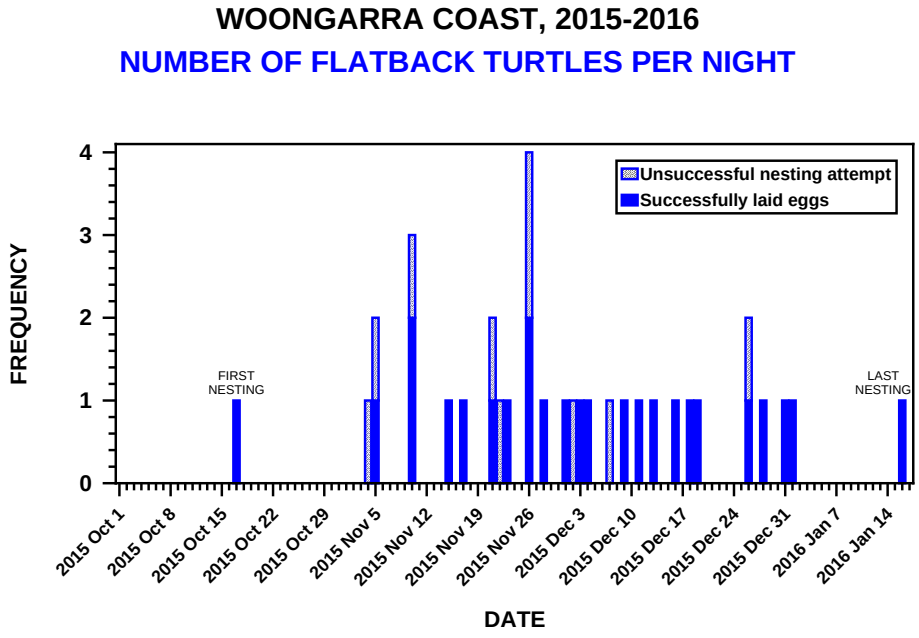
Figure 1B. Turtle nesting beaches on the Woongarra Coast. Flatback turtle nesting can be expected on Oaks, Mon Repos, Neilson Park, Bargara and Kelley's Beaches.

2A. South End Beach, Curtis Island **2B. Archie's Beach, Woongarra Coast**

Figure 2. Regional Councils are recognising turtle nesting beaches and placing signs that provide turtle conservation advice to the public.



A. South End Beach, Curtis Island



B. Woongarra Coast

Figure 3. Nightly number of flatback turtles, *Natator depressus*, ashore for nesting on (3A) South End Beach, Curtis Island and (3B) Woongarra Coast during the 2015-2016 nesting season. Every turtle was scored for nesting success on every night on the Woongarra Coast and for the indicated nights at Curtis Island.

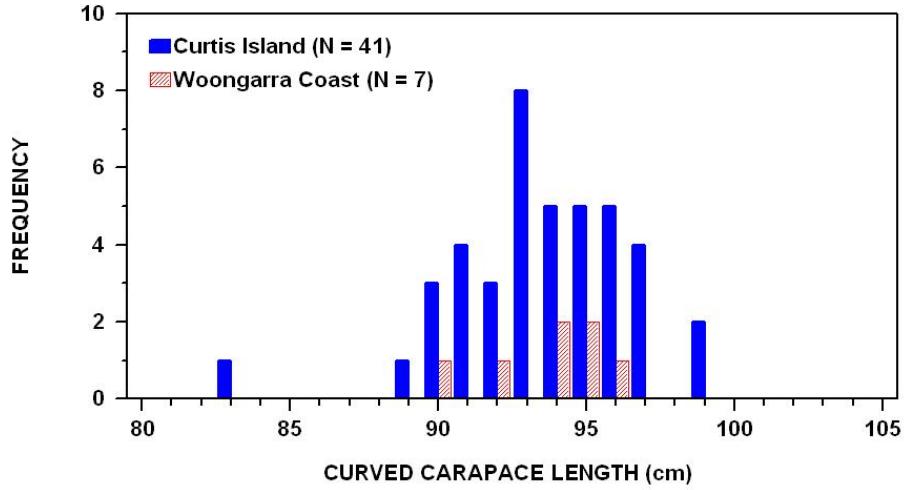


Figure 4. Size of nesting flatback turtles at Curtis Island and Woongarra Coast during the 2015-2016 breeding season.

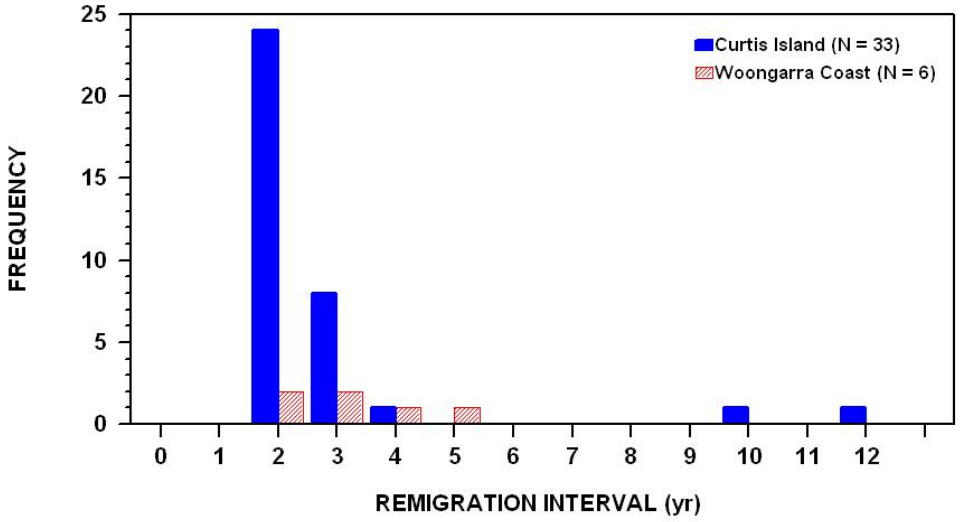


Figure 5. Remigration intervals recorded for nesting flatback turtles at Curtis Island and Woongarra Coast during the 2015-2016 breeding season.

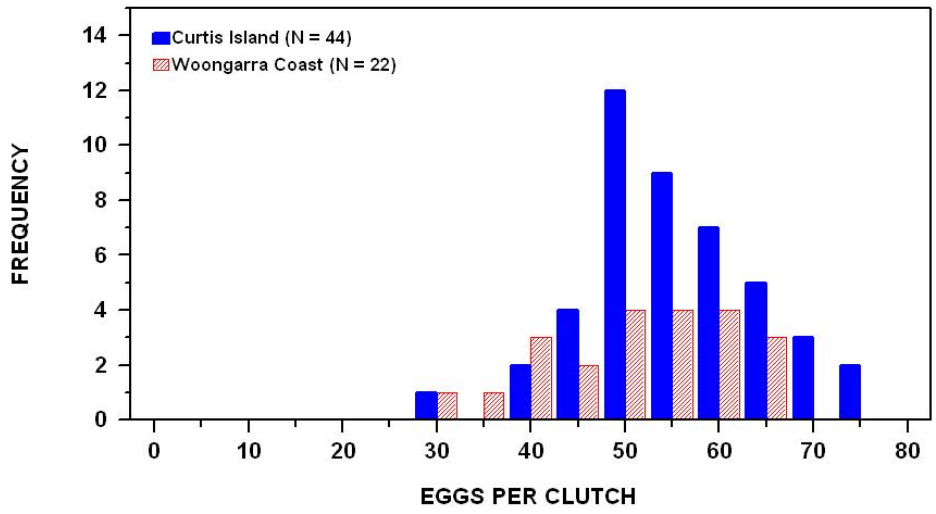


Figure 6. Clutch counts recorded for nesting flatback turtles at Curtis Island and Woongarra Coast during the 2015-2016 breeding season.

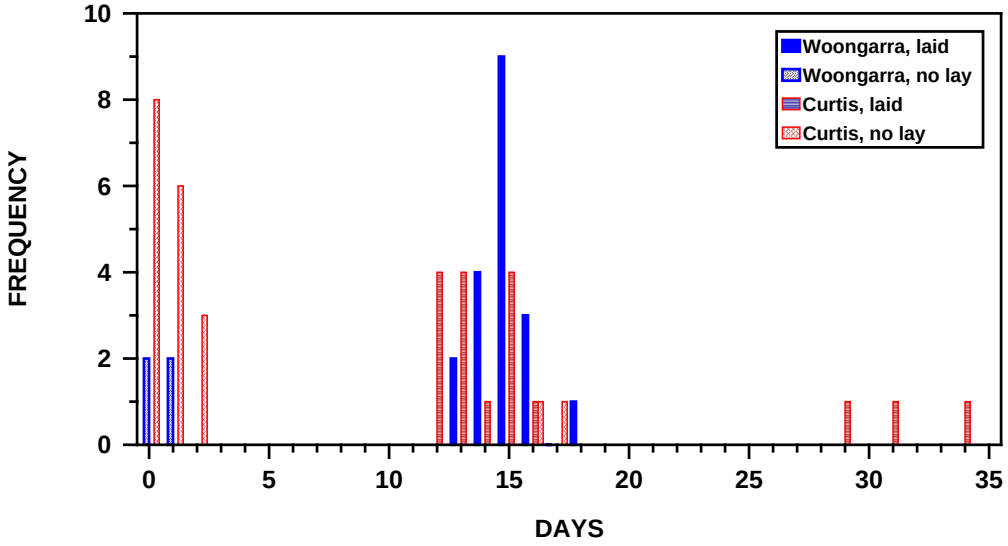


Figure 7. Return intervals recorded for nesting flatback turtle, *Natator depressus,* following both successful and unsuccessful nesting attempts at Curtis Island and Woongarra Coast during the 2015-2016 breeding season.

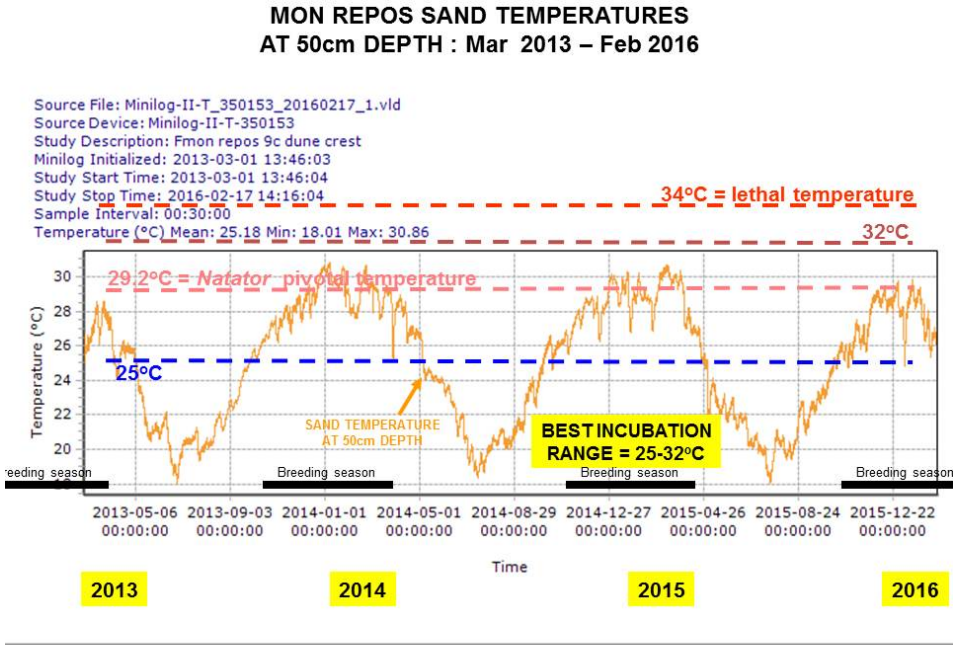
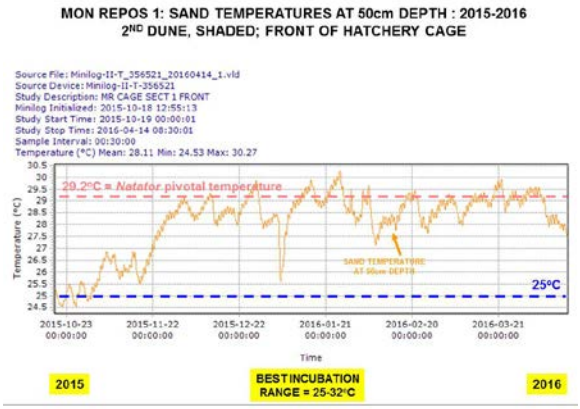
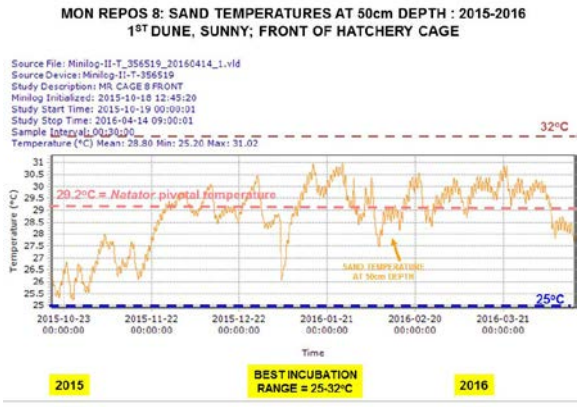


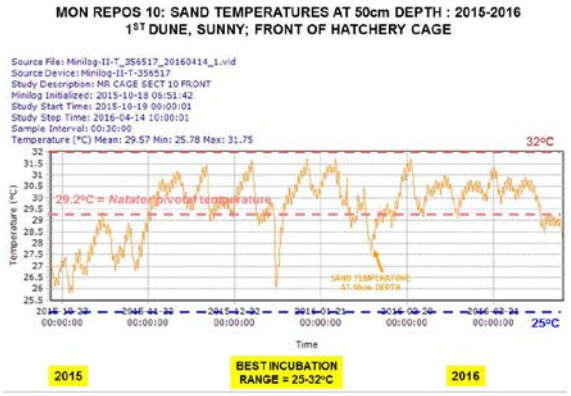
Figure 8. Sand temperatures measured at 50cm depth on Mon Repos Beach at sector marker 9C on the top of the second dune in open sun using Vemco Minilog II temperature data logger during 1 March 2013 to 25 February 2015.



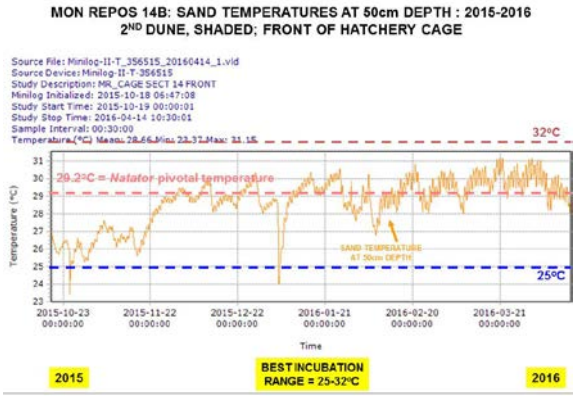
A. Elevated 2nd dune shaded by casuarina forest, northern Mon Repos



B. Lower 1st dune in open sun for most of day, northern Mon Repos.

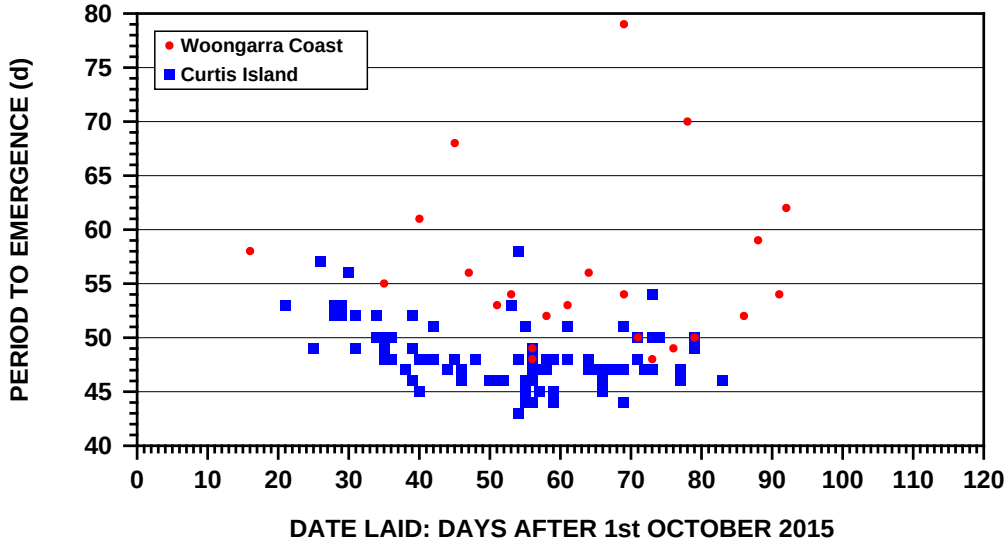


C. Lower 1st dune in open sun for entire day, northern Mon Repos.

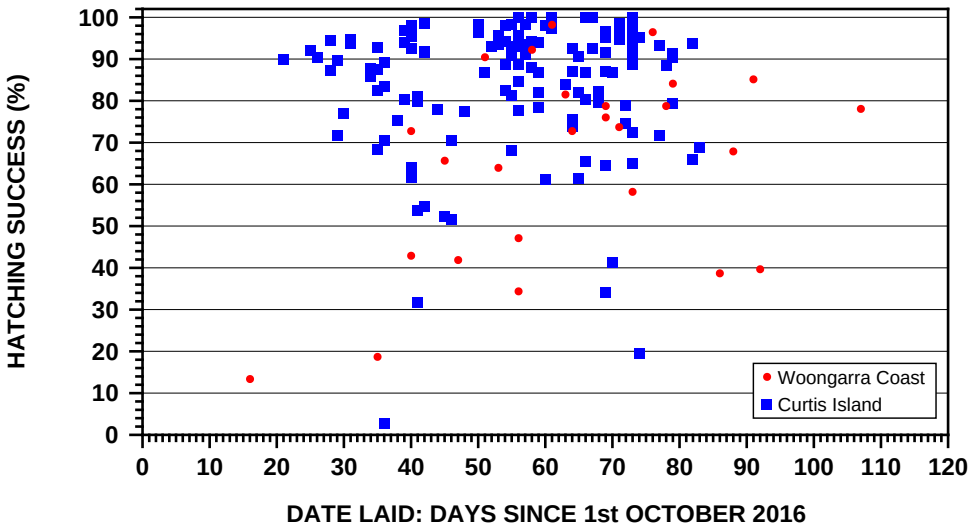


Elevated 2nd dune shaded by casuarina forest, southern Mon Repos.

Figure 9. Comparison of sand temperatures at 50 cm depth at four locations on Mon Repos beach recorded during the entire 2015-2016 breeding season using Vemco Minlog II temperature data loggers.



A. Period to emergence



B. Incubation success

Figure 10. Comparison of incubation parameters in relation to the date eggs laid through the 2015-2016 breeding season for flatback turtles nesting on Curtis Island and the Woongarra Coast: A. Period to emergence (period from laying to hatchling emergence) and B. Incubation success.

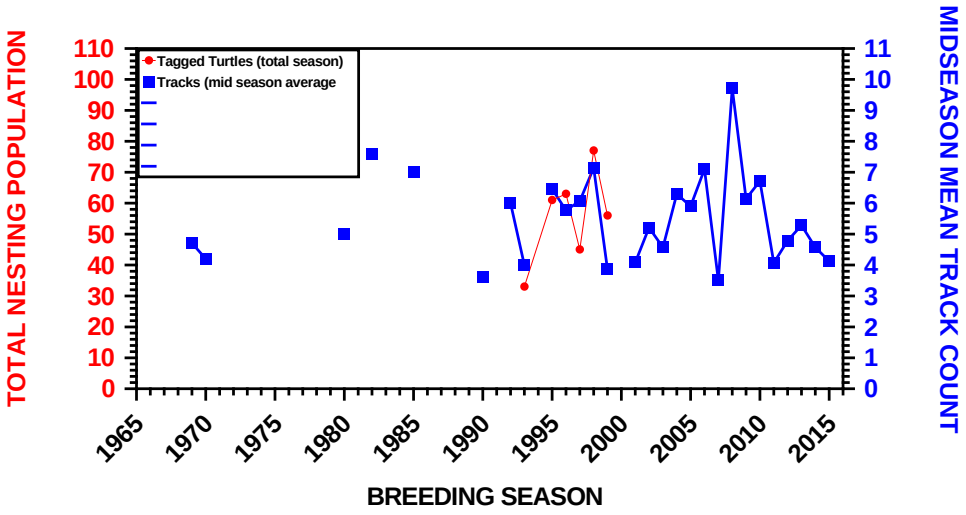


Figure 11a. Census of the annual flatback turtle, *Natator depressus*, population using track counts during the standard mid-season census period at Curtis Island, 1969-2015.

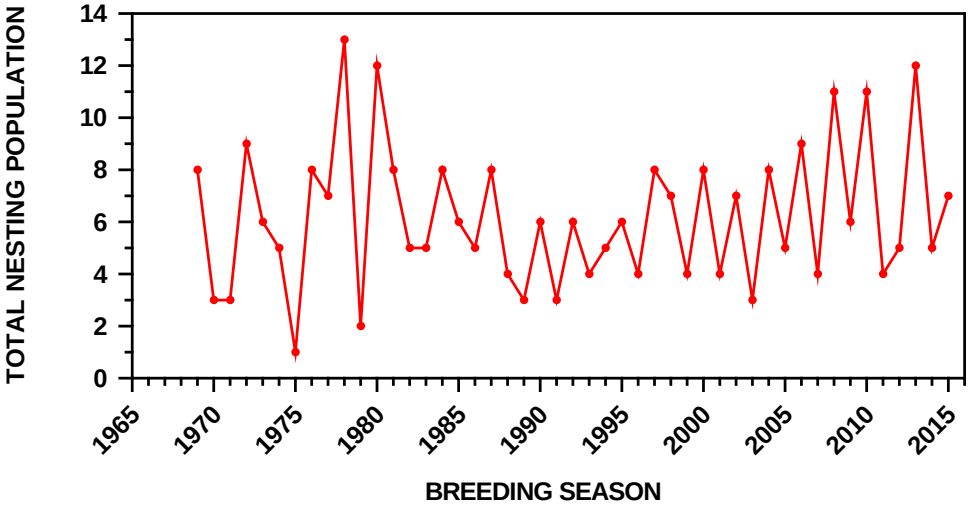


Figure 11b. Fluctuations in the size of total annual flatback turtle, *Natator depressus*, nesting population on the Woongarra Coast 1969 – 2015.

Appendix 1

DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION

MOORE PARK FLATBACK TURTLE NESTING STUDY, 2015-2016 breeding season.

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1. Threatened Species Unit, Department of Environment and Heritage Protection
2. Moore Park Beach Turtle Monitoring Group

Introduction

Flatback turtles, *Natator depressus*, come ashore in low numbers on all the beaches between the Woongarra coast and Curtis Island. Moore Park is the first large surf beach flanked by continuous sand dunes north of the Woongarra Coast (Figure 1).

There has been intermittent tagging of nesting turtles on Moore Park Beach since the late 1970s and nest protection actions by volunteers within the Department of Environment and Heritage Protection (EHP) Turtle Conservation Project. Over the past decade, the volunteers have been primarily local residents functioning within the Moore Park Beach Turtle Monitoring Group (MPBTMG).

As reported by Limpus and Giarola (2015), Moore Park Beach has changed considerably since the first comprehensive monitoring of turtle nesting at Moore Park during the 1993-1994 breeding season (Limpus, 1994) when there was a 14.3 km continuous sand beach from the mouth of Moore Park Creek north to the mouth of the Kolan River, with turtle nesting occurring throughout its length. The major changes occurred in late January 2013 with the passing of TC *Oswald* and the associated century scale record flooding that resulted in the Kolan River breaking through the frontal sand dunes at the northern end of Moore Park Beach at two locations, creating two new sand islands within the Kolan River Estuary (Figure 1). What was once a single beach still remains as three separate beaches.

It has not been logistically feasible for the volunteer team to monitor turtle nesting on the Northern and Southern Kolan Islands since February 2013. Therefore the reported turtle census data for Moore Park Beach commencing in October 2013 reports only for the 9.5 km of currently accessible “Moore Park Beach” and hence is not directly comparable to data collected in previous years from the longer beach.

Volunteers with the Moore Park Beach Turtle Monitoring Group successfully monitored turtle nesting and hatchling emergence for the entire nesting season during October to April each summer.

Summarised below are the flatback turtle data collected during this entire breeding season census of all turtle species nesting on Moore Park Beach for the 2015-2016 breeding season.

Flatback turtle, *Natator depressus*, 2015-2016 breeding season

Methods

No attempt was made to intercept every nesting turtle. Rather, emphasis was placed on early morning patrols of the beach, by foot and quad bike, to locate all nesting crawls from the previous night, to identify the species from the tracks, to determine whether or not a the turtle had laid eggs and provide protection to the eggs if required. The beach was patrolled at least each morning from 20 October 2015 to 25 March 2016.
Nest protection included:

- Relocation of eggs laid low on the beach and at elevated risk of loss through flooding or erosion to artificial nest sites higher up the dunes. Eggs were relocated with the minimum of rotation and shifted either within 2 hr of being laid or after 3 wk of being laid (Pfallar et al. 2008).
- Relocation of eggs from sections of the dunes exposed to direct strong light spillage from adjacent urban development to a darker section of dunes, using the same movement protocols as above.

- Placing 1 m square aluminium mesh predator exclusion device (PED: 1 m^2 sheet of mesh; with 30 cm vertical sides on all four sides; 7 cm diameter mesh size) over the nest to prevent vertebrate predators digging into the eggs. To place the PED, 10 to 15 cm of sand was removed from over the nest, the mesh was positioned centrally over the eggs and the sand replaced to bring the beach level to about the top of the PED (Figure 2).

There were also intermittent patrols of the beach at night. Any turtles encountered were tagged and measured.

Results

Breeding season

	Flatback turtle ***Natator depressus***	**Loggerhead turtle** ***Caretta Caretta***	**Green turtle** ***Chelonia mydas***
First nesting crawl	29 October 2015	8 November 2015	1 November 2015
Last nesting crawl	28 December 2015	26 January 2016	26 January 2016
First hatchling emergence	19 December 2015	30 December 2015	03 January 2015
Last hatchling emergence	25 February 2016	24 March 2016	25 March 2016

Nesting population

Thirteen flatback turtle nesting crawls were recorded for the season that resulted in the successful laying of six clutches of eggs on Moore Park Beach: nesting success = 46%. There was disturbance to nesting turtles from unregulated vehicle traffic and the public on foot on this public beach.

Examination of tracks indicated that dogs made close approaches to turtles crossing the beach.

The mean number of nesting crawls per night during the standard track census period for flatback turtles (24 Nov – 7 Dec) was 0.143 tracks/night which resulted in 0.071 clutches being laid per night (Table 1).

No nesting flatback turtles were tagged this summer. However, based on the sequence of dates for nesting crawls and returns following a successful nesting, these clutches are consistent with the clutch production by three nesting female flatback turtles for the entire summer.

Also nesting on this beach were tens of loggerhead turtles, *Caretta caretta*, and less than 10 green turtles, *Chelonia mydas*, during this 2015-2016 breeding season.

Eggs and incubation

Flatback turtles nesting at Moore Park laid an average of 54 eggs per clutch (Table 2).

The five flatback clutches for the 2015-2016 breeding season incubating on Moore Park Beach had a mean incubation to emergence period of 53.7 days (Table 2). With a pivotal temperature of 29.2^{o}C the eastern Australian flatback stock (Limpus, 2007), most of these incubation to emergence periods are indicative of a female biased hatchling production for this beach.

MPBTMG relocated four of the six flatback clutches because they had been laid low down on the beach and risk of erosion or flooding during storms. The clutches were relocated to more secure incubation habitat higher up the dune.

Predation and clutch loss

One of the six flatback clutches was dug into by a goanna which destroyed seven eggs. The remaining eggs were protected from further loss by an aluminium mesh Predator Exclusion Device being pegged down over the nest.

One flatback nest relocated at three weeks post oviposition had been inundated by the water table beneath the dune associated with nearby Moore Park Creek. Only 36 of the 59 eggs in the clutch were white and still viable.

Foxes and dogs were active along the beach during the breeding season but did not dig into any of the flatback clutches.

References

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Limpus, C. J. (2007). A biological review of Australian marine turtles. 5. Flatback turtle *Natator depressus* (Linneaus). (Queensland Environmental Protection Agency: Brisbane.)

Limpus, C. J. and Giarola, J. (2015) Moore Park Flatback Turtle Nesting Study, 2014-2015 breeding season, Appendix 1 in: Limpus, C. J., McLaren, M., McLaren, G., Gatley, C. and Twaddle, H. (2015). EHP Threatened Species Unit Turtle Conservation Project: Curtis Island and Woongarra Coast Flatback Turtles, 2014-2015 breeding season. Brisbane: Department of Environment and Heritage Protection, Queensland Government.

Pfaller, J. B., Limpus, C. J., and Bjorndal, K. A. (2008). Nest-site selection in individual loggerhead turtles and consequences of doomed-egg relocation. *Conservation Biology* **23**, 72-80.

Table 1. Nightly census data recorded for marine turtles nesting on Moore Park Beach during the standard census periods for each species during the 2015-2016 nesting season.

	Flatback turtle *Natator depressus*	**Loggerhead turtle *Caretta Caretta***	**Green turtle *Chelonia mydas***
Census Period	**24 Nov – 7 Dec (n = 14)**	**16-31 Dec (n = 16)**	**16-31 Dec (n = 16)**
Mean number of nesting crawls per night	0.14 ± 0.363; range = 0-1	2.13 ± 2.895; range = 0-12	0.25 ± 0.447; range = 0-1
Mean number of clutches laid per night	0.07 ± 0.267; range = 0-1	0.87 ± 1.025; range = 0-4	0.06 ± 0.250; range = 0-1

Table 2. Clutch counts and incubation-to-hatchling-emergence periods for marine turtle clutches that were laid at Moore Park Beach, 2015-2016 breeding season.

	Mean	**SD**	**Range**	**N**
Flatback turtles				
Eggs per clutch	54.5	4.655	50-59	4
Period to hatchling emergence from eggs being laid (d)	53.7	2.805	51-59	6
Loggerhead turtles				
Eggs per clutch	123.9	20.707	85-175	40
Period to hatchling emergence from eggs being laid (d)	55.5	2.827	45-61	54
Green turtles				
Eggs per clutch	116.3	13.745	97-129	4
Period to hatchling emergence from eggs being laid (d)	58.9	5.303	53-66	8

Figure 1. Moore Park Beach, a low density marine turtle nesting beach flanked by residential development.

Figure 2. A flatback turtle clutch protected from vertebrate depredation of the eggs by placement of an aluminium mesh Predator Exclusion Device (PED: 1 m x 1m with 30 cm buried vertical walls and 70 mm diameter meshes) on Moore Park Beach.