Sunshine Coast COUNCIL

Sunshine Coast
Turtle Nesting Report
2005-2016

Cover photograph:

Cover photographs: QA4840 'Matilda' turtle returning to the water. Photo credit: Christine Bull, Caught in Colour. Loggerhead turtle hatchlings emergence through a fox exclusion device at Wurtulla Beach 2014. Photo Credit: Melissa Rowe.

This report should be cited as:

Kate HOFMEISTER, Helen TWADDLE, Julie O'CONNOR, Colin J. LIMPUS, Bribie Island Turtle Trackers, TurtleCare Sunshine Coast Volunteers and Coolum and North Shore Coast Care Volunteers (2019). Marine Turtle Nesting Populations: Sunshine Coast Region 2005 – 2016. Caloundra: Sunshine Coast Council. 44pp.

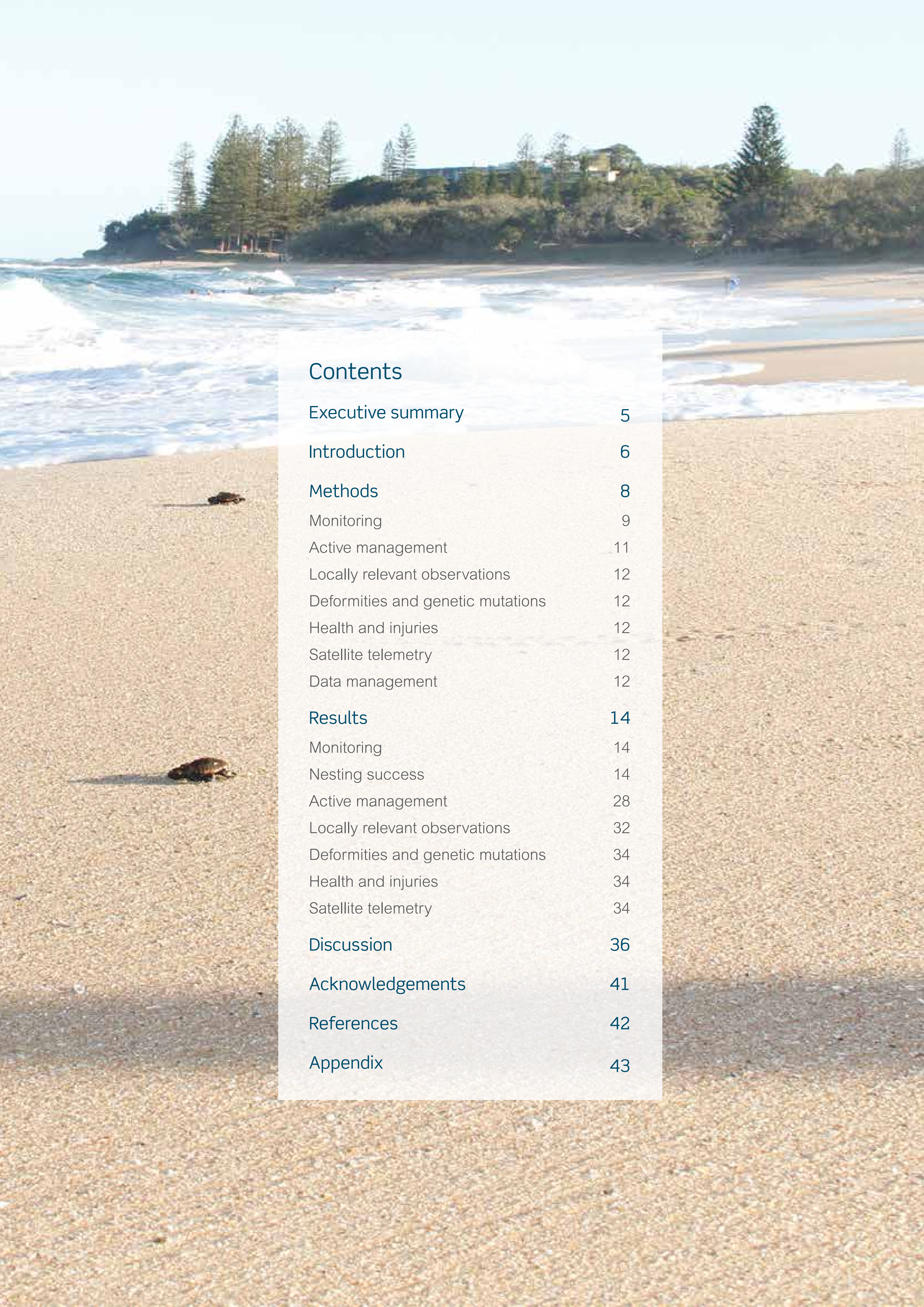
This publication has been compiled by Sunshine Coast Council (SCC) and the Queensland Department of Environment and Science (DES).

This study was conducted as part of the Queensland Turtle Conservation Project (QTCP) of DES in collaboration with SCC, Bribie Island Turtle Trackers, TurtleCare Sunshine Coast and Coolum and North Shore Coast Care.

This project was led and overseen by SCC and DES staff. The field work was conducted by a team comprised of Bribie Island Turtle Trackers, TurtleCare Sunshine Coast and Coolum and North Shore Coast Care volunteers. All volunteers undertaking management intervention and data submission for this report had been trained and accredited with the QTCP and authorised as a Turtle Conservation Collaborating Partner with the Queensland Government.

SCC and DES shared the lead role in organising the logistics, identifying priorities, developing methodologies and providing guidance and direction. SCC and DES maintain data quality through a strict quality assurance program of rigorous data checking and report reviews. Statistical modelling analyses were undertaken by Dr Milani Chaloupka of Ecological Modelling Services Pty Ltd.

SCC and DES would like to acknowledge and thank all volunteers for their contribution to this project.



Contents

Marine turtle nesting populations: Wider Sunshine Coast Region (SCR), 2005-2016 breeding seasons

Kate HOFMEISTER, Helen TWADDLE, Julie OCONNOR, Colin J. LIMPUS, Bribie Island Turtle Trackers, TurtleCare Sunshine Coast Volunteers and Coolum and North Shore Coast Care Volunteers.

Executive summary

- This report summarises the results of monitoring the eastern Australian loggerhead and green turtle nesting populations during the 2005 – 2016 breeding seasons on Sunshine Coast regional beaches.
  - A total of 1045 loggerhead turtle nesting crawls, 45 green turtle nesting crawls and 45 unidentified tracks were recorded during the monitoring periods.
  - All turtles laid a total of 808 clutches of eggs during the monitoring periods comprised of 742 loggerhead turtle, 35 green turtle and 31 unidentified turtle clutches.
  - A total of 37 loggerhead turtles and three green turtles were tagged during the monitoring period. Twelve tagged turtles returned as remigrants with remigration intervals ranging between one and eight years.
- These turtles show normal demographic features for the eastern Australian loggerhead and green turtle stock:
  - Nesting greens had a mean curved carapace length of 104.7 cm (n = 3) and loggerheads had a mean curved carapace length of 97.0 cm (n = 47)
  - Greens laid an average of 102 (n = 7) eggs per clutch and loggerheads laid an average of 129 (n = 227) eggs per clutch with few yolkless or multi-yolk eggs.
- 239 (30.4%) loggerhead and eight (22.9%) green nests were relocated across the SCR due to threats to clutch incubation or hatchling survivorship.
- 608 nests were excavated to assess incubation success during the monitoring period. 588 nests were analysed to determine hatch and emergence success. 20 records with greater than 10% error were excluded.
- Hatching and emergence success was on average 75.8% and 72.1% respectively for loggerheads. Green turtle hatching and emergence success was 76% and 73% respectively.

Coolum and North Shore Coast Care (CaNSCC) volunteers processing a turtle nest. Image supplied by CaNSCC.

Introduction

This report provides a summary of results from monitoring marine turtle nesting in the Sunshine Coast region from 2005 to 2016 breeding seasons. This report is presented in the prescribed format for programs working within the Queensland Turtle Conservation Program (QTCP) as part of the Collaborative Research Agreement between the Department of Environment and Science (DES) and the respective community groups operating on the Sunshine Coast.

The biology of the eastern Australian loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtles has previously been reviewed (Limpus, 2008 a,b).

For the purpose of this report, a combined study area has been formed and referred to herein as the Sunshine Coast Region (SCR). Together, three community groups monitor an almost continuous 97 km stretch of nesting beaches from the southern entrance of the Pumicestone Passage (27.098769° S, 153.164507°E) to Noosa River (26.380643°S, 153.682389°E).

The three community groups that operate within the SCR (Figure 1) are;

- Bribie Island Turtle Trackers (BITT) actively monitor approximately 7 km from Woorim in the south to ocean beach access track in the north. Bribie Island Turtle Trackers respond to all nesting reports for Bribie Island from Woorim to the northern bunker, in collaboration with the Queensland Parks and Wildlife Rangers on the Island. BITT operate within the Moreton Bay Regional Council local government area (LGA).
- TurtleCare Sunshine Coast (TC) actively monitor approximately 22 km from the northern bunker on Bribie Island in the south, to Point Cartwright in the north. TurtleCare responds to all nesting reports between North Bribie Island and the Mooloolah River. TurtleCare operate within Sunshine Coast Regional Council LGA.
- Coolum and North Shore Coast Care (CANSCC) actively monitor approximately 29km from Maroochy River to Sunshine Beach. Coolum and North Shore Coast Care respond to all nesting reports between Maroochy River and Noosa River, including within the Noosa National Park. Coolum and North Shore Coast Care operate within both Sunshine Coast Council and Noosa Council LGA's. Coolum and North Shore Coast Care and TC share the response to nesting reports between the Mooloolah and Maroochy Rivers.

The SCR is located in South East Queensland, Eastern Australia (Figure 2). The majority of nesting beaches are located in an urban setting, with the balance located adjacent to the Bribie Island National Park, the Noosa National Park and Council managed environmental reserves.

The SCR has various nesting beaches encompassing different landscape structures and beach shape. Nesting beaches are orientated predominately to the east across the region and have been described as 'dynamically stable' (Sunshine Coast Council, 2014) and are exposed to periodic significant erosion events. The beaches around Caloundra Head (e.g. Shelly Beach) are supplied with sand from local sources with high proportion of calcareous material (shell grit), where other beaches across the region receive sand through the northward drift, which has far smaller sand particle size (Sunshine Coast Council, 2014).

The occurrence of nesting loggerhead turtles has been accurately described on Sunshine Coast beaches since 1985 (Limpus, 1985), but potentially occurred prior to the 1950's (Nelson, 1966. Figure 3). Limpus (1985), described loggerhead nesting on Sunshine Coast beaches to be annual and low density on short sandy beaches adjacent to headlands. At this time, the local beaches were classified into a rookery class of 1 / 2, with on average, less than 1 turtle per night nesting during two weeks at peak nesting season.

Historic data from major rookeries in Queensland shows that loggerhead turtles experienced an 86% population decline between 1977 and 2000 (Limpus & Limpus, 2003). This was attributed to by-catch from trawl fisheries of eastern and Northern Australia (Limpus & Reimer, 1994) which was subsequently addressed and population recovery has been recorded.

TurtleCare commenced formal monitoring of turtle nesting at Shelly Beach in 2005, then expanded to other southern SCR beaches by 2006 and North Bribie Island in 2014. Coolum and North Shore Coast Care and BITT commenced formal monitoring in 2008 and 2009 respectively. Informal monitoring by untrained local residents occurred prior to that time.

Nesting seasons for marine turtle monitoring occur across two calendar years during the summer and adjacent months. For the purpose of this report, seasons are referred to by the first year, for example, the 2005/2006 season is referred to as 2005.

Shelly Beach is the designated index beach for marine turtle monitoring within Sunshine Coast region due to the consistently high monitoring effort applied across all years by trained volunteers since 2007. SCR supports a small (approximately 4%) (C. Limpus pers. comm.) but important component of the total loggerhead turtle (*Caretta caretta*) nesting population for eastern Australia, which is a part of the southwest Pacific Ocean genetic stock (management unit) of the loggerhead turtle (FitzSimmons and Limpus, 2014).

The area from Pumicestone Passage to Double Island Point has been identified as ‘Habitat Critical to Survival’ for the loggerhead in the 2017 – 2027 Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017).

Figure 1+2: Map of Sunshine Coast Region Study Area (Bribie Island – Noosa). Map of Queensland

Figure 3: Healthy loggerhead turtle found on Alexandra Headlands beach prior to 1966. Image by: Nelson, 1966

Methods

Standard DES Threatened species (Aquatic Species Program) Queensland Turtle Conservation Project methodologies (Limpus et al. 1983; Limpus C. J., 1985) were followed for the project and all field data is recorded on standardised data sheets (Appendix 1). The following methods are for data collected for nesting females, individual nests, eggs and hatchlings, subsequent data analysis and methods for protection of turtle nests from known threats.

Monitoring

Monitoring effort

Each summer, the following monitoring was conducted within the SCR between 1st November and 15th March.

South Bribie Island (Bribie Island Turtle Trackers) (2009 – 2016)

- Daily track count to record nesting crawls and associated nest success.
- Targeted surveys to assess incubation success of all recently emerged clutches

North Bribie Island – Maroochy River (South Sunshine Coast - TurtleCare) (2005 – 2016)

- Daily track count to record nesting crawls, associated nest success and apply predator exclusion meshing.
- Intermittent night patrols targeted to returning nesting turtles
- Targeted surveys to assess incubation success of all recently emerged clutches

Maroochy River – Noosa River (North Sunshine Coast – Coolum and North Shore Coast Care) (2008 – 2016)

- Daily track count to record nesting crawls, associated nest success and apply predator exclusion meshing.
- Intermittent night patrols targeted to returning nesting turtles
- Targeted surveys to assess incubation success of all recently emerged clutches

Note that formal monitoring studies commenced at North Bribie Island in 2014.

Nesting success

Each occurrence of a turtle on the beach was assessed to ascertain the species and whether the turtle laid eggs or not, along with other standard measures (time, date, habitat type etc.).

Nesting success was determined from the proportion of successful crawls (resulting in eggs laid) over total crawls.

A generalised additive mixed regression model (GAMM) (Wood, 2006) with Bernoulli likelihood was fitted to the nest probability data to account for nonlinear temporal (season) and spatial (subregion) effects. Season was also included as a random effect to account for annual sampling variability. This was due to a range of unrecorded factors such as different observers, variable sampling effort and season-specific weather conditions impacting sampling.

Nesting beaches were grouped into four subregions based on beach characteristics, aspect and contiguity (Figure 4).

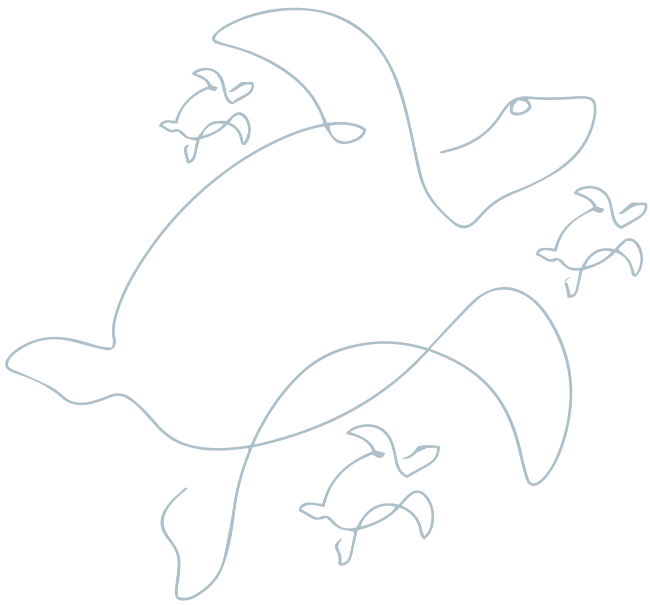


Figure 4: Location of the nesting beaches sampled in the Sunshine Coast region. Dot size shows relative beach-specific loggerhead nesting abundance recorded since 2009. Dot colour indicates the specific subregion that each beach was assigned to for analysis of nesting probability.

Tagging census

After oviposition, two titanium tags were attached to each turtle (manufactured by Stockbrands Australia) in the front left and right flipper tagging positions (Limpus, 1992), generally proximal to the flipper scute closest to the body. If scar tissue from previous tagging made this position unsuitable for tagging, tags were applied distally to this last scute. The tag number is recorded at each nesting event to track nesting females over their breeding life and can be used to understand population sizes.

Size of nesting females

Curved carapace length (CCL ± 0.1 cm) was measured from the skin/carapace junction at the anterior edge of the nuchal scale, along the midline, to the posterior junction of the end post-vertebral scutes at the rear of the carapace using a flexible fibreglass tape measure. Any barnacles living along the midline of the carapace were removed prior to measuring.

Remigration

The period of time in years between nesting seasons was calculated to determine the remigration interval of tagged nesting females.

Nest data

The study area was divided into suburbs, represented as locality. Beaches with higher nesting frequency (Buddina, Shelly Beach) were then subdivided into sectors identified by numbered posts. Beach divisions into locality were based on arbitrary man-made boundaries, rather than geographic boundaries.

Nest locations were recorded using a hand-held GPS (global positioning system) unit (± 4 m). Habitat type of the nest location was recorded. Where GPS was not recorded, coordinates have been digitised using descriptions available on raw data sheets. 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 assists in identifying the female that laid the clutch when hatchlings emerge some two to three months later.

Nest depth (± 0.1 cm) was measured from the natural sand level to the top of the eggs, and to the bottom of the nest using a flexible fibreglass tape measure.

Incubation success and hatchling production

Each clutch was assessed for incubation success and hatchling emergence success by excavating the nest, usually two to five days after emergence. 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.

Data was based on the following calculations:

- Estimated clutch count = hatched eggs + unhatched eggs + undeveloped eggs + predated eggs
- Hatching success = (hatched eggs ÷ estimated clutch count)*100 %
- Hatching success was also calculated using a generalised linear mixed regression model (GLMM) (Wood, 2006)
- 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. Records with a counting error greater than 10% were excluded from the analysed data set.

Hatching and emergence success were compared in relocated and naturally occurring nests using a GLMM. A zero-one-inflated Beta likelihood was fitted to combine the hatch and emergence data accounting for any potential nonlinear temporal (season) trend and the main effects of metric (hatch and emergence) and treatment (relocated or natural nests). Season was included as a random effect to account for annual sampling variability.

Hatching success was compared across beaches and separately, across habitat type. A GLMM with a zero-one-inflated Beta likelihood was fitted to the loggerhead hatch data accounting for beach-specific effects. Season was also included as a random effect to account for annual sampling variability. Beaches were grouped into six subregions from north to south based on beach characteristics, aspect and contiguity.

Nest depth was compared across beaches using analysis of variance.

Sand temperatures

Vemvo Minilog II temperature data loggers have been deployed for a number of years at turtle nesting beaches in Queensland as nest success and period to emergence are a function of sand temperature. The data loggers measure sand temperatures at 50cm depth at 30-minute intervals. These temperature recording instruments can record temperature continuously for up to 10 years.

Two data loggers have been deployed within the SCR in open sunny locations at;

- Shelly Beach, Beach Access 278, Sector 20 post on 27 October 2010, (26.79411°S, 153.148281° E)
- Yaroomba, Beach Access 90, adjacent to the Coastal Observation Programme - Engineering monitoring pole on 21 August 2008, and replaced on 27 October 2010, (26.555278°S, 153.148281°E)

Active management

Doomed egg relocation

Within the study area, the three groups participate in a project coordinated by the QTCP to rescue doomed turtle eggs 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 hatchlings to move inland away from the sea. Relocation of 'doomed eggs' have been undertaken at nesting rookeries by the QTCP since 1990 (Pfaller et al, 2008).

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 were relocated to artificial nests that are 55-60 cm deep with a 50 cm radius "body pit" from which groundcover vegetation (*typically Spinifex sericeus*) was cleared to replicate the natural nest environment. Eggs were relocated within 2 hours or after 21 days of oviposition and with the minimum of rotation (Limpus et al. 1979).

All clutches laid at Mooloolaba – Maroochydore and Noosa main beach were relocated due to potential negative impacts from adjacent artificial lighting

Standard methodology for QTCP does not include 'reason for clutch relocation' as a data collection field. Light disorientation is an emerging issue for urban nesting beaches within the SCR. Consequently, this data has been collected informally for TC and CANSCC from mid-way through the 2015 nesting season.

Predation

Predator exclusion methods (O'Connor et al, 2017) were followed for the project. These included:

- All turtle nests from Caloundra north to Noosa River were fitted with a standard fox exclusion device (FED). The standard FED comprised a 1x1m piece of plastic mesh with 100mmx100mm openings. The FED was laid horizontally over each nest after removal of 2cm of sand. Each FED was pegged into place using eight 30cm-long polycarbonate pegs and then covered with 2cm of sand. The FED was placed over each nest in a manner that ensured the centre of the FED was positioned directly over the egg chamber.
- Two other styles of standard FED were used during the study period. The first alternative was a purpose built aluminium exclosure, 1m x 1m x 25cm with 100mm x 100mm openings. The second alternative was a lattice FED, 1.2mx1.2m with 90mmx90mm openings. This lattice FED was removed prior to hatchling emergence due to the inability for hatchlings to emerge en masse through openings that were smaller than those in the standard and aluminium FEDs.
- In addition to the above uses, nests on north Bribie Island were fitted with the aluminium FED to mitigate against Varanid predation.

Light pollution and orientation of turtles

Light measurements were not included during the study period however nesting and hatchling behavioural responses are known indicators of light impacts. Light impacts may be associated with vegetation loss or increased intensity of artificial light in the coastal environment. The risks associated with artificial light were mitigated as much as practicable by trained volunteers on all beaches using the following:

- Clutch relocation to adjacent dark section of beach or nearby adjacent
- Use of purpose-built fabric guard on dark beaches where vegetated dune was not sufficient to block direct residential and/or street lighting and light glow*.
- Human intervention where required and available using torch light to guide hatchlings to the ocean.

Each of the light mitigation strategies are dependent on a number of factors including volunteer availability; availability of a dark relocation site and timing to respond, and therefore was not always a viable method.

Locally relevant observations

Localised conditions or events that affected nesting success were recorded.

Deformities and genetic mutations

Observations of hatchlings with deformities or genetic mutations were recorded on data sheets.

Health and injuries

Any damage to turtles or unusual features were recorded and photographed where possible.

Satellite telemetry

Turtles selected for satellite telemetry studies were fitted with a Sirtrack Kiwisat tracking device using the methods as described in Shimada et al. (2012).

Data management

Data custodians SCC and DES maintain data quality through a strict quality assurance program of rigorous data checking and report review.

This report does not address the in-water foraging and migrating populations of marine turtles adjacent to nesting beaches.

* Where artificial light or significant public interest was evident and could not be managed at a nest site, volunteers used a novel purpose-made thick fabric guard (12.5cm height, 10m length). The guard was installed daily overnight around the nest site to guide hatchlings towards the ocean and prevent them from moving into the dunes and towards houses. Due to high public use of beaches, the guard was installed at sunset and removed at sunrise until emergence occurred. The guard was placed around the back of the nest and extended down towards the water allowing for movement of emerging hatchlings towards the ocean in a natural fan shape. The guard's purpose was twofold, to shield some of the artificial light impacts from adjacent urban infrastructure and, where required, to delineate a safe viewing area for members of the public. This approach required close monitoring of the nest to predict emergence, which was not always possible.

Results

Monitoring

Nesting success

A total of 1135 nesting crawls were recorded within the study area during the 2005 – 2016 nesting seasons. Of these there were 808 successful beachings resulting in eggs being laid (Figure 5). This equates to 71.2% nest success for both species at all locations.

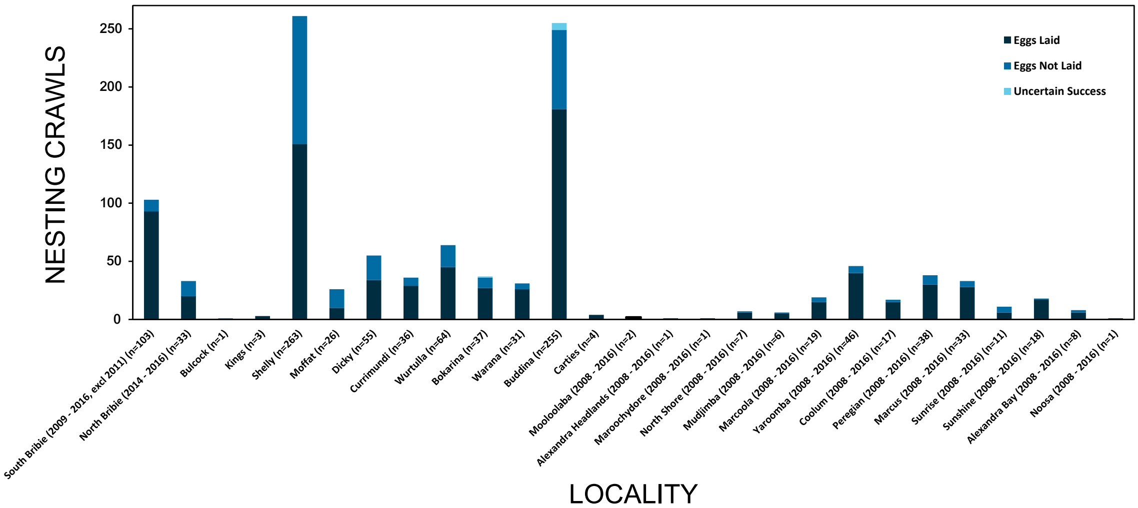


Figure 5: Frequency distribution of all marine turtle nesting crawls (tracks) and nesting success by locality, Sunshine Coast Region 2005 – 2016.

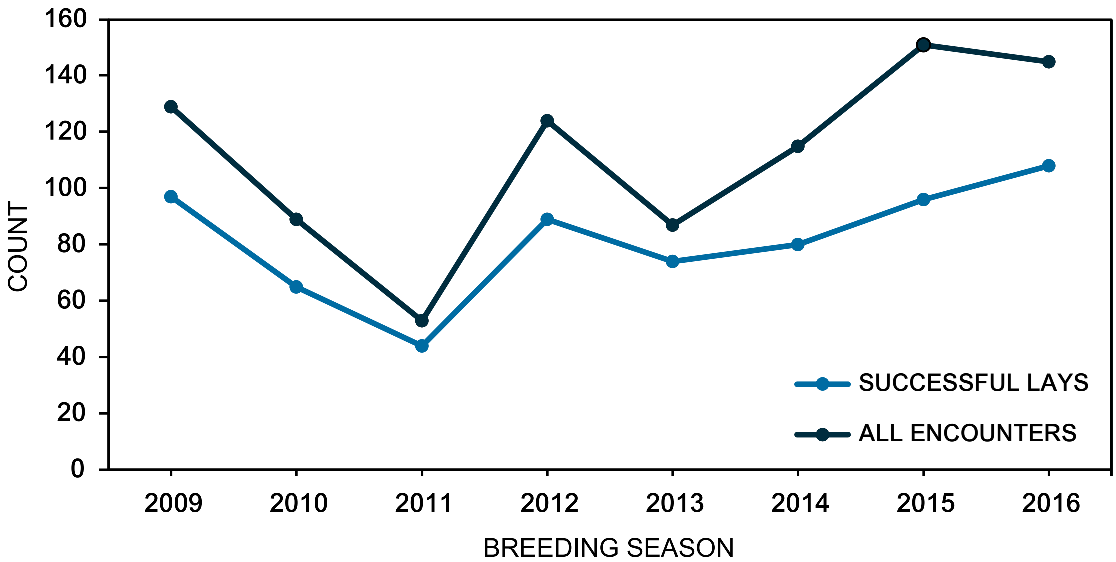


Figure 6: Changes in the number of total nests laid and turtle encounters, in the nesting population on the Sunshine Coast 2009 - 2016.

A total of 1045 nesting crawls were attributed to loggerhead turtles, of which, 742 resulted in eggs laid, equating to an overall nest success of 71% for loggerhead turtles across all locations.

A total of 45 nesting crawls were attributed to green turtles, of which, 35 resulted in eggs laid, equating to a 77.8% nest success for green turtles across all locations.

The Bernoulli GAMM was a good fit to the nesting probability data with the annual subregion-specific estimates in Table 1 and shown in Figure 7 (with 95% uncertainty intervals).

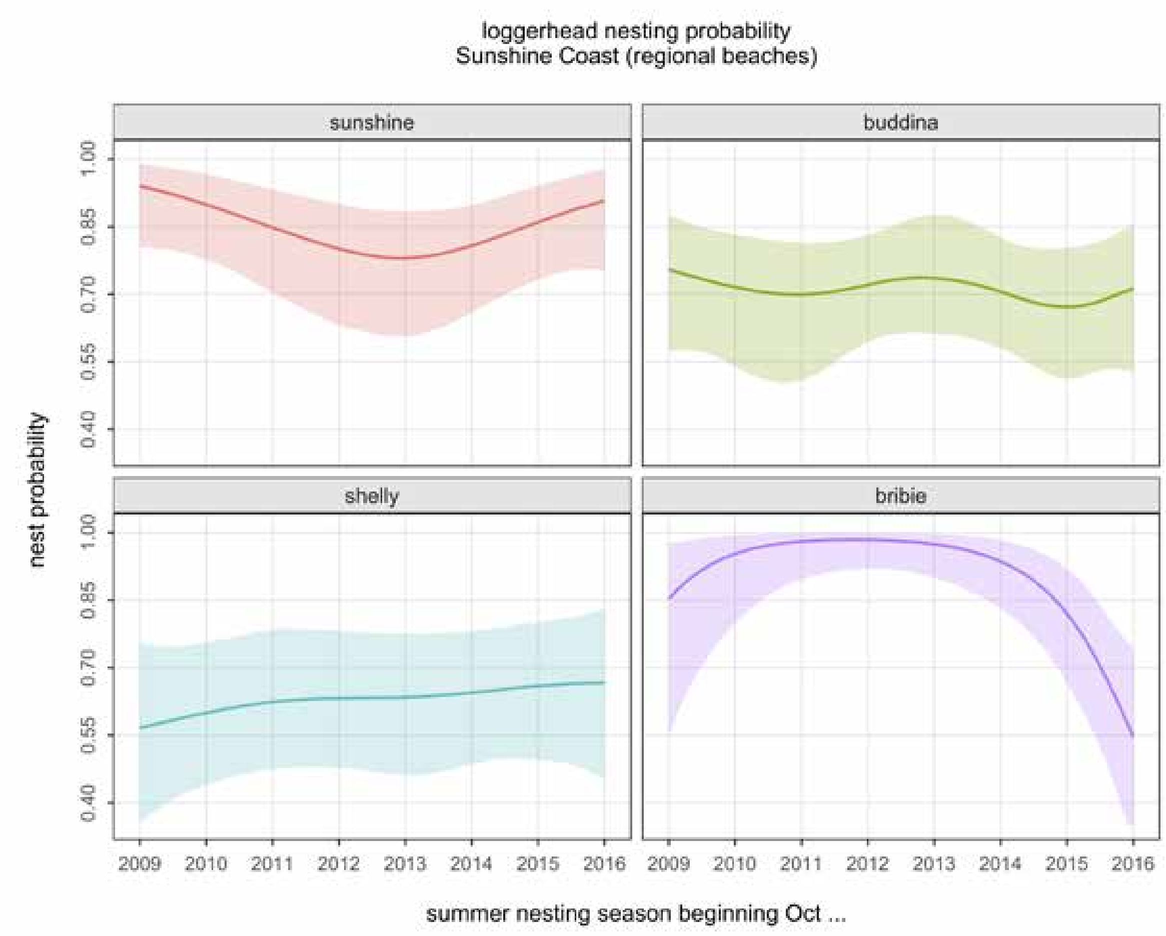


Figure 7: Subregion-specific nest probability (the probability that a loggerhead turtle that emerged onto the beach then laid a clutch of eggs) for the nesting seasons from 2009 – 2016. Solid curve in each panel shows the estimated posterior mean effect with the polygon showing the 95% uncertainty or credible interval.

The return interval is defined as the time elapsed between a turtle returning to nest following a previous unsuccessful nesting attempt. In the SCR, the return interval was unable to be quantified due to variable effort in night time survey and associated tagging, however, the data that was collected is summarised in Table 2.

Table 1: Estimated region-specific rate or probability of a loggerhead that emerged on the beach then successfully laying a clutch of eggs – the 95% credible interval shows the lower and upper probability limits of uncertainty associated with the nesting success rate estimate. Regions ordered from south to north. Nesting beaches grouped into subregions shown in Figure 4.

			95% credible interval	
Season	Region	Rate	Lower	Upper
2009	Bribie	0.851	0.554	0.976
	Shelly	0.569	0.355	0.748
	Buddina	0.754	0.576	0.878
	Sunshine	0.940	0.803	0.990
2010	Bribie	0.952	0.797	0.993
	Shelly	0.602	0.438	0.756
	Buddina	0.715	0.540	0.833
	Sunshine	0.899	0.776	0.967
2011	Bribie	0.980	0.893	0.999
	Shelly	0.625	0.472	0.786
	Buddina	0.699	0.506	0.816
	Sunshine	0.848	0.705	0.933
2012	Bribie	0.984	0.920	0.999
	Shelly	0.632	0.480	0.784
	Buddina	0.721	0.592	0.833
	Sunshine	0.801	0.626	0.900
2013	Bribie	0.974	0.899	0.997
	Shelly	0.634	0.460	0.777
	Buddina	0.737	0.610	0.878
	Sunshine	0.780	0.603	0.885
2014	Bribie	0.935	0.829	0.983
	Shelly	0.644	0.483	0.785
	Buddina	0.704	0.579	0.827
	Sunshine	0.806	0.656	0.900
2015	Bribie	0.819	0.667	0.923
	Shelly	0.659	0.496	0.805
	Buddina	0.671	0.511	0.803
	Sunshine	0.859	0.729	0.941
2016	Bribie	0.546	0.315	0.744
	Shelly	0.666	0.447	0.830
	Buddina	0.714	0.524	0.857
	Sunshine	0.906	0.750	0.977

Table 2: Tagging history of all Marine Turtles recorded nesting on Sunshine Coast regional beaches during nesting surveys from 2005 – 2016.

Tagging history of turtles	loggerhead turtles (*Caretta caretta*)	green turtle (*Chelonia mydas*)
First time tagged females (Primary tagged turtles)	37	3
Recaptures (over all seasons)	11	0
Recaptured with tag scars only, previous applied tags lost	0	0
Recaptures (Within season change of colony)	1	0

Tagging census

A total of 40 nesting turtles were tagged during the monitoring period, 37 loggerhead and three green turtles.

Twelve tagged turtles returned as remigrants within the study period. Eleven of the 12 remigrant turtles have returned to the locality where they were initially tagged.

In each season intraregional nesting crawls were not recorded or quantified due to the arbitrary locality boundaries within the study area and the variable effort of night patrols for tag recoveries of returning turtles.

Two within-season changes of colony have been recorded within the study area. One turtle (QA4803) tagged at Peregian Beach on 19 November 2015 was recorded subsequently nesting at Mon Repos (Woongarra Coast) on 31 December 2015.

A second within-season change of colony was recorded for the Sunshine Coast Region, although it was outside of the study period for this report. A green turtle (K35620) tagged at Sandy Cape (Fraser Island) 17 November 2001, subsequently nested on Bribie Island on 5 January 2002.

Due to variable effort of night patrols for returning nesting turtles, it has not been possible to assess recruitment rate of first time breeding females.

The mean nightly number of turtles coming ashore for nesting (track count) during the peak nesting period (weeks 8 – 12) was 1.3 (SD = 1.4, n = 336, range = 0 – 7). The mean number of clutches laid per night was 0.88 (SD = 1, n =336, range = 0 – 6).

There were 1044 recorded loggerhead turtle nesting crawls during the monitoring period. In 2005, one loggerhead nest was recorded on 24th October, outside the normal monitoring period for the groups. This record was omitted from the track count calculation due to the record falling outside of typical monitoring period for the study area, but is within the range of nesting for the species on the Woongarra Coast.

The frequency distribution of nesting crawls by locality is summarised in Figure 5. The majority of the nesting turtles came ashore at Shelly and Buddina beaches. Approximately 23km of Bribie Island between the two monitored areas remains unquantified, however, intermittent survey by Queensland Parks and Wildlife Service Rangers indicates that nesting may be equal to or less than what is recorded in other locations on Bribie Island.

Inter-nesting periods, the time between a turtle nesting and her next nesting event, could not be determined due to variable effort of night time patrol for returning nesting turtles.

Foraging turtles in waters adjacent to the nesting beaches

No turtles were tagged in waters adjacent to nesting beaches under the three programs activities.

Size of nesting females

The mean curved carapace length (CCL) of the nesting female loggerhead turtles was 97.7cm (Table 3, Figure 8).

The mean curved carapace length (CCL) of the nesting female green turtles was 104.7 cm (Table 4, Figure 8).

Females that were tagged for the first time were unable to be distinguished from remigrant turtles as they were not distinguishable by external features such as curved carapace length, and due to the low incidence of capture and tagging of adult turtles in this study.

Table 3: Summary of curved carapace measurements and remigration intervals of nesting loggerhead turtles on Sunshine Coast Region Beaches from 2005 – 2016.

Caretta caretta	Mean	Std. Dev.	Minimum	Maximum	Sample size
	CURVED CARAPACE LENGTH (cm)				
First time tagged Turtles	96.7	5.4	83.0	109.0	32
All remigrant turtles	98.7	4.4	93.0	104.0	15
ALL TURTLES	97.0	5.1	83.0	109.0	47
	REMIGRATION INTERVAL (yr)				
All remigrant turtles	2.7	1.7	1	8	15

Table 4: Summary of curved carapace measurements and remigration intervals of nesting green turtles on Sunshine Coast Region Beaches from 2005 – 2016.

Chelonia mydas	Mean	Std. Dev.	Minimum	Maximum	Sample size
	CURVED CARAPACE LENGTH (cm)				
First time tagged	104.7	2.6	101.7	106.3	3
All remigrant turtles	nil recorded				
ALL TURTLES	104.7	2.6	101.7	106.3	3
	REMIGRATION INTERVAL (yr)				
All remigrant turtles	nil recorded				

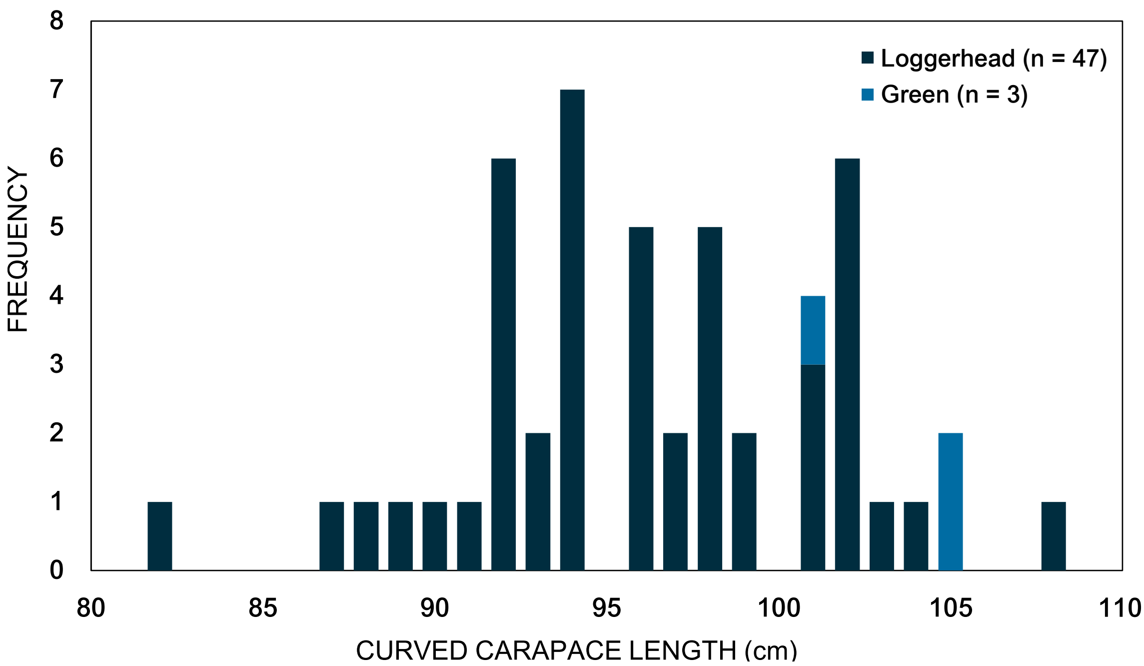


Figure 8: Frequency distribution of curved carapace length of all marine turtles, recorded nesting on Sunshine Coast Region beaches from 2005 - 2016.

Remigration

The mean remigration interval, the number of years between recorded breeding seasons, for adult female loggerhead turtles at Sunshine Coast beaches was difficult to accurately describe due to variable night time survey effort for returning nesting turtles, and therefore, limited samples for assessment.

There are 15 records of individual turtles that have been observed nesting at what would be considered normal remigration intervals, 1 – 8 years (Table 3, Figure 9).

No remigration of tagged green turtles has been recorded.

Nest data

A total of 808 clutches (nests) (includes multiple clutches at some nest locations) were laid by all species during the 10-year study period. On average, 2.9 (SD = 3.3, n = 691) nests were laid per week. Average weekly numbers of nesting attempts and clutches laid are summarised in Figure 10. During the 2-week peak nesting period (weeks 9 and 10 from 1st November), an average of 11.7 nests were laid (SD = 6.2, n = 12).

The number of eggs per clutch, including yolkless and multi-yolk eggs, and nest depths are summarised in Table 5, Table 6 and Figure 11.

The loggerhead turtle clutches had on average 129 eggs per clutch (n=227), 0.1 yolkless eggs and 0.03 multi-yolk eggs per clutch.
No morphometric data were taken of the eggs during the study period. The nests were on average 31.5 cm deep to the top of the eggs and 54.1 cm to the bottom.

The green turtle clutches had on average 102 eggs per clutch (n=7) with no recorded yolkless or multi-yolk eggs during the study period. The nests were on average 30cm deep to the top of eggs and 56.8cm to the bottom.

None of the turtles within the study area were observed digging into existing clutches.

Loggerheads laid 56.4% of nests on the beach or slope and 43.6% in dune habitat (n = 555). Greens laid 34.4% of nests on the beach or slope and 65.6% in dune habitat (n = 32).

Table 5: Loggerhead turtle clutches, and nest descriptions on Sunshine Coast Regional beaches 2006-2016 breeding seasons.

	Mean	Std. Dev.	Range	N
Eggs per clutch	129	26.2	42 - 192	227
Yolkless eggs per clutch	0.11	0.5	0 - 4	228
Multiyolked eggs per clutch	0.03	0.2	0 - 2	227
Nest depth, top (cm)	31.5	9	4 - 69	239
Nest depth, bottom (cm)	54.1	7	24 - 82	190

Table 6: Green turtle clutches, and nest descriptions on Sunshine Coast Regional beaches 2006-2016 breeding seasons.

	Mean	Std. Dev.	Range	N
Eggs per clutch	102	16.5	84 - 126	7
Yolkless eggs per clutch	nil recorded			
Multiyolked eggs per clutch	nil recorded			
Nest depth, top (cm)	30	8.1	17 - 42	7
Nest depth, bottom (cm)	56.8	8.7	45 - 68	7

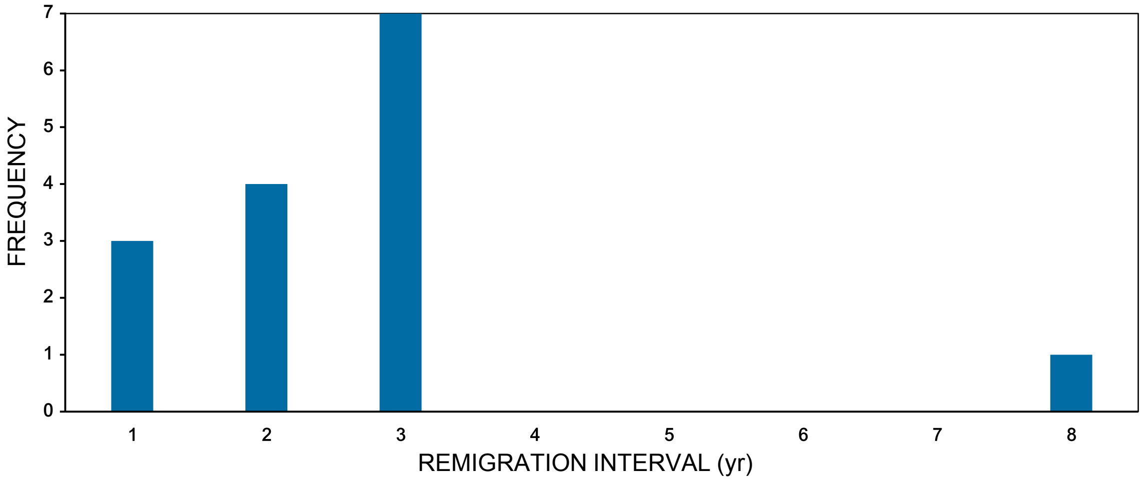


Figure 9: Frequency distribution of remigration interval of all marine turtles, recorded nesting on Sunshine Coast Region beaches from 2005 – 2016.

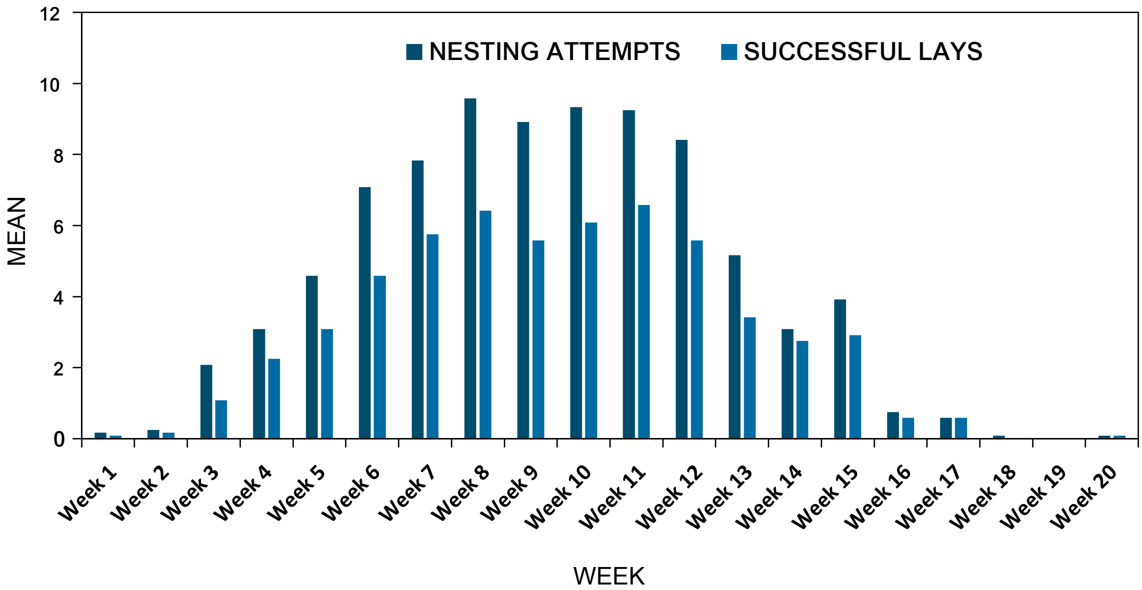


Figure 10: Mean frequency distribution of nesting activity of all marine turtles recorded nesting on Sunshine Coast Region beaches per week from 1st November 2005 – 2016.

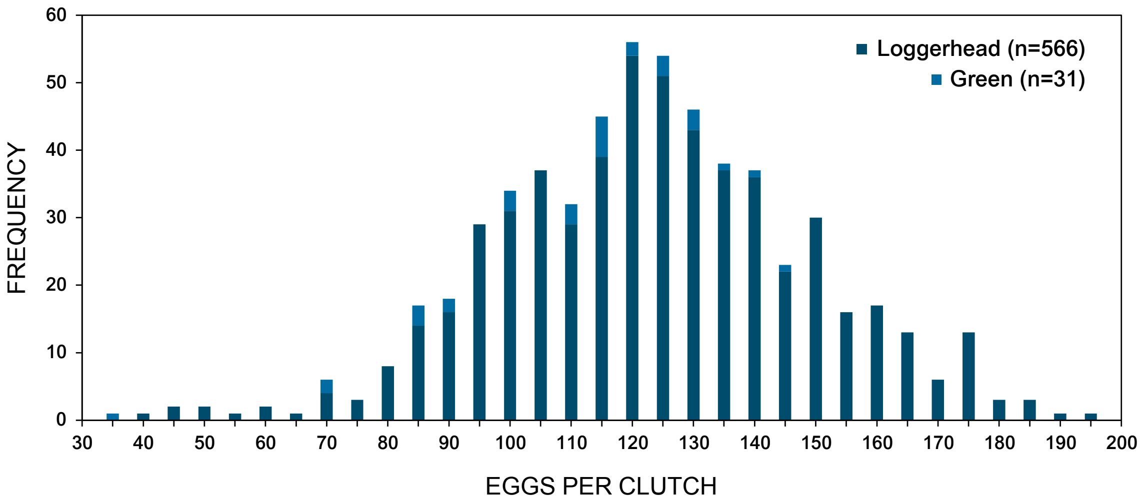


Figure 11: Frequency distribution of the number of eggs per clutch of all marine turtles, recorded nesting on Sunshine Coast Region beaches from 2005 – 2016.

Incubation success and hatchling production

608 nests were excavated to assess incubation success during the monitoring period. 588 nests were analysed to determine hatching and emergence success. 20 records with greater than 10% error from known clutch counts were excluded. Counters' results were analysed for repeat high error, none were excluded.

The mean hatching success of loggerhead nests was 75.8% (SD = 29.0, n = 588) and the mean hatchling emergence to the beach surface was 72.1% (SD = 29.3, n = 588) from 2006 - 2016. A summary of the incubation to hatch and emergence success is displayed in Figure 12.

The loggerhead hatch success rate (irrespective of beach or habitat) based on a GLMM with zero-one-inflated Beta likelihood was 0.764 (76.4%) (95% uncertainty interval: 0.73-0.79).

On average, the period to emergence for loggerheads was 66 days (n = 514, SD = 8.5) (Table 7).

282 nests (49.7% of 567 nests) contained dead hatchlings, and 412 nests (72.7%) contained live and/or dead hatchlings. Combined counts of live and dead hatchlings represented 2.8% of all eggs laid.

The mean hatching success of green nests was 76% (SD = 26.2, n = 31) and the mean hatchling emergence to the beach surface was 73% (SD = 26.9, n = 31) from 2006 - 2016. A summary of the incubation to hatch and emergence success is displayed in Figure 13.

Table 7: Incubation and hatchling emergence success and incubation period for loggerhead turtle clutches on Sunshine Coast Regional beaches 2006 - 2016.

	Mean	Std. Dev.	Range	N
Incubation period (oviposition to emergence) (days)	66	8.5	45 - 125	514
Hatching success of eggs (%)	78.1	25.9	0 - 100	547 clutches
Hatchling emergence success (%)	74.3	26.4	0 - 99.2	547 clutches

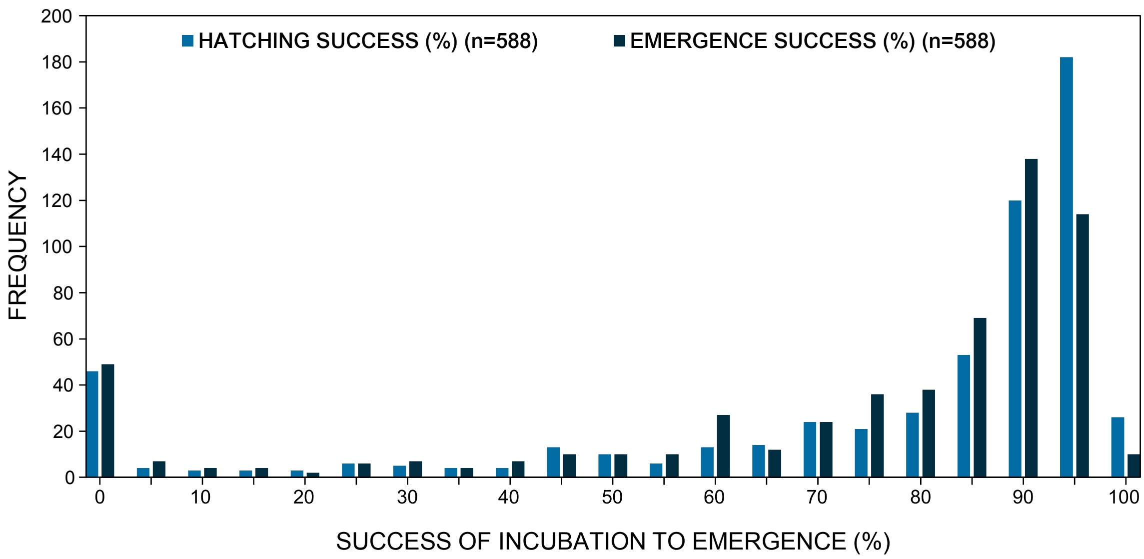


Figure 12: Distribution of the percentage of incubation and emergence success across loggerhead turtle clutches on Sunshine Coast Region beaches from 2006 - 2016.

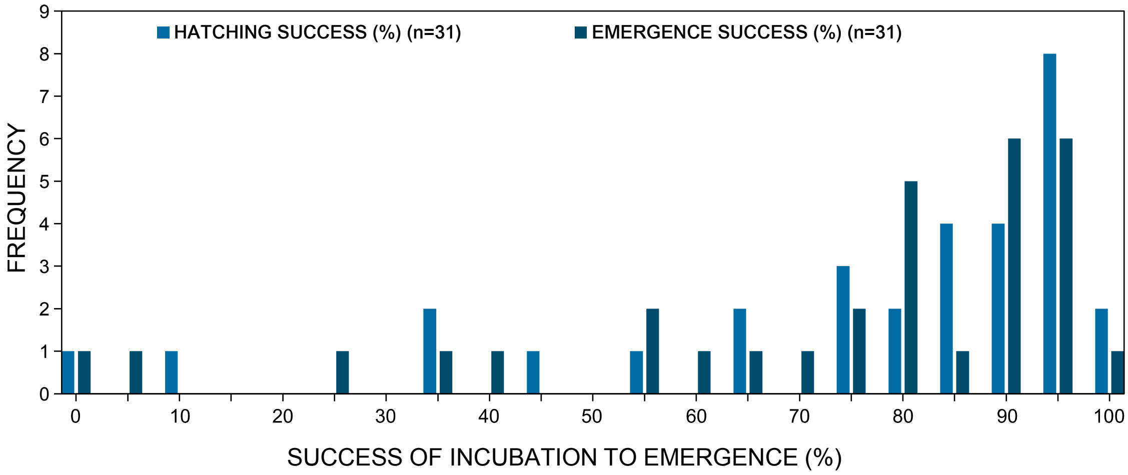


Figure 13: Distribution of the percentage of incubation and emergence success across green turtle clutches on Sunshine Coast Region beaches from 2006 - 2016.

On average, the period to emergence in green turtles was 69 days (SD = 7.5, n = 29) (Table 8).

The period to emergence for all species increased over time from January through to May (period to emergence: t= 11.4, df= 550, p<0.001). However, the r2 value of this analysis was low, indicating that other factors affect this trend apart from the date (Figure 14).

Of the 31 green nests excavated, 14 nests (45.2%) contained dead hatchlings, and 22 nests (71%) contained live and/or dead hatchlings. Combined counts of live and dead hatchlings represented 3% of all eggs laid.

The zero-one-inflated Beta GLMM was a good fit to the loggerhead hatch and emergence success data with the metric-specific (hatch, emergence) rate estimates for relocated and natural loggerhead nests shown in Figure 15 (with 95% uncertainty intervals).

Natural nests have higher hatch and emergence rates than relocated nests. The hatch success rate for natural loggerhead nests were 0.775 (77.5%) (95% uncertainty interval: 0.73-0.81) and relocated loggerhead nests were 0.704 (70.4%) (95% uncertainty interval: 0.65-0.75)

Table 8: Incubation and hatchling emergence success and incubation period for green turtle, Chelonia mydas clutches on Sunshine Coast Regional beaches 2006 - 2016.

	Mean	Std. Dev.	Range	N
Incubation period (oviposition to emergence) (days)	69	7.5	50 - 84	29
Hatching success of eggs (%)	76	26.2	1.7 - 99.2	31 clutches
Hatchling emergence success (%)	73	26.9	0 - 98.3	31 clutches

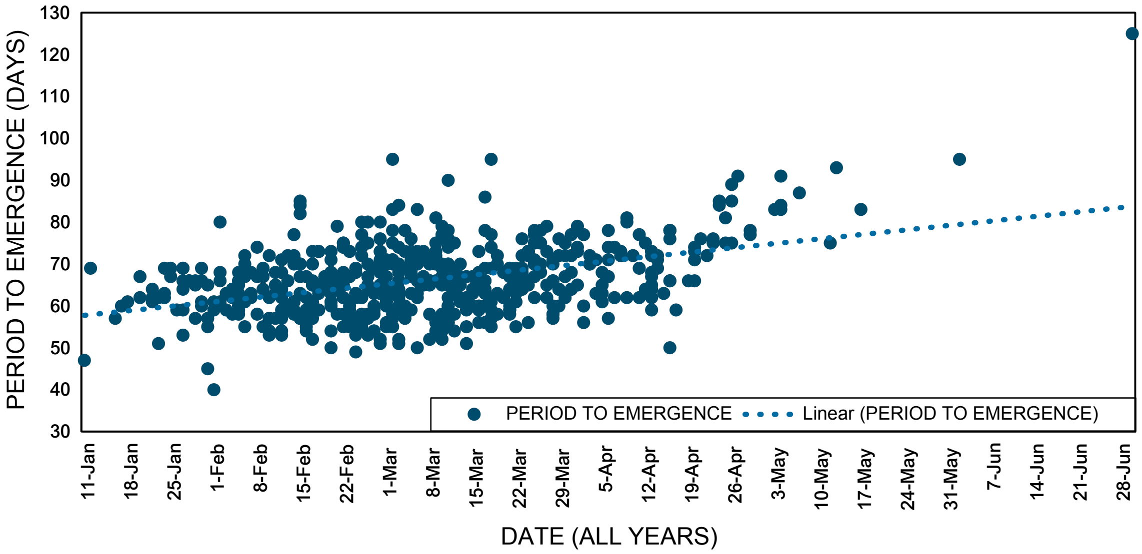


Figure 14: Period to emergence of all clutches laid on Sunshine Coast region beaches from 2005 – 2016.

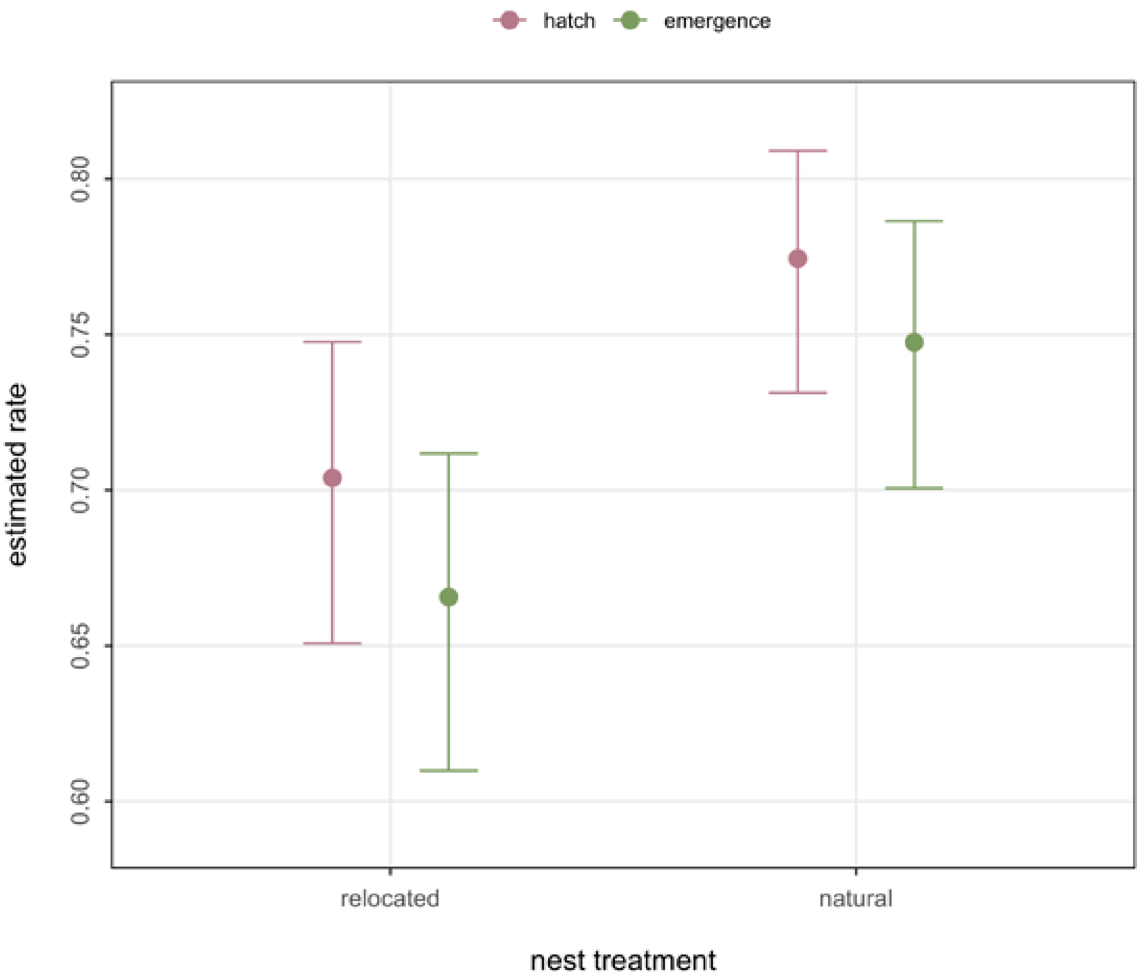


Figure 15: Estimated hatch and emergence success rate for relocated loggerhead nests and natural (in-situ) loggerhead nests. Solid dot = posterior mean estimate, vertical bar = 95% uncertainty or credible interval.

There was a significant increasing trend in both hatch and emergence success rates from 2009 onwards for both natural and relocated nests (Figure 16).

Beach specific loggerhead hatch success rates are shown in Figure 17. Loggerhead hatch success was lower in the northern Sunshine Coast beaches (Twin waters to Noosa) than beaches south of Buddina. The Buddina to Wurtulla stretch reported marginally higher hatch success rates than other southern beaches which had similar results.

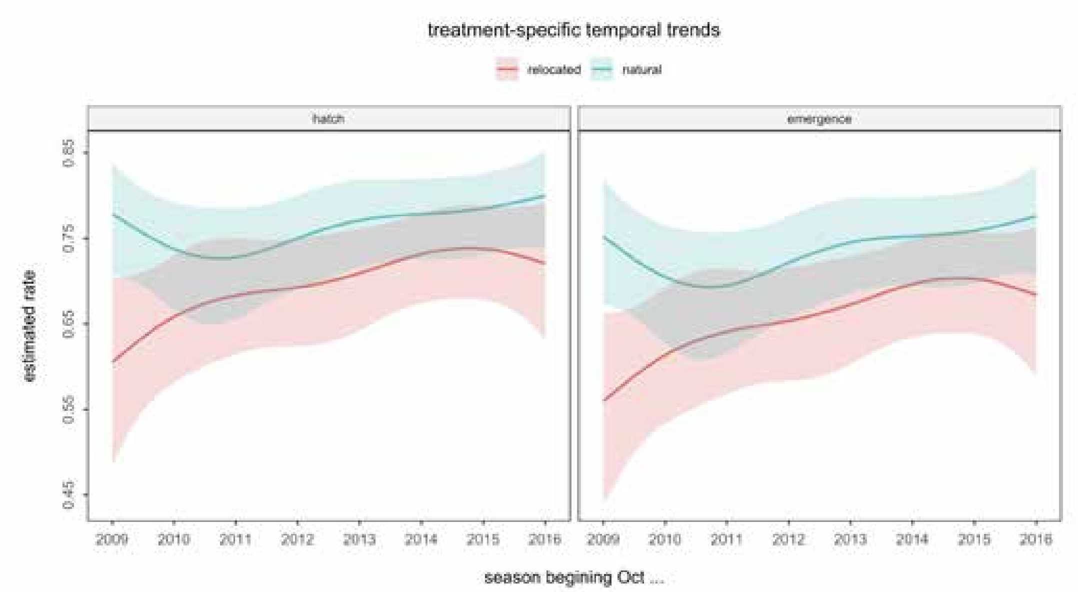


Figure 16: The nonlinear treatment specific temporal trends from the model summarised in Figure 15. Solid curves in each panel shows the estimated posterior mean effect for relocated nests and natural (in-situ) nests with the polygons showing the 95% uncertainty or credible intervals.

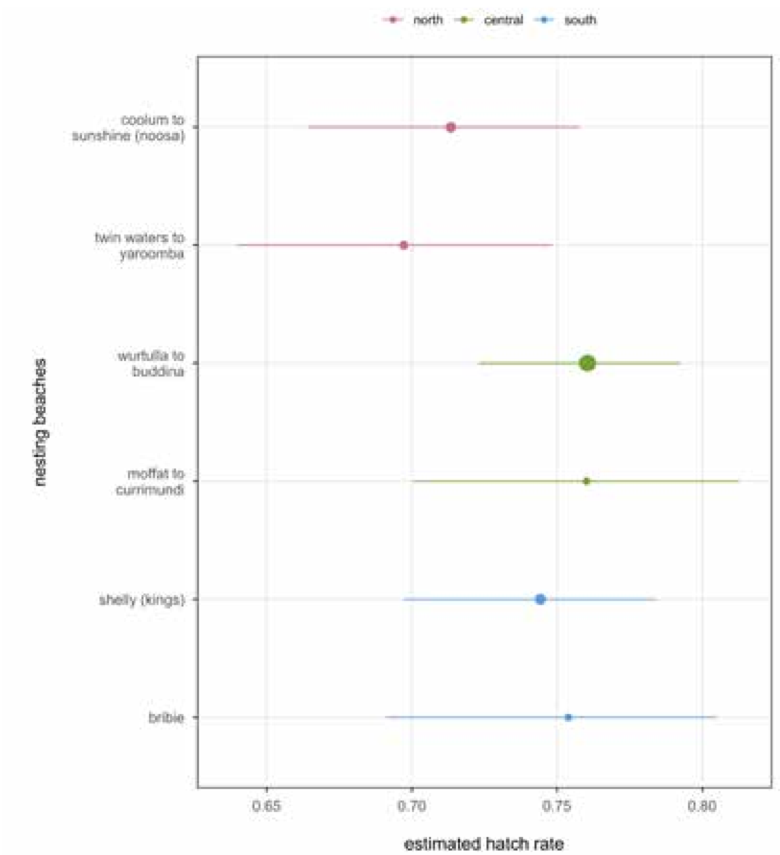


Figure 17: Estimated beach-specific loggerhead hatch success rates from north to south. Solid dot = posterior mean estimate, horizontal bar = 96% uncertainty or credible interval. Dot size is proportional to sample size.

The size of each clutch was included as a potentially informative nonlinear covariate (following Ditmer and Stapleton, 2012) for the analyses on hatch success and nesting beach. However it was not found to be informative.

Habitat specific hatch success is shown in Figure 18 with 95% confidence intervals. Most of the data were for dune habitat (dune grass or dune sand) where the estimates have high precision. Due to weak inference in other habitat types, there appears to be no habitat-specific hatching rate effect, despite the apparent loggerhead preference for dune habitat.

No relationship was detected between hatch success and depth to the bottom of the nest ($F = 1.60$, $df = 1$, $p = 0.21$), (Figure 19).

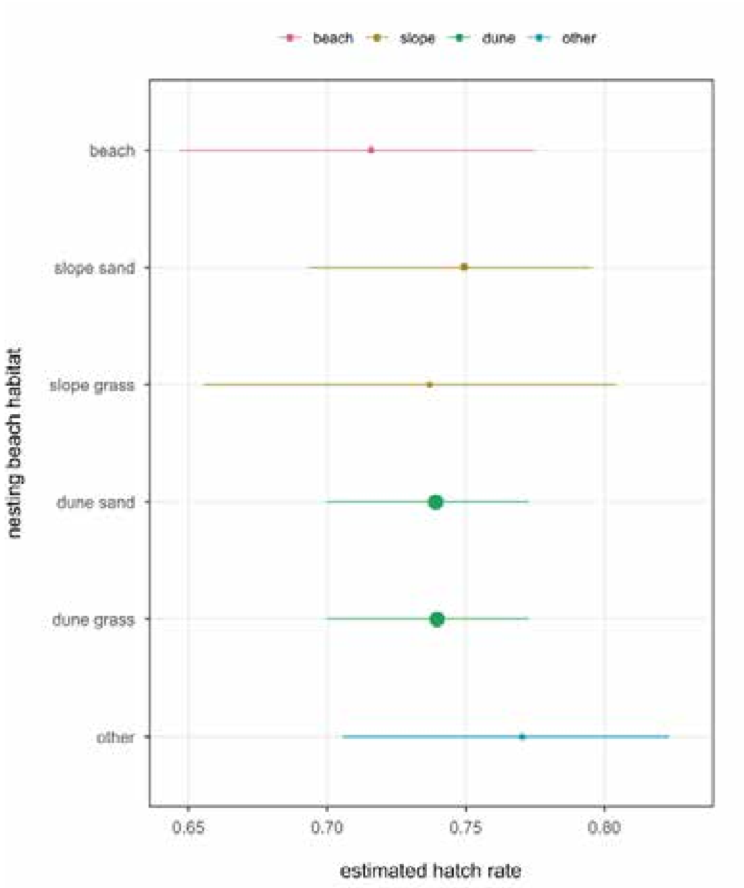


Figure 18: Estimated habitat-specific loggerhead hatch rates arranged from bottom to top of the beach. Solid dot = posterior mean estimate, horizontal bar = 95% uncertainty or credible interval. Dot size is proportional to sample size.

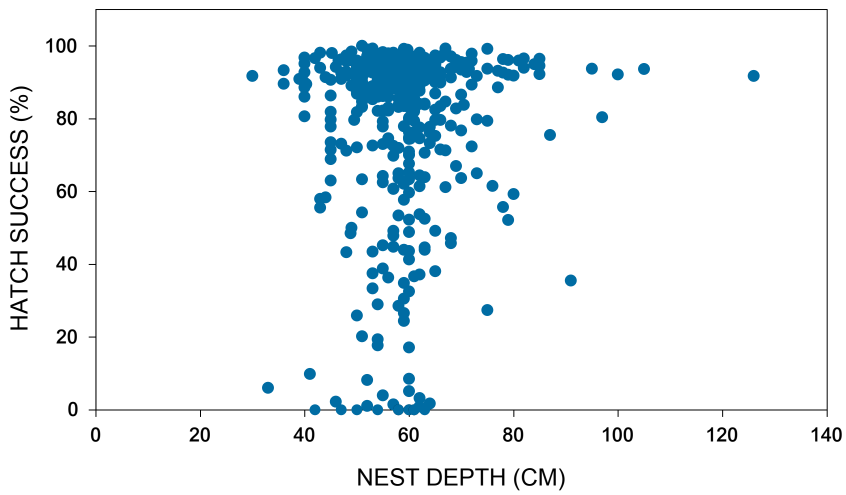


Figure 19: Hatch success graphed against nest depths in the Sunshine Coast region from 2005 – 2016.

Sand temperatures

The sand temperature profiles from the standard monitoring sites at Shelly Beach and Yaroomba Beach, both in open sun locations, are summarised in Figure 20, Figure 21 and Figure 22.

Typically, the incubation environment at both Shelly and Yaroomba Beaches was below the pivotal temperature for temperature dependent sex determination of 28.6°C (Limpus et al. 1985). The typical sand temperatures at nest depth for both beaches are indicative of a male biased sex ratio.

Recorded sand temperatures were within the optimal range for incubation for almost the entire nesting season. Sand temperatures typically fall below the lower lethal limit of 25°C for clutch incubation (Limpus et al, 1985) between the end of March and April. All temperatures recorded in the study were below the higher lethal limit of 33°C (Limpus et al, 1985) for nest incubation. Usually interspersed throughout the yearly average temperatures are short periods of lower temperatures, caused by the typical low-pressure storms that occur in the region annually in February/March.

At Shelly Beach, there were short periods of elevated temperatures above 28.6°C, indicating the beach may produce female hatchlings for short periods. The sand composition at Shelly Beach is coarser (containing more shell grit) than most other beaches on the Sunshine Coast (Sunshine Coast Council, 2014).

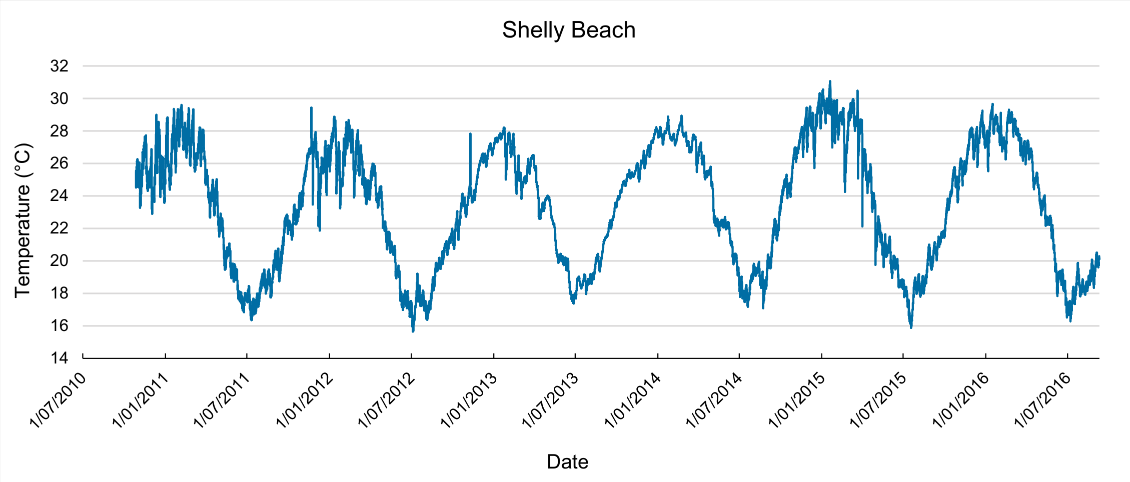


Figure 20: Sand temperature at 50 cm depth from 27 October 2010 – 9 September 2016 at Shelly Beach.

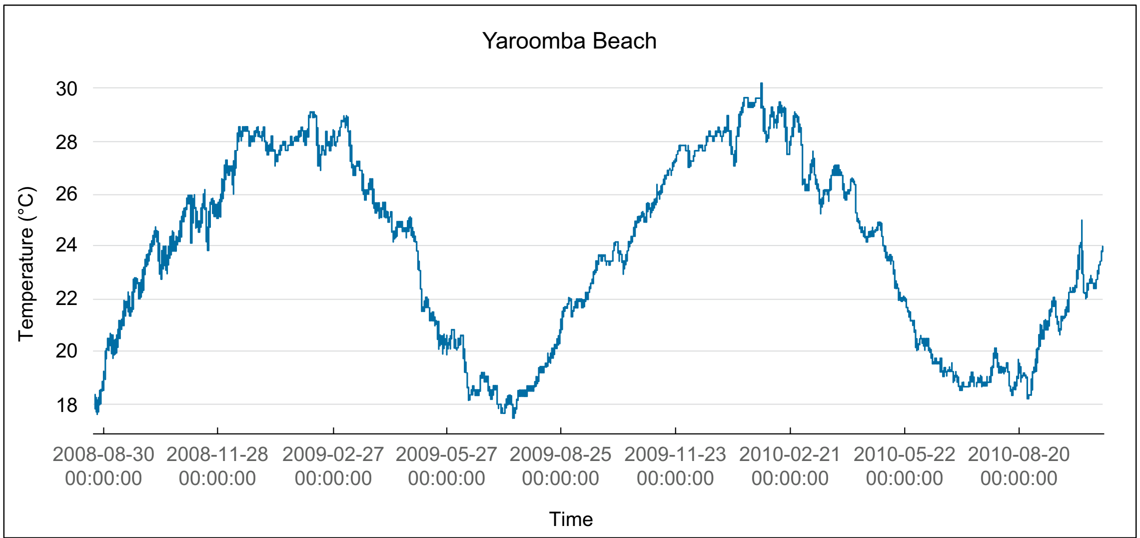


Figure 21: Sand temperature at 50cm depth from 22 August 2008 – 27 October 2010 at Yaroomba Beach.

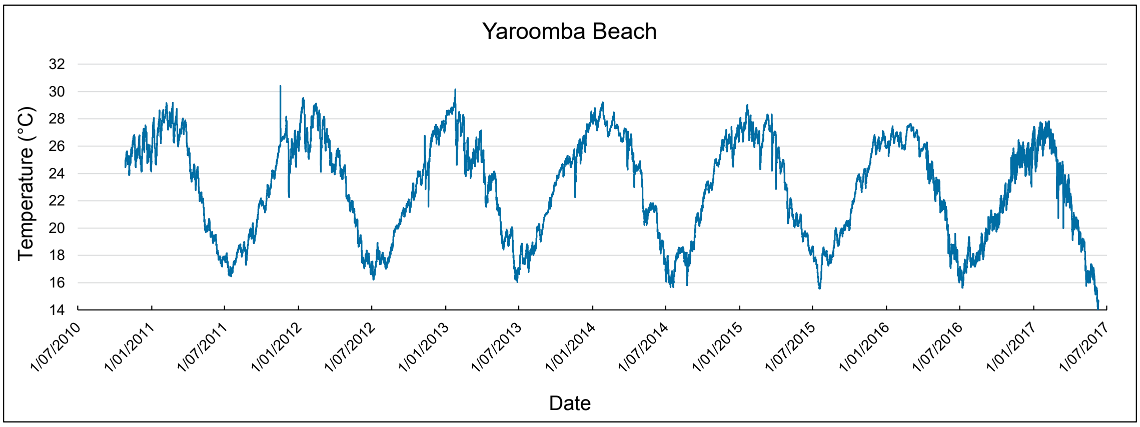


Figure 22: Sand temperature at variable depth (see discussion) from 27 October 2010 – 10 June 2017 at Yaroomba Beach.

Active management

Doomed egg relocation data

Eggs laid at Kings, Mooloolaba, Alexandra Headlands and Maroochydore beaches were routinely relocated to adjacent dark nesting beaches due to high levels of artificial light.

A total of 239 (30.4%) loggerhead clutches were relocated during the study period. Of the 313 nests laid on the beach or slope, 53% (n = 166) were relocated. Of the 242 nests laid in the dune, 24.4% (n = 59) were relocated.

A total of 8 (22.9%) green clutches were relocated during the study period.

Of the 11 nests laid on the beach or slope, 27.2% (n = 3) were relocated. Of the 21 nests laid in the dune, 23.8% (n = 5) were relocated.

Details of the percentage of all nests that were relocated at each beach can be found in Figure 23. A trend analysis was calculated for the two beaches with sector markers installed (Buddina and Shelly beaches). The results were not suitable for reporting as the low density of nesting in some sectors did not allow for meaningful statistical analysis.

Depredation and predation

Depredation and/or loss of clutches was attributed to grass roots (variety of species), European Red Fox (*Vulpes vulpes*), Goanna (*Varanus varius*), Ghost Crab (*Ocypode cordimana*), ants, erosion and flooding.

The four nests that were breached by Goanna on North Bribe Island were typically accessed from the back of the elevated dunes. Aluminium FED exclosures were applied post-predation to reduce likelihood of subsequent breaches.

Potential bird predators of hatchlings recorded during the field studies included Osprey (*Pandion haliaetus*), Brahminy Kite (*Haliastur indus*) and Silver Gull (*Chroicocephalus novaehollandiae*). Depredation of hatchlings on the beach surface was attributed to European Red Fox, Ghost Crab, Osprey, Brahminy Kite, Australian White Ibis (*Thresokornis australis*), and domestic cat.

Bird predation of hatchlings was recorded on two occasions (Brahminy Kite and Australian White Ibis). Volunteers were typically in attendance during emergence, which may have deterred bird predators.

An Australian White Ibis was observed depredating a green turtle hatchling where light disorientation had led the hatchling away from the coastal environment into a freshwater creek (Figure 24). Similarly, a domestic cat predation event occurred when hatchlings were disorientated due to artificial light, leading them behind the dune into a suburban area of Buddina.

One hatchling on Shelly Beach was picked up by a small domestic dog after being freed from the nest during a nest success dig in the 2007/2008 season. The hatchling was checked for injury and released unharmed.

A nest was dug into several hours after emergence by a domestic dog at Woorim on 24 March 2017. Four hatchlings were uncovered and released by the attending owner.

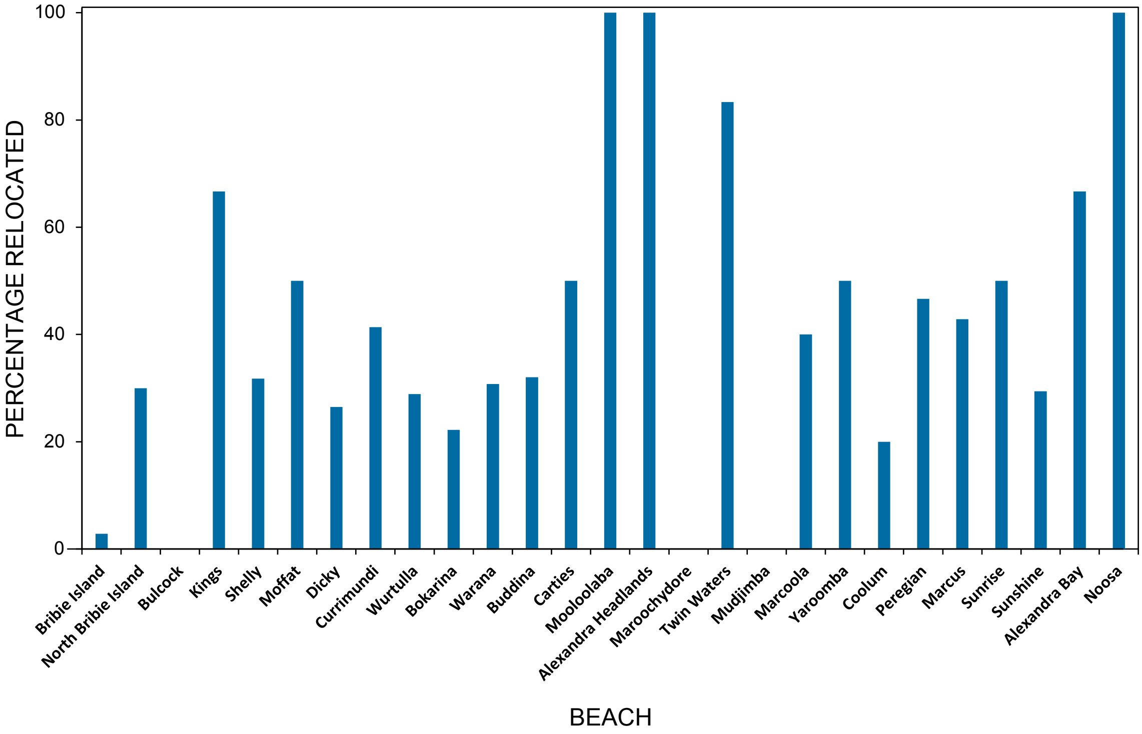


Figure 23: Percentage of all nests laid at each beach that were relocated at Sunshine Coast Region beaches from 2005 – 2016.

Figure 24: Green turtle hatchling depredation by Ibis at Dicky Beach.
Image supplied by K. Smith, TCSCC.

Fox predation

Egg and Hatchling predation by the European Red Fox (*Vulpes vulpes*) was identified as a major issue for Sunshine Coast nesting during early years of monitoring. In 2010 TC Coordinator Julie O'Connor commenced a PhD study to investigate coastal foxes within the southern Sunshine Coast area.

a South Sunshine Coast O'Connor et al. (2017) investigated the impact of foxes on turtle nests between Shelly Beach and Point Cartwright over ten nesting seasons. Meshing was undertaken on all nests over the ten-year period accompanied by lethal fox control in the first five-year period, but not in the second five-year period.

During the lethal fox control period, foxes breached 27% of nests. During the second period with no lethal fox control, foxes breached under 3%.

b North Sunshine Coast Meshing and lethal fox control was undertaken in all years on and nearby to beaches north of the Maroochy River. Three nests were predated by foxes during the study period (2014, 2015 and 2016).

No fox predation of turtle nests has been recorded on Bribie Island.

On 29 January 2017, two loggerhead hatchlings were caught and perished in the predator exclusion meshing during emergence. The mesh and hatchlings were located under the sand surface and therefore not visible to attending volunteers.

Table 9: Light mitigation actions undertaken from 2006 – 2016.

Season	Organisation	Light Mitigation Action
2006	Sunshine Coast Council	William St, Shelly Beach: Installation of 30cm shield. Victoria Tce, Shelly Beach: Installation of internal baffle shield and high pressure sodium light (amber).
2011	Moreton Bay Regional Council	Queens Beach North, Scarborough: Change from white LED to lower intensity amber luminaire.
2012	Sunshine Coast Council and Energex	Pacific Blvd, Buddina: Luminaire swap from semi-cut-off to Aero screen style.
2013	Sunshine Coast Council	Pacific Blvd, Buddina: Luminaire swap from semi-cut-off to Aero screen style. David Low Way, Coolum: swap from semi-cut-off to Aero screen style. Victoria Tce, Shelly Beach: Replace floodlights with lower height LED with zero rearward spill. Kawana SLSC, Buddina: Shielding of Flood Light.
2014	Sunshine Coast Council and Energex	Pacific Blvd, Buddina: 3 street lights lowered in height and front glare shields installed. Point Cartwright Reserve, Buddina: Relocation of external facilities light to inside features of building and internal shielding applied. Dicky Beach Park, Dicky Beach: Adjustment of flood lighting to reduce spill onto nesting beach, temporary removal of a single flood light and short-term internal shielding applied. Moffat Beach Park, Moffat Beach: Adjustment of flood lights to reduce spill onto nesting beach.
2015	Sunshine Coast Council	Viewing platform, Mudjimba: Installation of proximity sensor and shielded amber LED. Sporting Complex, Coolum: Shielding applied to sporting light towers.
2016	Sunshine Coast Council and Energex	Pacific Blvd, Buddina: Internal glare shields applied to street lights. Kawana Surf Life Saving Club Car park, Buddina: Upgrade to dimmable LED, shielding and application of amber (theatrical) gels into luminaire.

Light pollution and orientation of turtles

Light pollution and turtle orientation were not formally documented through hatchling fan studies. Informal reporting of incidence resulted in the following reports of significance (in date order);

- A large number of loggerhead hatchlings were found disorientated on 9 March 2010, more than 100m upstream in Stumers Creek Coolum, and near the Stumers Creek car park. Tall and high intensity light from the adjacent sporting complex was observed to be in operation until approximately 9pm. Once lights were switched off, CANSCC volunteers used torch light to attract hatchlings downstream towards the beach. Hatchlings were collected and released further north on the same beach.
- Two hatchlings were found deceased after being run over by a vehicle and two hatchlings predated by a domestic cat on Gulai St Buddina on 13 March 2010. The hatchlings travelled approximately 70 metres from the nest site.
- A nest emergence occurred on 27 April 2011 at Coolum Main Beach, which was attended by CANSCC Volunteers. Within 20 minutes, volunteers subsequently observed several hatchlings emerging from the water towards Tickle Park, approximately 50 metres from the nest location. Hatchlings were collected and released north of Stumers Creek.
- Use of purpose-built fabric guard on dark beaches where vegetated dune is not sufficient to block direct residential and/or street lighting and light glow occurred at Buddina from 2012, and between Caloundra and Warana from February 2015.
- A number of hatchlings were observed by members of the public in a flooded swale behind BA277 at Shelly Beach on 3 March 2013. Hatchlings were subsequently released on the beach.
- Approximately ten loggerhead and green Hatchlings (from two nests) were found in the creek within the Dicky Beach Caravan Park in the 2013 season, one of which was predated by Ibis.
- Approximately 15 hatchling tracks were observed in a south-southwest direction towards the artificial lighting of the Sunshine Beach Surf Life Saving Club at Sunshine Beach on 2 March 2017. Hatchling tracks ceased north of Beach Access 31, approximately 20 metres from the nest site (Figure 25). The fate of the hatchlings is unknown.

Prior to 2015, the reasons for nest relocations have not been specific enough to undertake a trend analysis on artificial light.

The success of the novel light guards around nests has not been formally tested. Anecdotal reports suggest that incidence of disorientated hatchlings at emergence are reduced with their use. However once outside the light guard shield, observations of tracks show that hatchlings resume disorientation from direct light or light glow despite being greater than 10m away from the nest site.

Sunshine Coast and Moreton Bay Regional Councils have undertaken several actions to reduce the direct light visible from nesting beaches (Table 9). All light mitigation actions were undertaken in response to either a significant hatchling disorientation event or scheduled upgrades to coastal infrastructure resulting in increased light on nesting beaches.

Figure 25: Hatchling disorientation at Sunshine Beach. Flagged sticks indicate nest location, polycarbonate pegs indicate hatchling track extent, volunteer position indicating where hatchling tracks ceased. Image supplied by S. Richards CANSCC.

Locally relevant observations

Beach armouring

Beach armouring has been identified as a threat to the recovery of the loggerhead turtle in the SSAP, and is unquantified across the species range. Rock armoured walls represent 3.1% (1.71km) of the study area.

There were 13 unsuccessful nesting attempts over the study period due to beach armouring preventing access to prime nesting habitat (Sunshine Coast Council, 2018). The nesting success for all attempts directly in front of rock armoured walls within the study area was 27.9% (n=18).

Extreme weather

Sunshine Coast beaches are normally affected, particularly in the summer months, by periodic tropical lows and associated high seas which can result in moderate to severe erosion on nesting beaches.

Thirty-one nests were lost or partially lost during the study period due to severe weather or erosion (Table 10).

Table 10: Nests partially or entirely lost due to severe weather or erosion.

Season	Weather Event	Nests lost or partially lost due to severe weather or erosion
2005/2006		2
2008/2009	Ex TC Hamish	6
2009/2010		4
2010/2011		1
2012/2013	TC Oswald	16
2014/2015	Ex TC Marcia	0
2015/2016	Ex TC Winston	1
2016/2017	Ex TC Debbie	1

Pacific adventurer oil spill

On 11 March 2009, the Pacific Adventurer container ship lost 31 containers off the northern tip of Moreton Island with resulting breaching of her hull and releasing 200 tonnes of fuel oil into the ocean. This oil coated nesting beaches within the study area.

To prevent hatchlings entering the oil spill, the Queensland Department of Environment and Resource Management instructed and permitted Sunshine Coast Council to enclose the nests to contain and collect hatchlings at nest sites for release outside the footprint of the oil plume.

Sixteen nests were protected with purpose built enclosures that attached to the FEDs in place on remaining nests. The enclosures were expected to contain emerging hatchlings, and were checked three times each evening.

Three nests emerged in the days immediately following the spill and hatchlings were collected and released at the unaffected Teewah beach to the north of the study area (26.3297°S, 153.0610°E (digitised coordinates)).

Three nests emerged in the days following and were released at Shelly and Dicky beaches, which were free of oil contamination. Two further nests emerged during the beach closure where hatchlings were released at the nest site as the locations had been confirmed to be clear of any oil hazard.

At least three loggerhead hatchlings were predated by a fox at Wurtulla during the short period the nest was left unattended. The fox breached the purpose built enclosure during an emergence. All enclosures in use were reinforced after the incident to reduce likelihood of further predation events during the spill recovery.

No hatchlings crossed the beach to enter the oil contaminated section of the coast.

Other observations

On 2 March 2015, a previously unrecorded clutch of loggerhead hatchlings emerged from the Victoria Terrace revegetation zone at Shelly Beach. An 18t D6 bulldozer had, in the hours prior to emergence, ceased daytime beach renourishment operations in response to major erosion caused by Tropical Cyclone Marcia.

Hatchlings were observed to emerge from the nest and successfully navigate around the D6 and construction barriers to reach the ocean (Figure 26). The nest was meshed after emergence and subsequently recorded 95.1% emergence success. The machine operator had previously been advised by the TurtleCare Coordinator that all nest and emergence activity was completed at Shelly beach for the season.

Figure 26: Loggerhead turtle nest with 18t Bulldozer, Shelly Beach. Image supplied by K. Hofmeister SCC.

Deformities and genetic mutations

Occasional deformities and genetic mutations were noted throughout the survey period during nest success digs. The following is a summary of noteworthy occurrences.

In the 2009 nesting season, one occurrence of parasitic twin loggerhead hatchlings was observed at Wurtulla on 14 January 2010.

A green hatchling displaying albinism was found on 7 February 2016 during a nest success dig of an untagged turtle at Marcus Beach. The hatchling was photographed (Figure 27) and released on site. The emergence of this clutch was not observed by CANSCC volunteers, and no remaining unhatched embryos within the clutch displayed the albinism characteristic.

A loggerhead embryo, discovered alive and unhatched, displayed leucism and facial deformities during a nest success dig of an untagged turtle at Wurtulla in 2013. No remaining unhatched embryos within the clutch displayed deformities or genetic mutations.

Figure 27: Albino green turtle hatchling, Marcus Beach. Image supplied by A. Savage CANSCC.

Figure 28: Pre-release photograph of QA4840 'Matilda' and community volunteers, Shelly Beach. Image supplied by C. Bull TCSCC.

Health and injuries

One nesting turtle was reported to have died at Woorim on Bribie Island in the 2009 nesting season when it flipped over while crawling over a dune. It was discovered in a D4 carcass condition, several weeks afterwards. A nest was unable to be located.

None of the nesting turtles observed during the study period displayed fresh or recent injuries. No fibropapilloma tumours were observed on any of the turtles.

One turtle (QA4826) was observed to display a healed rear flipper injury that limited its capacity to dig a nesting chamber. On the one occasion this turtle was observed, it was assisted to lay by attending volunteers. Nesting turtles with healed injuries have been recorded within the study area, although it has not been quantified within this report. Typically, nesting can occur without assistance for these individuals.

Satellite telemetry

On 6 January 2012 a nesting loggerhead turtle (QA4840 'Matilda'; PTT = 49961) from Shelly Beach was fitted with a Sirtrack Kiwisat tracking device (Figure 28).

Tracking results suggests QA4840 subsequently nested at Currimundi Beach on 20 January 2012 prior to migration to her foraging grounds at the Cumberland Islands Group to the west of Brampton Island (Figure 29, Figure 30, Figure 31 and Figure 32). The tracking device operated for 207 days. Last recorded transmission was 15 August 2012.

Figure 29: Inter-nesting habitat use of QA4840 'Matilda', 6 – 20 January 2012.

Figure 31: Migratory route of QA4840 'Matilda'.

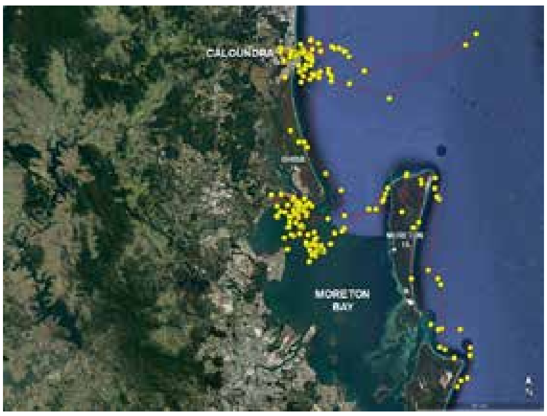


Figure 30: Post-nesting foraging behaviour of QA4840 'Matilda'.

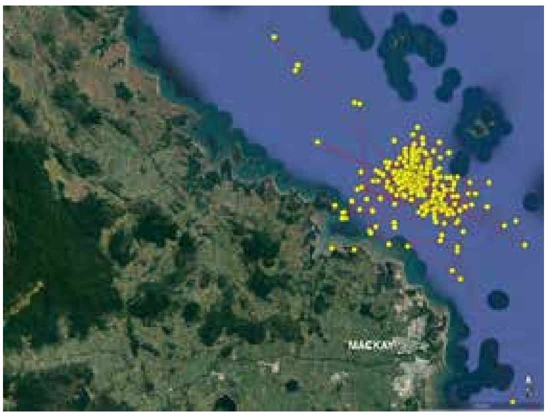


Figure 32: Foraging behaviour of QA4840 'Matilda'.


Image: Claudia Sheils

Discussion

This study examined the loggerhead and green turtle nesting population on the Sunshine Coast from 2005 - 2016. These are small nesting populations towards the southern extremity of the breeding range within the eastern Australian stock. While the flatback turtle, *Natator depressus*, is an annual nesting species on the beaches north from Bundaberg, no flatback turtle nesting has been recorded in the Sunshine Coast region.

Assessment of the overall trend in nesting numbers in the Sunshine Coast region was outside the scope of this technical report. It is recommended that this is investigated to understand long term trends in the local loggerhead nesting population.

Approximately 23km of Bribie Island between the two monitored areas remains unquantified for turtle nesting. Anecdotal surveys by Queensland Parks and Wildlife Service Rangers indicate that nesting may be equal or less than what is recorded in other locations on Bribie Island. Nesting records for the North Bribie Island beach are under-represented in this report as monitoring effort commenced only in 2014, several years after adjacent beaches.

The annual peak nesting period within the study area is approximately between weeks 9 and 10 (week 1 commences on 1st November annually). This typically falls across the last week in December and first week of January. This 'census period' of peak nesting is delayed by one to two weeks in comparison to the major rookeries of Mon Repos and Heron Island (Limpus et. al. 2013) and is consistent with the delay typically observed in season commencement at SCR beaches when compared with the major rookeries in central Queensland.

It is possible that SCR loggerhead nesting populations suffered the same population decline (86% reduction between 1977 and 2000) that was described at the major rookeries in Queensland (Limpus & Limpus, 2003). This decline was attributed to mortality of loggerhead turtles in trawl fisheries of eastern and Northern Australia (Limpus & Reimer, 1994). There was no close monitoring of turtle mortality within the study area during this time, and therefore adult mortality during inter-nesting and foraging cannot be confirmed for the SCR.

The earliest nesting observations for the region were published in 1985, which means no pre-decline (pre-1977) nesting data is available for the SCR. It is difficult to assess the long-term changes in the local population from the observations reported in Limpus (1985) due to the varying levels of monitoring effort. It will be important to continue to collect long term nesting data to assess recovery or otherwise on local beaches.

The annual fluctuations of numbers of total nests and crawls over the study period are typical of nesting beaches, as individual female turtles usually do not nest annually and there may be unseasonal events impacting turtle nesting behaviour. For example, the downturn in nesting crawls observed in the 2011/2012 season is consistent with results observed at other loggerhead turtle rookeries. Limpus et al., (2013) suggests this may have been an outcome from a possible reduction in breeding effort due to the impacts of flooding and cyclones on foraging habitat in south and central Queensland in 2010 – 2011.

A 71.2% nest success across all species was observed from 2005-2016. This is considered to be an acceptable value for maintaining a sustainable population.

There was little temporal trend in nesting probability for loggerheads nesting on beaches in the Sunshine, Buddina and Shelly subregions (Figure 7). Relatively stable nesting probability may indicate that external factors (such as artificial light or human disturbance) that influence turtle nesting success may also be largely unchanged. With projected high population growth in southeast Queensland, it will be important to continue monitoring turtle nests, introduce timely mitigation measures and repeat the analyses once more data is available.

A significant declining trend was apparent from 2013 for loggerheads nesting in the Bribie Island subregion (Figure 7). In 2014 monitoring commenced on the northern 5km of Bribie Island by TC volunteers. In addition to this, the BITT monitoring effort grew along with volunteer expertise.

It is possible that the decline in nesting success is reflective of the additional sampling location and increased reporting of false crawls rather than a true decline in nesting success. However, it is also possible that the decline is reflective of reduced availability or poorer quality nesting habitat. North Bribie Island has continually narrowed, broken through and reformed in a relatively long term process that has occurred over hundreds of years (Barnes, 2015). It will be important to continue to monitor the change in nesting distribution in this location as the spit continues to evolve.

Beaches were assigned to a subregion to better understand the nesting success based on similar attributes such as characteristics, aspect and beach contiguity. Population density was not a characteristic identified when grouping beaches, however, results appear to indicate differences in nesting probability between the southern and northern (higher nesting probability) beaches of the Sunshine Coast (delineated by the Maroochy River), where there are varying levels of population density. Human disturbance through incidental encounters and beach use at night (e.g. vehicle and street lighting, bonfires and other recreational activities) may be a factor in lower nesting probability in the southern Sunshine Coast, although this requires further study.

Nesting turtles within the study area show normal demographic features for eastern Australian loggerhead and green turtle stock for both curved carapace length and number of eggs per clutch (Limpus & Limpus, 2003 and Limpus et al, 1984). This measurement is a reflection of the physical health of the population.

Average hatch success of 75.8% for loggerheads and 76% for greens is within the expected range of natural hatch success for these species (Limpus, 2008 a,b,). Because clutches were dug between 2 and 5 days after hatchlings were first observed to emerge, the emergence success is considered to be a true reflection of the nest results.

Higher hatch and emergence success rates for naturally laid nests compared to relocated nests (Figure 15) is expected given the circumstances and timing of nest relocation occurrence within the SCR. The programs operating in the study area do not regularly patrol beaches during evenings, and as such, are typically unable to relocate at risk clutches during the 2-hour period of embryonic diapause where clutch relocation does not impact hatching and emergence success (Limpus et al., 1979). Consequently, clutches are often relocated during development of the embryo, typically 21 days after oviposition, when the embryo is robust enough to survive gentle movement.

In some cases, clutches under immediate threat of partial or complete loss have been relocated within the critical period for embryonic development (>2hours to <21 days). Intervention at this time can result in reduced hatching and emergence success (Limpus et al., 1979). Notwithstanding this, without relocation, all of these nests were at significant risk of partial or complete loss due to erosion and flooding, or would have had reduced hatchling survivorship due to light disorientation, and therefore, were likely to have had better outcomes with intervention.

A significantly increasing trend in both hatch and emergence success (Figure 16) for either natural or relocated nests warrants further consideration. This is likely to be due to better sampling and recording (training and experience of volunteers) and or environmental effects (such as the 24% reduction in predation as a result of fox exclusion meshing). It is also possible that there may be an increasing proportion of experienced nesters, however, this is unable to be investigated due to the low incidence of capture and tagging of adult turtles in this study.

These results identify and reinforce the importance of ongoing training of accredited volunteers in the 'doomed egg' relocation process, particularly where undertaken during the critical period for embryonic development.

It is not known why hatch success was lower in the Twin waters to Noosa than the Buddina to Bribie stretch of beaches. If this trend continues long term, the reduced success at this subregion would warrant further investigation.

The increase in period to emergence over the hatching period of each season is not unexpected. Sand temperature is well understood to be most likely the factor that affects the trend other than emergence date.

The management approach to predation has reduced and maintained clutch loss to a low level. The historical impact of foxes on turtle populations in the SCR will likely never be known. Fox depredation of turtle nests within the study area was not managed until 2005 and it is not possible to determine how long SCR nests have experienced fox predation. If fox predation of turtle nests was occurring from early in the 20th century when foxes first reached southern Queensland, the full population implications (i.e. reduced recruitment) may have been influencing population size for many decades.

Domestic animal interference has not been a problem on nesting beaches of the wider Sunshine Coast. Two separate incidences have occurred with domestic dogs, both of which occurred under direct supervision of the dog owner and did not result in hatchling mortality. Volunteer presence and low density nesting in combination with the use of fox exclusion meshing across the region is likely to have reduced the potential for domestic animal interference.

The sand temperature data correlates with distribution patterns for turtles in Australia. The SCR is one of the southernmost rookeries for the loggerhead population, and this is reflected in the lower sand temperatures that are recorded along the coastline as compared with major rookeries of Queensland. Clutches laid after February are unlikely to emerge within the normal range for incubation periods, e.g. in a cool year, a clutch laid on 25 February 2015 emerged on 30 June at 125 days with very low emergence and hatch success.

Higher sand temperatures were recorded between Shelly and Yaroomba beach due to the different type of sand caused by unique coastal processes affecting sand composition and colour. Shelly Beach has coarse sand likely originating from the near shore environment and Yaroomba beach receives high sediment transfer from southern beaches that travels longer distances, resulting in a smaller grain size (Sunshine Coast Council, 2014). In 2015 and 2016, sand accretion at Yaroomba may also have resulted in decreased temperature records due to the data logger being at greater depth than 50cm.

Armouring of dune systems is a typical treatment undertaken to protect coastal infrastructure and has been identified as a 'Moderate Risk' threat within the 2014 Single Species Action Plan for the loggerhead turtle in the South Pacific (United Nations Environment Program, 2014). Currently 3.1% of the study area has rock armouring that prevents turtles from reaching nesting habitat, with an associated low nesting success rate. The threat of habitat removal through beach armouring may require continued monitoring and engagement with local government in future to ensure that significant nesting beaches are not impacted.

Impacts of light pollution on hatchling orientation have been documented annually throughout the study area, however, these records do not represent a complete inventory of hatchling mortality associated with inland movement in relation to artificial light at night. Light pollution has been identified as a 'Very High Risk' threat under the Single Species Action Plan (United Nations Environment Program, 2014).

Marine turtle response to artificial light can be measured using track orientation data. Hatchling orientation behaviour in response to biologically relevant light was observed but not formally measured during the study period. Orientation data will be formally recorded on Sunshine Coast regional beaches from 2017 onwards.

The benefits of using the novel light guard to manage artificial light at nest sites outweigh the challenges of use. This approach is not considered sustainable without a dedicated volunteer workforce due to the requirement for daily installation and removal. Further, once outside the 10m of light shield provided by the guard, hatchlings resume dis/misorientation from artificial light sources or sky glow. A coordinated approach by public lighting owners and community is required to reduce light impacts at nesting beaches. Limpus and Kramrowski (2013) suggest the management of nesting beaches to protect or create elevated dark silhouettes will promote successful ocean-finding behaviour.

Actions have been taken to mitigate light impacts for planned infrastructure upgrades within the study area. These include internal Council recommendations for shielding, beach access alignment, intensity reduction and light colour change.

In some cases, light mitigation actions undertaken in response to planned infrastructure upgrades have not been able to achieve pre-upgrade lighting conditions on the nesting beach. For example, the 2016 Kawana Surf Life Saving Club car park upgrades resulted in additional light spill at Buddina beach. Despite subsequent mitigation applied through shielding, intensity reduction and colour change, lighting levels appear not to have returned to pre-upgrade levels.

To date, the results of light mitigation strategies have not been formally quantified due to both the absence of pre-upgrade lighting data and the difficulty in measuring biologically relevant artificial light. Where light spill to the beach can be prevented through direct shielding, such as installation of meandering beach accesses, the outcomes appear to be more effective at mitigating light impacts than management of the luminaire for colour and intensity.

A southerly shift in nesting habitat is one potential response that marine turtles may have to climate change, resulting in turtles nesting away from the protected zones of Mon Repos and the Great Barrier Reef and into urban environments such as the Sunshine Coast (Hamman et al, 2007). Whilst currently the three groups manage individual nests to ensure hatchling survivorship, if the nesting population increases over the coming decades due to climate change adaptation there may be more pressure for government to regulate the light that impacts nesting beaches.

The wider Sunshine Coast region is predicted to have high human population growth in the next decade, which will place associated pressures on the coastal environment. It will be important to continue to monitor marine turtle nesting across the entire 97km of coastline to ensure that early detection of impacts may be recognised and managed to minimise impacts to the coast's critical habitat and threatened species.

Acknowledgements

Turtle conservation in the wider Sunshine Coast region began with a small group of passionate and like-minded local residents walking the beaches throughout the night and early mornings, recording nest locations and educating local residents.

It has grown into three accredited groups, Bribie Island Turtle Trackers TurtleCare Sunshine Coast and Coolum and North Shore Coast Care with combined membership of over 200 local residents. Many of the original members are still walking beaches today, and continue to inspire the community to care for these ancient reptiles.

These studies have been authorised as collaborative studies within the DES Queensland Turtle Conservation Project and included within the approved DES Animal Research Ethics Projects: SA 2015-11-524, 525, 526, 528, 529, 531.

We gratefully acknowledge Dr Milani Chaloupka for the statistical modelling analyses and results interpretation for Figures 7 and 16 – 18.

The results of this report are a direct outcome of the thousands of hours that have spent on the beach working towards the conservation of marine turtle nesting on the wider Sunshine Coast region.

The authors and the Sunshine Coast community thank these volunteers for their dedication, passion and indefatigable efforts to preserve marine turtle nesting on local beaches.

Special thanks to Diane Oxenford, Leigh Warneminde, Sherida Holford, Stephanie Phillips, Suzanne Aspland, Talisa Kath, Jacqueline Nolen, Simone Bosshard and various Sunshine Coast Council local government officers for their contribution to the coordination of the programs and review of this report.

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Appendix

QUEENSLAND TURTLE CONSERVATION PROJECT
Nesting Turtles

Tag No.		Posn
New		
Recapt		

PIT tag No.	Posn

Tag scar/s positions

WEIGHT kg

NOTES

Locality: Sunshine Coast **Suburb:** entered O
Beach Access: **Date:** **Time:** **am** **pm**
GPS:

Relocated GPS: **Event #:**

COMMENSALS
Chelonibia.......... o
Burrowing barnacles........... o
Algae, thick......... o
Mud, thick........... o
Other

DAMAGE
carapace.............. o
LFF..................... o
RFF..................... o
LHF..................... o
RHF..................... o

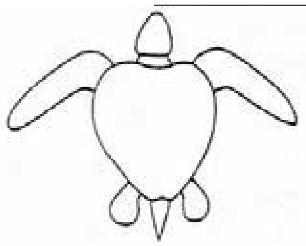
Fibropapillomas yes / no
Lumps yes / no

NEST LOCATION
dune 2nd............. o
dune 1st............... o
grass slope........... o
below slope.......... o
below HW............ o

under tree............ o
under shrub......... o
in grass................ o
in bare sand......... o

HOW MANY EGG CHAMBERS?_____

WHY MORE THAN ONE CHAMBER?
____



SPECIES
green.................... o
loggerhead........... o
flatback................ o
hawksbill............. o
ridley.................... o
leatherback........... o

CARAPACE
length_______cm

ACTIVITY
____
laid....................... o
laid/dist................ o
no lay................... o

CAUSE OF DISTURBANCE
____
____

CLUTCH DESTRUCTION
No.eggs dist ________
Tag No. ________
Date ________

NEST AND CLUTCH DATA
Nest tag in nest yes / no
Clutch relocation yes / no

Clutch count __________
Yolkless eggs __________
Multiyolk eggs __________

NEST DEPTH
Top _______cm
Bottom_______cm

TEMPERATURE
at 50cm_____°C

RELOCATION NOTES **Date:**

NEST MAP
Post No. Post No.
\ /
. **m** . **m**
\ /
\ /
NEST
Landward/seaward

NEST MAP – Relocated Nest
Post No. Post No.
\ /
. **m** . **m**
\ /
\ /
NEST
Landward/seaward

RECORDERS
measured __________
recorded __________

mturt_datash_nesting.doc

Appendix 1: Queensland Turtle Conservation Project data sheet

Sunshine Coast COUNCIL

Our region.
Healthy.
Smart.
Creative.

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