MONITORING OF EASTERN AUSTRALIAN FLATBACK TURTLE, *Natator depressus*, BREEDING POPULATIONS IN THE GLADSTONE REGION: 2020-2021 BREEDING SEASON

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Queensland Government

Department of
Environment and Science

Cover photographs:
Scenes from the census of nesting Flatback turtles, *Natator depressus,* 2020 – 2021 at Peak Island and Wild Duck Island. Photographs taken by Duncan J Limpus, Leisa Fien, Cathy Perkins, Ian Anderson, Ebony King

This report should be cited as:

Colin J. Limpus, Nancy N. FitzSimmons, Ian Anderson, Wayne Bennet, Leisa Baldwin, Leisa Fien, Fiona Hoffmann, Erwin Hoffmann, Duncan J. Limpus, and Trevor Turner (2021). Monitoring of eastern Australian Flatback turtle, *Natator depressus,* breeding populations in the Gladstone region: 2020-2021 breeding season. Brisbane: Department of Environment and Science, Queensland Government. Report produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program. 64 pp.

This report has been produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program. The study was undertaken under a Consultancy Agreement (CA12000291 [130032]) between Gladstone Ports Corporation and the Queensland Department of Environment and Science to monitor marine turtle nesting at Peak, Wild Duck and Curtis Islands.

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

Disclaimer:

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Contents

EXECUTIVE SUMMARY

This report summarises the results of monitoring the eastern Australian (eAust) Flatback turtle nesting population at Curtis, Peak and Wild Duck Islands during the 2020-2021 breeding season. A two-week mid-season census was conducted at all three islands with a more extensive monitoring of nesting at Curtis Island. Table 1 provides a comparison of reproductive parameters recorded at these three central Queensland Flatback turtle index beaches with shading of those parameters that are considered to be indicators of poor population performance.

Number of nesting females and nests

- A total of 95 nesting crawls from 67 individual tagged nesting Flatback turtles and 72 clutches of eggs laid were recorded at Curtis Island during the census period (24 November – 7 December 2020).

- A total of 322 nesting crawls from 209 tagged individual nesting Flatback turtles and 190 clutches of eggs laid were recorded at Peak Island during the census period from 24 November – 7 December 2020.

- A total of 432 nesting crawls, 329 individual nesting Flatback turtles and 291 clutches were recorded at Wild Duck Island during the census period from 24 November – 7 December 2020.

Recruitment of new females into the annual breeding population

- Curtis Island had the lowest level of recruitment since 2002, at 13.4%, during the census period.
- Recruitment of new nesting females into the breeding population during the census period has been declining at Peak Island, but it was the second highest at 13.6% since the 2015-2016 season.
- During the census period at Wild Duck Island 63.2% of nesting turtles were first time tagged turtles. This very high value is a reflection of a 12-year gap in monitoring and is expected to decrease over the next several years.

Remigration intervals and rookery fidelity

- Most remigration intervals for nesting females at Curtis Island were two-four years. At Peak Island most turtles re-migrated after three years. At Wild Duck Island, accurate estimates of remigration are not possible. Some turtles remigrated after one year. Re-sightings of turtles tagged several years ago included time spans of up to 38 years.
- Nesting females continue to display high fidelity to each island. Only two recaptured females were originally tagged while nesting at a different rookery. At Peak Island 15 turtles had nesting histories of more than 30 years. At Wild Duck Island 21, turtles were re-sighted after 30 or more years.

Demographic parameters

- Nesting Flatback turtles at all three islands show normal demographic features for the eastern Australian Flatback turtle stock in terms of female size, clutch size and egg and hatchling size.

- At Curtis, Peak, and Wild Duck Islands, first time tagged turtles (new recruits) to the nesting population were smaller than females with a past breeding history.
- The length of the nesting season was recorded at Curtis Island with nesting commencing on 24 October 2020 and the last clutch laid on 27 January 2021.
- The first emergence of hatchlings occurred on 14 December 2020 on Curtis Island. Commencement of hatchling emergence was not recorded at Peak and Wild Duck Islands.
- The average incubation period from laying to hatchling emergence to the beach surface was 47.9 days at Curtis Island, 49.6 days at Peak Island and 53.8 days at Wild Duck Island.

Population trends

- At Curtis Island, the number of nesting turtles during the census period has returned to a higher value (67 nesters) than observed since 2013. This coincided with the lowest recruitment rate (13.4%) of new adults into the nesting population over the same period.
- At Peak Island, the census counts of mean numbers of nesting crawls and the mean number of clutches laid and the total number of tagged turtles all were the highest values than the previous three years. This is encouraging given the suggestion that the nesting population has been declining at a slow rate across the last 11 breeding seasons.
- At Wild Duck Island, the census count (n = 329) was less the previous season (n = 380), but this still indicates that this rookery is the largest for the eAust Flatbck stock.

Hatchling production

- Curtis Island: Nesting success was 75.8% from the census period. Incubation success of eggs was 82.4% and hatchling emergence success was 80%.
- Peak Island: Nesting success was 72.8%, which is considerably higher than values for the previous several years due to a recalibration in determining nest success that excludes uncertain outcomes. Incubation and hatchling emergence success at Peak Island were higher than average at 80.5% and 76.7% for nests known to be laid during the census period. Invasive roots and inundation of nests during high tides reduced success.
- Wild Duck Island: Nesting success was 75.4%, which compares well to that at Curtis Island and Peak Island rookeries. Incubation and hatchling emergence success (91.9% and 91.2%, respectively) were recorded as very high values, but this is due in part to the data being based only on opportunistically observed emergent nests.

Temperature profiles and weather events

- The Bureau of Meteorology (BOM) Queensland summary data for the 2020-2021 summer reported the mean summer temperatures that were 0.85 °C above the long-term average and mean maximum temperature was 0.46°C above average.
- Heatwaves occurred in December and February. Significant weather included high rainfall near the end of October, end of December, mid-March and early April.
- Limited sand temperatures at nest depth at Curtis Island from mid-January were in the range that should have produced an excessively female hatchling sex ratio

throughout most of the breeding season. Period to emergence data also suggested a strongly female biased hatchling sex ratio.

- Sand temperatures at nest depth at Peak Island, and period to emergence data suggested that hatchling sex ratio from clutches laid up until early January 2020 are expected to have been strongly female-biased, but with periods of male hatching production.
- Period to emergence data at Wild Duck Island suggested that 41% of the observed nests would have produced at least some males, and some clutches would have produced predominately males. Wild Duck Island appears to have produced a balance of male and female hatchlings for at least part of the breeding season.

Management considerations

- Existing management of feral animals by Queensland Parks and Wildlife Service (QPWS) within the Curtis Island National Park is maintaining Flatback turtle clutch loss to predators such as pigs, dogs and foxes at a negligible level.
- Continued management of invasive plants in the turtle nesting habitat at Peak Island would benefit improved hatchling production.
- Purchase of the tourism lease at Wild Duck Island in May 2021 now provides managed protection for the entire island. Plans are being formulated for a greater presence of land managers and monitoring teams on the island. This will help secure important protected habitat for the eastern Australian nesting population of Flatback turtles in an area free of large terrestrial predators of their eggs and well removed from the impacts of urban and industrial development.

CHAPTER 1. INTRODUCTION

This study has been conducted under an agreement between the Gladstone Ports Corporation (GPC) and the Queensland Department of Environment and Science (DES) to continue monitoring of Flatback turtle,*Natator depressus*, nesting and hatching at Curtis Island and Peak Island for the 2020-2021 breeding season and to replace the monitoring at Avoid Island with monitoring at Wild Duck Island (Figure 1). This monitoring is supported by the GPC's Ecosystem Research and Monitoring Program (ERMP). This is the eighth year of monitoring of the east Australian Flatback turtle nesting populations by the ERMP.

Flatback turtle are essentially endemic to Australia, as they only nest in Australia and their foraging areas are mostly restricted to Australian continental shelf waters. The three rookeries being monitored are part of the eastern Australian Flatback turtle population, also referred to as the eAust Flatback turtle genetic stock or management unit (FitzSimmons and Limpus, 2014a). This population is distinct from all other Flatback rookeries to the west of Torres Strait (FitzSimmons and Limpus, 2014a; FitzSimmons *et al*. 2020). The biology of the eAust Flatback turtle population has been reviewed (Limpus, 2007; Limpus *et al*. 2013).

Curtis Island is a moderate sized rookery that is located adjacent to Port Curtis with substantial industrial development and potential light pollution. It is one of the index nesting areas that has been monitored annually across decades for this species since 1993.

Peak Island, in Keppel Bay, has previously supported the largest nesting aggregation for Flatback turtles within the eAust stock and is an established index beach for long-term monitoring of Flatback turtles since 1980.

Wild Duck Island has previously supported the second largest Flatback nesting population within the eAust stock and was monitored from 1981 to 2006 by Dr C. J. Parmenter, Central Queensland University (Limpus *et al*. 2013). At the request of QPWS, annual monitoring of the Wild Duck Island nesting population was recommenced in the 2019-2020 nesting season within DES Queensland Turtle Conservation Project (QTCP). This large nesting population is located at the mid nesting range of the species in eastern Australia (Limpus *et al*. 2002) in a remote area that is not influenced by industrial development or light pollution from the mainland.

Monitoring of the rookeries is conducted to determine the size of the nesting population and population trends over time, the proportion of newly recruiting females, the size of females, clutch size, egg size, incubation and emergence success, hatchling size and condition and variability in hatchling production in different areas of the beaches monitored. To assess the impacts of artificial light, data are collected on the orientation ability of females when they ascend the beach to lay eggs and descend afterwards, and of hatchlings as they travel to the water's edge, which will be presented in a separate report. Additionally, data are collected on beach sand temperatures at nest depth to determine the likely sex ratio of hatchlings.

CHAPTER 2. GENERAL METHODS

Standard methodologies of the Queensland Turtle Conservation Project (QTCP) within the DES Aquatic Threatened Species Program were followed for the project to monitor nesting females and their clutches (Limpus *et al*. 1983; Limpus, 1985). Statistical procedures follow Zar (1984). Proportional data were presented as the value ± 95% confidence interval.

The methods followed during the 2020-2021 summer followed the methods employed during the previous years of the GPC funded studies (FitzSimmons and Limpus 2014b, 2015, 2016; Limpus *et. al*. 2017, 2018, 2019, 2020).

Monitoring teams included DES staff and QTCP Volunteers with prior training for the methods being implemented.

Nesting activity

Data on nesting activity were recorded at all three rookeries during a minimum of the two-week, mid-season census period:

- At Curtis Island, daily monitoring occurred from 24 October 2020 - 12 January 2021 and included the standard census period from 24 November - 7 December 2020. Additional data on nesting females was obtained by QTCP volunteers from 17 – 29 January 2021.
- At Peak Island, the census period was from 24 November - 7 December 2020.
- At Wild Duck Island the census period was from 25 November - 8 December 2019.

Data from only the two-week mid-season census are referred to as the ‘census data’.

Nightly monitoring began at least two hours before high tide and continued for at least two hours after low tide, or longer if turtles were still active on the beach. Procedures included:

- Encountered turtles left the beach with a minimum of two titanium tags (manufactured by Stockbrands Australia) in the front left and right flippers at a designated tagging position (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 scute.
- Passive Integrated Transponder (PIT) tags (Parmenter, 1993) were injected into the upper left (or occasionally right) shoulder (just below the carapace) of nesting females. PIT tags were manufactured by Animal Electronic I.D Systems or Smartrac.
- 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 two 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.
- Any damage to the turtle or unusual features were recorded and photographed if possible.
- 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 enabled identification of individual clutches of eggs when excavated following hatchling emergence some two months later. The vast majority of this plastic material was removed from the beach during excavation of clutches following hatchling emergence.

- A subset of clutches of eggs were counted and 10 eggs were selected to represent a cross-section of eggs from top to bottom of the nest. Each selected egg was weighed (± 0.1 g) on a digital balance and measured for maximum and minimum diameter (± 0.1 mm) with Vernier callipers. To minimise movement induced mortality of eggs all handled eggs were returned to their respective nests within two hours of being laid and with the minimum of rotation (Limpus *et al*. 1979).
- Nest locations were recorded using a hand-held GPS (global positioning system) unit (± 4 m). Habitat type of the nest location was recorded including the beach profile location and vegetation type near the nest.
- To identify marked nests after hatchling emergence, somewhat different techniques were used at each rookery in addition to GPS locations:
    - At Curtis Island, all clutches were marked with two timber marker pegs (25 mm x 25 mm x 400 mm) that were labelled with a unique nest number. One marker peg was placed two hand spans from the nest, and the second maker peg was placed one hand span from the first marker peg, in line with the nest.
    - At Peak Island, nests were not mapped and data were collected only from emerged clutches, most of which had nest identification tags within the nest.
    - At Wild Duck Island, nests were not mapped and data were collected only from emerged clutches.

Rescuing doomed eggs

DES supports the rescue of doomed turtle eggs for highly threatened populations when eggs are laid in areas considered to be at risk of loss from predation, flooding or erosion during incubation (Pfaller *et al.* 2008). Eggs may also be rescued where coastal lighting is likely to disrupt hatchling ocean finding behaviour and cause hatchlings 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 area of beach in response to the identified threats. Eggs are relocated (within two hours of oviposition and with the minimum of rotation) 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).

Incubation and emergence success

Data on incubation and emergence were obtained for all three rookeries:

- At Curtis Island, nest excavations occurred from 15 December 2020 - 26 February 2021 largely through the efforts of local QTCP volunteers.
- At Peak Island, nest excavations occurred from 14 - 28 January 2021.
- At Wild Duck Island nest excavations occurred from 15 - 28 January 2021.

Nests were excavated after hatchlings had emerged for assessing incubation, including incubation success and hatchling emergence success. Previously marked nests were located using GPS locations, and measurements from marker trees, posts or pegs and confirmed by the presence of nest tags. Nests were dug no sooner than 24 hours after hatchling emergence or later than 8 weeks if hatchlings had not emerged.

Procedures included:

- If hatchling emergence was observed and when logistically feasible, a sample of 10 hatchlings (+ any live -in nest) were weighed (± 0.1 g), measured (± 0.1 mm) with Vernier callipers and the scale pattern counted.
- Observations of heat stress were noted that included:
  - dead hatchlings in the neck of the nest that were not otherwise trapped by roots from emerging,
  - dead hatchlings that had emerged but died in the vicinity of the nest, with no signs of predation.
- The number of hatched eggs was determined by counting the number of eggshell fragments that were larger than 50% of that expected from an entire egg.
- Clutches were assessed for any signs of predation by crabs or other animals and counts were made of any hatched live or dead hatchlings within the nest.
- Un-hatched eggs were opened to determine whether the embryo had developed to an observable stage or whether it appeared to be undeveloped.
- Incubation success was calculated as: (hatched eggs/estimated clutch count) x 100%.
- Emergence success was calculated as: (hatched eggs – [live + dead in nest hatchlings]/estimated clutch count) x 100%.
- Counting error, the accuracy of counting broken eggshells was calculated as: estimated clutch count following hatchling emergence minus clutch count made when the eggs were laid.
- The depth to the bottom of the egg chamber was measured (± 5 mm) and observations on the nest environment were made with respect to erosion and water inundation.

Environmental Monitoring

Vemco Minilog II temperature data loggers have been deployed for several 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. Temperature data loggers were deployed at various times and locations at these three rookeries to monitor long-term temperature variability in the nesting habitats.

Daily rainfall data at selected recording stations were obtained via the BOM website. The BOM Queensland summary data (Figure 2) for the 2020-2021 summer reported the mean summer temperatures that were 0.85°C above the long-term average and mean maximum temperature was 0.46°C above average. Heatwaves occurred in December and February. Significant weather included high rainfall near the end of October, end of December, mid-March and Early April.

Hatchling sex ratio theory

The sex of marine turtle hatchlings is determined by the temperature of the nest presumably during the middle third of incubation (Reed, 1980; Yntema and Mrovosky, 1982). The pivotal temperature, the theoretical temperature that will result in equal proportions of male and female hatchlings for the eAust Flatback turtle population is 29.3^{o}C (Limpus, 2007), with higher temperatures producing females and lower temperatures producing males. If Flatback eggs incubate at a constant temperature of 29.3^{o}C, hatchlings should emerge from the eggs approximately 52 days after the eggs were laid (DES unpublished data). Thus, incubation duration can also be informative about the sex of hatchlings. Allowing for the time taken for hatchlings to dig to the surface from the hatched eggs, the pivotal period from laying to hatchling emergence to the beach surface (period to emergence) should be approximately 54 days. Longer incubation period from laying to hatchling emergence should be indicative of cooler nests when the sex is determined and hence increased male ratio among hatchlings. A shorter period to emergence should be indicative of warmer nests and increased female ratio. Rainfall will influence this as cool rain results in a decline in sand temperatures at nesting beaches. In contrast, sand temperatures increase in the short term in the absence of rain due to reduced evaporative cooling within the sand (Reed, 1980).

CHAPTER 3. CURTIS ISLAND STUDY

METHODS

Study Area

South End Beach, Curtis Island (23º45'S, 151º18'E), has supported 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 ~100 km to the north. The small South End township lies on the south-eastern tip of the island (Figure 3.1). The majority of the turtle nesting for the island occurs on the adjacent South End Beach, which is approximately 5 km in length. 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, 2013, 2017, 2018, 2019, 2020, 2022c). Curtis Island has one of the longest histories of monitoring of Flatback turtle breeding in Australia and hence the world.

Methods specific to Curtis Island

South End Beach was monitored on a daily basis commencing 2 November 2020 until 14 December 2021 for nesting activity, including the two-week mid-season census period from 24 November - 7 December. Monitoring of incubation and emergence success and period to emergence occurred from 17 - 29 January 2021. Monitoring of incubation and emergence success occurred throughout the season until 26 February 2021. Additional intermittent monitoring of nesting activity was done by local QTCP volunteers from 24 October 2020 until 26 February 2021.

Turtles were observed to nest at all times of day and throughout the tide cycle, so the beach was monitored from 3 pm onwards and this was followed by a morning patrol. A Land Rover and ATV were used to patrol the beach.

New sector posts were placed above the high tide line for the duration of the nesting season and nests were marked with two wooden pegs that identified sequential nest numbers in addition to the identification tapes placed with the eggs.

Sand temperature data from the two Vemco Minilog II temperature data loggers that have been deployed in open sunny areas within the nesting habitat at opposite ends of South End Beach, Curtis Island since the 2016-2017 breeding season were not uploaded during the 2020-2021 breeding season. A Hobo MX2201 temperature data logger, which collected data every 30 minutes, was deployed on 18 January 2021 and data were uploaded on 29 January 2021.

Predation monitoring
No fox exclusion devices (FEDs) were deployed over clutches of eggs during the 2020-2021 turtle breeding season. During monitoring patrols, tracks or observations

of wildlife that have the potential for negatively impacting successful turtle egg incubation were recorded, including cattle, horses, dogs and foxes.

RESULTS

Nesting activity, nesting success and recruitment

A total of 73 tagged Flatback turtles were encountered during the entire 2020-2021 breeding season at Curtis Island and 67 of these were encountered during the two-week mid-season census. Sixty-four separate turtles, including seven turtles missed for tagging, laid eggs during the two-week mid-season census period (Figure 3.2). Four tagged Green turtles were recorded nesting during the 2020-2021 breeding season at South End Beach, Curtis Island. Table 3.1 summarises the breeding history of these turtles.

The first Flatback nest was laid on 24 October 2020 and the last clutch laid was on 27 January 2021 (Figure 3.2). A total of 288 clutches were recorded for the entire season. Hatchlings emerged from the first Flatback clutch laid for the season on 14 December 2020 (51-day period to emergence) but the date of emergence of hatchlings from the last clutch was not recorded.

The mean nightly number of Flatback turtle activities during the mid-season census period (14 nights) on South End Beach were 6.8 tracks (SD = 2.5, range = 3-13), 5.1 clutches (SD= 2.6, range = 3-10) and 5.8 turtles (SD = 2.0, range = 1-8) (Table 3.2. These values were greater than in previous years (Figure 3.3).

A total of 95 nesting crawls by Flatback turtles were recorded on South End Beach during the two-week mid-season census. Of these, there were 72 successful beachings that resulted in eggs being laid. This equates to a nesting success of 75.8% ± 8.6% during the census period (Table 1). Across the entire nesting season, there were an estimated 288 clutches laid.

The proportion of new recruits to the nesting population (first time tagged turtles) was 13.4% ± 8.1% of turtles tagged during the standard mid-season census period (Tables 1, 3.1) and 16.4 ± 8.5% for all turtles tagged across the entire breeding season. Recruitment was lower than on several of the previous years (Figure 3.4). Turtles coming ashore to attempt nesting during daylight hours between 4:00 – 6:30 pm, occurred intermittently with 15.7% ± 7.6% of beachings occurring in daylight hours during the mid-season census period.

Nesting females: size, fecundity

The CCL (cm) of nesting female Flatback turtles ranged 84.3 – 99.3 cm at Curtis Island (Table 3.3 and Figure 3.5). As in previous seasons, turtles with a past breeding history (remigrants) had a greater mean CCL (94.0 cm) than new recruit females that were tagged for the first time (91.9 cm) (Table 3.3).

Sixty Flatback turtles with tags applied in previous breeding seasons were recorded at Curtis Island during the 2020-2021 breeding season. All had been tagged

originally at Curtis Island (Table 3.1). These remigrant turtles mostly returned after a two- to four-year remigration interval (mean = 3.63 yr, SD = 1.84, range = 2-11, n = 52) (93.6).

The mean renesting interval between a successful nesting and the subsequent return to lay another clutch was 13.0 days (Table 3.4, Figure 3.7). A turtle that did not lay during a nesting crawl usually returned to attempt another nesting by the next night.

Twenty-five clutches of Flatback turtle eggs were counted at laying and eggs from 9 nests were weighed and measured for the season. Estimated clutch size data as measured upon nest excavation are shown in Figure 3.8. The number of eggs per clutch, egg measurements and nest depths are summarised in Table 3.4.

Health and injuries

In contrast to some years, no nesting Flatback turtles died at South End Beach during the 2020-2021 season. None of the nesting Flatback turtles were recorded with fibropapilloma tumours. None were recorded entangled in fishing line or rope. No nesting female turtle was recorded with fresh or recent fractures resulting from injuries since the turtles had been previously recorded nesting at Curtis Island.

Sand temperature monitoring

A Hobo MX2201 temperature data logger recorded sand temperatures at nest depth during 18-29 January 2021 above 31°C, which is above the pivotal temperature of 29.3ºC from the eAust Flatback population (Figure 3.9).

The Australian Bureau of Meteorology (BOM) reported the occurrence of heatwave conditions impacting coastal central Queensland during the eastern Queensland Flatback turtle nesting season of 2020-2021 (Figure 2). For comparison to sand temperature data across the turtle breeding season, daily rainfall data and maximum daily temperatures recorded at the BOM weather station at Gladstone Airport (station 39326) were examined (Figures 3.9, 3.10). High rainfall (57 mm) was recorded on 30 and 31 December, which would have cooled the sand temperature. Only three smaller increases in rainfall of approximately 20 mm occurred when clutches were incubating. These higher rainfall events may have contributed to increased male hatchling production.

Maximum daily temperatures were mostly between 30-32°C from mid-November throughout the period when clutches were incubating. Temperatures spiked at 34°C in early December and early February, with a large spike to 38.7°C on 22 February, which could have negatively affected hatchlings near the beach surface.

Nest and hatchling disturbance and depredation and island fauna

Because no fox tracks were sighted at the start of the nesting season, no fox exclusion devices (FEDs) were placed over clutches this season. No disturbance of incubating clutches of turtle eggs by nesting turtles on South End Beach was recorded during the 2020-2021 breeding season. No incubating eggs, hatchlings or

adult turtles were recorded being impacted by cattle or horses trampling and no clutches were predated by canids during the 2020-2021 breeding season. The team was notified that a visitor had observed a crow take a hatchling as it headed to the water.

Estimation of hatchling sex ratio from period to emergence data

The mean period to emergence was 47.9 days within the census period and 48.2 days for the entire season (Table 3.5). The changing period to emergence through the breeding season is summarised in Figure 3.11.

There was only one clutch out of 172 clutches with a period to emergence longer than 54 days recorded during this summer. Consequently, few male hatchlings are expected to have been produced, suggesting a strongly female biased hatchling sex ratio from the 2020-2021 breeding season at Curtis Island.

Incubation and emergence success

At Curtis Island, 11 of the 353 (3.1% ± 2.1%) Flatback clutches recorded being laid across the entire season were laid below the area of potential tidal inundation. These clutches 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. As a result of this management action, no Flatback clutches appear to have been lost to erosion or flooding at South End Beach during the 2020-2021 breeding season.

Accuracy of counting eggs in emerged clutches was not assessed this season.

For the mid-season census, Curtis Island Flatback clutches successfully incubated without disturbance by vertebrate predators. Nine clutches were relocated higher up the beach to prevent inundation by wave wash. The mean mid-season incubation success was 82.4% (Table 3.5; Figure 3.12) and the corresponding hatchling emergence success was 80.0% (Table 3.5; Figure 3.13). There was a somewhat lower incubation success (78.0%) and hatchling emergence success (75.1%) measured across the entire season (Table 3.5).

DISCUSSION

This study examined the Flatback turtles nesting on South End Beach, Curtis Island during the 2020-2021 breeding season, which is now a small-sized nesting population, within the eAust stock.

This nesting population continues to display strong long-term fidelity to its chosen nesting beach as recorded previously for Flatback turtles nesting at Curtis Island and the Woongarra Coast (Limpus *et al*. 1984).

South End Beach is characterised by a number of features which contribute to its functioning as a high quality turtle rookery:

- Nightly nesting success was high (76%). There was no significant disturbance of the nesting turtles when they come ashore that resulted in excessive unsuccessful nesting effort.
- All clutches of eggs laid on this beach, or relocated higher up the beach, survived to incubate eggs in response to QPWS management of feral predators (pigs, dogs and foxes) and large grazing stock (cattle and horses) and the monitoring team's relocation into safer incubation locations of clutches at risk of loss through erosion or flooding.
- The Curtis Island South End dune sands constitute a very good incubation medium. Clutches that had not been interfered with by feral predators or impacted by storm surge or high tide erosion had a high incubation success of 82% and an acceptable hatchling emergence rate from the nests of 80%.

In contrast, extreme concern should be held regarding other characteristics of this nesting population:

- The size of the nesting population during the two-week mid-season census period has indicated a reduction in the population by approximately 50% during the past decade (Limpus *et al*. 2020). It is encouraging to see a rise in the number of nesters, from around 30 for the past four seasons (Limpus *et* al. 2021) to 67 nesters during the census (Table 1). The increase in the number of nesters corresponded with the lowest recorded recruitment (13.4%) of new adults into the nesting population. The increase in nesting number was mostly due to an increase in the number of experienced breeders from the past returning to breed this season (Table 1).
- A predicted strongly female biased hatchling sex ratio for the season is based on the short mean period to emergence. The recurring strongly female biased hatchling sex ratio should be viewed with concern (Hamann *et al*. 2008; Limpus, 2008; Poloczanska *et al*. 2009). Increased effort is warranted for identifying if there are other nesting beaches within the breeding range of the eAust Flatback turtle genetic stock that consistently produce large numbers of male hatchlings. If not, then management options could be considered that can counter the consequences of global warming that is feminising this marine turtle nesting population.
- Flatback turtles do not instinctively know the way to the ocean. As they leave the nest, hatchlings orient to move towards the horizon at the lowest angle of elevation from their viewpoint and they move away from elevated dark horizons (Limpus, 1971b; Limpus and Kamrowski, 2013). Although not investigated in the present study, the extremely bright sky glow emanating from Gladstone and Port Curtis (Kamrowski *et al*. 2012; Pendoley Environmental, 2012) is having negative impacts on the breeding success of marine turtle nesting on the Curtis Coast (Shiimada *et al.* 2021):
    - It is expected that the bright sky glow inland of the nesting beach will result in an elevated mortality of hatchlings dispersing out to sea from the beaches as has been recorded for green turtle hatchlings dispersing from Heron Island, impacted by the tourist resort and research station lighting (Truscott *et al*. 2017).
    - It is expected that with the increased bright sky glow behind South End Beach since the construction in 2011 of the three LNG port facilities on

Curtis Island and the Wiggins Island Coal Terminal could be causing the reduction in adult female numbers visiting the beach for breeding.

Significant reduction of the intensity of the sky glow created by Gladstone and Port Curtis industrial facilities is warranted.

Trends

The trend in track count numbers, numbers of tagged turtles and number of clutches laid during the standard mid-season census period (Figure 3.3) had been towards increasing numbers from approximately 2001 until 2008. Since 2008 there has been a continuing downward trend in these indicators of population performance. These data suggest that either this population may not be maintaining population stability as was indicated by the capture-mark-recapture analysis of data up to the 2012-2013 and 2016-2017 breeding season that was reported by Limpus *et al*. (2013, 2017) or that individual turtles are now returning less frequently. It is therefore encouraging to see the substantial increase in the number of nesting turtles and clutches laid during the 2021nesting season.

Annual recruitment of first-time breeding turtles into the nesting population has been strongly fluctuating since 2013, ranging from a high of 32.3% in 2019-2020 to a low of 13.4% this season (Figure 3.4). It is not known at present what is driving this variation.

Unfortunately, there are no studies of the population dynamics of Flatback turtles within their dispersed foraging areas that would allow for more comprehensive investigation of these parameters. There are no additional data available to further assess these trends in the dynamics of this breeding population.

CHAPTER 4. PEAK ISLAND STUDY

Study Area

Peak Island, 23.333ºS, 150.933ºE, is a continental island in Keppel Bay and lies approximately 15 km off the mainland coast southeast of Yeppoon in eastern Australia (Figure 4.1). Tenure of the island is "National Park (Scientific)", which is the strongest level of land management protection under the *Nature Conservation Act 1992*. Peak Island is also surrounded by a Preservation Zone within the Great Barrier Reef Coast Marine Park and the Great Barrier Reef Marine Park. The island is managed by DES in accordance with the Keppel Bay Islands National Park (Scientific) and adjoining State Waters Management Plan. As a consequence, the turtle nesting habitat of Peak Island and the immediately adjacent inter-nesting habitat are managed to provide the highest level of habitat protection available to any turtle nesting population. The island is closed to visitation by the general public and is uninhabited except by the turtle monitoring team during annual monitoring visits. There is no built structure on the island. The principal nesting beach on Peak Island is on the north-western corner that faces westerly towards the mainland. Only 300 m of this beach provides access to sand dunes suitable for turtle nesting. The dune habitat on the small beach on the north-eastern side of the island is inaccessible for nesting because of an erosion bank while the accessible sandy beach on the south-eastern side of the island has rocks under the sand at dune level preventing successful egg chambering.

Peak Island has supported one of the largest populations of nesting Flatback turtles in the eAust stock (Limpus *et al*. 2013) and is recognised as an index beach for long-term monitoring of Flatback turtles within the eAust stock. Census of the Peak Island Flatback turtle nesting population commenced in the 1980-1981 breeding season (Limpus *et al*. 1981). Monitoring of turtle nesting at Peak Island was led by Dr C. J. Parmenter of Central Queensland University during 1981-2006 (Parmenter 1993). Monitoring recommenced in 2008 within QTCP and has continued to the present with funding support from the GPC ERMP (Twaddle *et al*. 2014, 2015; Pople *et al*. 2016; Limpus and Limpus, 2018; Limpus *et al*. 2017, 2018, 2019, 2022b).

Methods specific to Peak Island

- At Peak Island the nesting beach is subdivided into 25 m sectors identified by numbered posts to allow comparisons across sectors. Sectors 0 - 5 are fronted by inter-tidal rocks with a sandy beach above the high tide level. Sectors 14 - 17 are fronted by extensive inter-tidal rocks which extend to exposed rocky rubble above the high tide level and into the dunes. The remainder of the beach has a sandy approach to the dunes.
- Clutches of eggs were not mapped by triangulation from the sector posts during the 2020-2021 census period.
- The work program at Peak Island was not designed to collect data for the full duration of the Flatback turtle nesting season. A two-week, mid-season census was conducted during 24 November – 7 December 2020. Data were collected from emerged clutches during a 14-day trip 15 - 29 January 2021

- A 15-day trip to Peak Island during 15 – 29 January 2021 sampled nests from which hatchlings had emerged to assess incubation and emergence success and period to emergence.
- A Vemco Minilog II temperature data logger that was buried at a depth of 50 cm in front of the Sector 10 post in late January 2017. The temperature data logger was successfully downloaded on 7 December 2020.

RESULTS

Nesting activity, nesting success and recruitment

A total of 209 tagged individual Flatback turtles were recorded during the two-week census period (Table 4.1). No other species of turtle was recorded nesting during this period. There were 180 females that had been recorded with a prior nesting history at Peak Island. Nesting histories of experienced breeders ranged from 2 – 40 years, with 15 turtles having histories of over 30 years. All returning females had been previously tagged at Peak Island.

The work program at Peak Island was not designed to define the duration of the Flatback turtle nesting season. However, with respect to commencement of hatchling emergence, there was no evidence of hatchling tracks in the beach on arrival on 24 November 2020 and no evidence of hatchling emergence was found during 24 November – 7 December 2020 (Table 4.2).

There were 322 recorded Flatback turtle nesting crawls during the census period (Table 4.2). The frequency distribution of nesting crawls by beach sectors is summarised in Figure 4.3. The majority of successfully nesting turtles came ashore within sectors 6 - 13, which was fronted by a sandy beach. Nesting success was fair to good in sectors 4 - 13 and extremely low in sectors 14 - 16 (Figure 4.3). Based on turtles for which it was known whether they laid eggs or not (n = 268) nesting success, the proportion of nesting crawls that resulted in eggs being laid by the turtle, was 72.8 %± 5.3% (Table 1).

The mean nightly census of nesting turtles coming ashore during the mid-season census period was 23.0 tracks and 13.6 clutches laid per night (Table 4.2). These values were higher than in recent years (Figure 4.4).

The recruitment rate of first-time breeding females into the adult nesting population, as measured by the proportion of first time tagged nesting females was 13.6 ± 4.6% for turtles within the mid-season census period (Table 1). This was similar to the past five years (Figure 4.5).

Nesting females: size and fecundity

The mean CCL (cm) of nesting female Flatback turtles was 93.7 cm (Table 4.3, Figure 4.6). Females that were tagged for their first recorded nesting season, presumed first time breeding turtles, were significantly smaller than remigrant turtles with a past breeding history (t-test; $p < 0.01$).

The mean observed remigration interval, the number of years between recorded breeding seasons, for adult female Flatback turtles at Peak Island during the 24 November – 7 December 2020 census period was 3.5 yr (Table 4.3, Figure 4.7). The most common remigration interval was 3 yr (33.9%) followed by 2 yr (24.0%) or 4 yr (21.9%).

The mean return interval for a turtle returning to attempt to lay eggs following its return to the sea after an unsuccessful nesting crawl was 1.3 days (n = 71). Nearly all females returned to re-attempt nesting within two nights after an unsuccessful nesting attempt (Table 4.3; Figure 4.8).

Four nesting females that had successfully laid a clutch were recorded returning to lay an additional clutch 12 or 13 days later (Table 4.3; Figure 4.8).

A total of 190 clutches were laid during the two-week census (Table 4.2). There were 24 clutches relocated to suitable nesting habitat. The number of eggs per clutch, yolkless and multi-yolked eggs, egg diameters, egg weights and nest depths are summarised in Table 4.4 and Figure 4.9. The sampled Flatback turtle clutches had on average: 49.3 eggs counted at laying, 0.15 yolkless eggs and 0.03 multi-yolked eggs per clutch; with eggs averaging 5.2 cm in diameter and weighing 74.9 g. The nests were on average 29.2 cm deep to the top of the eggs and 48.6 cm to the bottom at laying.

Health and injuries

- One Flatback turtle was recorded with fresh propeller damage to the carapace.

Sand temperature monitoring

At Peak Island, sand temperatures at nest depth were recorded, commencing 1 February 2017, until 29 January 2020 (Figure 4.10). The data logger was redeployed to continue sand temperature monitoring. Sand temperatures recorded at approximately nest depth during October – January, which includes a major part of the 2020-2021 Flatback turtle incubation period, initially fluctuated around the pivotal temperature of 29.3^{o}C for the eAust Flatback turtle population. A cooling dip in temperatures coincided with a major rainfall even at the end of December (Figure 4.11), which was followed by temperatures that climbed back above the pivotal temperature. Based on these sand temperature records and given that the embryo's gender is determined during mid-incubation, the Peak Island Flatback hatchling sex ratio from clutches laid up until early January 2020 is expected to have been female-biased, but with periods of male hatching production.

The mid-summer Flatback turtle nesting season typically coincides with a summer peak annual rainfall. Rainfall results in a decline in sand temperatures at nesting beaches and sand temperatures increase in the short term in the absence of rain (Reed, 1980). In the absence of rain, dry surface sand conditions will favour higher sand temperatures as a result of reduced evaporative cooling within the sand.

BOM reported the occurrence of heatwave conditions impacting coastal central Queensland during the eastern Queensland Flatback turtle nesting season of 2020-

2021 (Figure 2). In support of sand temperature data across the turtle breeding season, daily rainfall data recorded at the BOM weather station at Yeppoon were examined (Figure 4.11), showing heavy rainfall recorded on 30 and 31 December, which substantially cooled the sand temperature. This would have contributed to increased male hatchling production.

Mid to late January 2019 was very hot with only one elevated rainfall event on 10 January 2021. Evidence of previous high surface sand temperatures was supported by observations of numerous dead, desiccated hatchlings upon arrival at the beach on 15 January 2021. During the hatchling monitoring very few hatchlings were observed to emerge during the day.

Nest and hatchling disturbance and hatchling depredation and island fauna

During 17 - 29 January 2020, only two clutches were recorded as being heat stressed, which only affected two hatchling that were live in the nest, and one dead in nest just below the surface.

A total of 29 clutches were dug into by the activity of other nesting females and four turtles were disturbed while laying eggs. Large terrestrial predators (pigs, dogs, foxes, varanid lizards and humans) of turtle eggs remain absent from this island. However, 16 clutches were invaded by roots from grasses and vines (equivalent to 8.4 ± 3.9% of clutches examined from before and during the mid-season census period), which resulted in increased incubation failure and entrapment of hatchlings within the nest. There were also 12 clutches affected by flooding of eggs by high tides, representing 6.3 ± 3.5% of clutches examined.

A pair of beach thick-knees, *Esacus magnirostris*, were recorded as nocturnal predators of Flatback hatchlings as they crawled from the nest to the sea. At daylight, two adult white bellied sea eagles, *Haliaeetus leucogaster*, patrolled the beach around sectors 11 - 14 daily and one immature sea eagle was present on the island. Torresian crows, *Corvus orru*, were observed to patrol the beach.

Ghost crabs, *Ocypode ceratothalmus* and *O.cordimanus,* were recorded as a predator of Flatback turtle hatchlings crossing the beach, with evidence of predation each night

By day and night there were numerous small (less than 1.5 m) carcharinid (whaler) sharks of multiple species patrolling the shallows against the shoreline. These sharks preyed on hatchlings as they entered the sea.

Hatchling mortality rates from the above sources of avian, crab and shark depredation and other mortality sources for hatchlings as the left their nests and crossed to the sea were not quantified at Peak Island during the 2020-2021 breeding season.

Estimation of hatchling sex ratio from period to emergence data

There were 107 nests that had been previously marked at laying and had identifying nest tags. The dates laid spanned the mid-season census period from 24 November

to 7 December 2020. Of these nests there were 79 clutches that were observed as hatchlings emerged. The mean period to emergence for these clutches was 49.6 days (Table 4.5, Figure 4.12).

Only two of 79 clutches had a period to emergence that was equal to or greater than the pivotal period to emergence of 54 days (Figure 4.12). These data suggest that a low proportion of male hatchlings were produced at Peak Island from clutches laid during the 2020-2021 mid-season census period.

Incubation and emergence success

There were some problems in accurately assessing incubation success by counting the broken eggshells in the clutches from which hatchlings had emerged. Of the 17 clutches analysed, 6 had an accuracy of >5% and the data had to be rejected for two of these. The mean counting error was 2.4 eggs per nest (SD = 2.6, range = -37 to +2 eggs

Incubation success of eggs and emergence success of hatchlings from the nests are summarised in Table 4.5. Clutches that were identified as laid during the mid-season census period (n = 77) had a mean incubation success of 79.1% and a mean hatchling emergence to the beach surface of 74.5% (Table 4.5).

Additional clutches, with unknown dates of laying had similar incubation success and hatchling emergence success. When combined with the previously identified nests they had a mean incubation success of 81.8% and a mean hatchling emergence to the beach surface of 77.3% (Table 4.5, Figure 4.13).

The 16 clutches invaded by roots from grasses and vines had an average incubation success of 75.3 ± 20.8% and a hatchling emergence success of 61.9 ± 25.3%. Clutches that were strongly affected by flooding had an average hatchling success of 48.1 ± 25.2% and a hatchling emergence success of 46.3 ± 24.6%.

Discussion

Peak Island was not directly impacted by cyclones during the 2020-2021 Flatback turtle breeding season and only received elevated rainfall as a consequence of two cyclones in the northern Coral Sea during the latter half of the breeding season (mid-March and early April). There was also elevated rainfall at the end of October and end of December.

The Peak Island nesting Flatback turtles continued to display normal demographic parameters for the eAust stock: mean CCL = 93.7 cm; mean number of eggs in a clutch = 51.6; mean remigration interval = 3.5 yr (Tables 4.3, 4.4).

Nesting Flatback turtles at Peak Island displayed a relatively high nesting success (72.8) when excluding the emergence activity that could not be determined as resulting in a successful nest. This value is higher than previously reported estimates that included all emergence tracks. If all emergence tracks are considered, then nest success would only be 58.9%, similar to previous years. In comparison to the 2018-

2019 season there was less nesting activity in sectors 1 - 3 and 14 – 17, which have had low nest success.

The 2020-2021 incubation and emergence success (81.8% and 77.3%) at Peak Island was greater than the recorded mean values since 2013 (75.0% and 66.8%; Limpus *et al*. 2021) (Table 4.5). Poor incubation and hatchling emergence success was noted for nests affected by flooding and the intrusion of roots. Heat stress appeared to be less of a problem for the nests laid during the mid-season census. It should be noted that incubation and hatchling emergence success values are overestimates since they do not include nests with 0% success and few nests with very low success (should they occur).

Weed vegetation within the nesting habitat that caused problems with root intrusion into nests, or could cause harm to the team (e.g., spines of prickly pear) was removed by the hatchling emergence team. Previous weed removal by monitoring teams and QPWS staff since the 2018 incubation monitoring has probably contributed to reducing the proportion of clutches negatively impacted by roots to 8.4% of nests.

Given the complexity to quantify hatchling sex ratios from a nesting beach including:

- There is currently no reliably documented non-lethal method for determining the gender of live hatchlings captured as they leave the beach.
- There are variable sand temperatures within the nesting habitat of individual beaches influenced by elevation above the water table, extent of shading from vegetation, aspect towards the sun, and sand colour.
- Intra- and inter seasonal variation in sand temperatures at nest depth in response to regional air temperature variability, rainfall variability, cloud cover.

It is not possible to provide a precise quantification of hatchling sex ratios from a nesting beach.

The sex ratio from within a single clutch could be reliably predicted if a temperature data logger provided temperature data during the mid-incubation period. However, it would be impracticable to attempt this quantification of every clutch laid during an extended sampling period. Thus, only general comments can be made regarding expected sex ratios when based on small samples of period to emergence and beach sand temperature data from a few isolated temperature data loggers.

Flatback eggs that incubate at a constant temperature of 29.3^{o}C, the pivotal temperature, should have hatchlings emerging after approximately 54 days (Limpus, 2007). The majority of clutches at Peak Island laid during the census period had an observed period to emergence less than 54 days (Figure 4.12), which indicates that a biased proportion of female hatchlings would have been produced at Peak Island during the 2020-2021 summer.

Trends

Limpus *et al*. (2013) identified a downward trend in population size at Peak Island over recent decades. The number of tagged turtles observed this season increased compared to the previous three seasons and is among the higher values since 2008 (Figure 4.4).

The recruitment rate (13.6%) of estimated 1st time nesters (turtles not previously tagged) is less than observed during the 2019-2020 census, but greater than the four years previous to that (Limpus *et al*. 2021) (Figure 4.5). This recruitment parameter should continue to be monitored.

CHAPTER 5. WILD DUCK ISLAND STUDY

Study Area

This report provides a summary of results from monitoring marine turtle nesting activity at Wild Duck Island during the 2019-2020 and 2020-2021 breeding seasons. Wild Duck Island was first identified as a significant Flatback turtle breeding site during an aerial survey in 1971 (Limpus, 1985). Annual capture-tagging-recapture census monitoring of the Wild Duck Island nesting population by Dr C. J. Parmenter, Central Queensland University, commenced in 1981 and continued until the 2006-2007 breeding season (Limpus *et al*. 2013). A pilot 14-day mid-season census was conducted in 2019-2020 in response to requests from QPWS for information on the population performance. A large number of nesting turtles (~380) were encountered which prompted the recommencement of annual monitoring of the Wild Duck Island nesting population in 2020-2021.

Wild Duck Island, 21.002ºS, 149.860ºE, is a continental island located just north of Broad Sound and lying approximately 34 km from the nearest mainland shore and approximately 120 km southeast of the Mackay on the mainland coast of eastern Australia. Wild Duck Island sits within a Habitat Protection Zone of the Great Barrier Reef Coast Marine Park and the Great Barrier Reef Marine Park. The island is closed to visitation by the general public and is uninhabited except by the turtle monitoring team during annual monitoring visits. Consequently, the turtle nesting habitat of Wild Duck Island and the immediately adjacent inter-nesting habitat are managed to provide a high level of habitat protection to the turtle nesting population. There are abandoned cabins from a previous resort on the north side of the island. There is an unmaintained grass airstrip.

The Island is approximately 4 km long and 2 km wide and has undulating terrain with a highest ground on the eastern end of the island (Figure 5.1). There is one main nesting beach on the northern side of the island that is bordered by rocky outcrops. Other beaches on the island have not been well surveyed for nesting activity.

Wild Duck Island supports the largest number of nesting Flatback turtles of the East Australian (eAust) stock (FitzSimmons and Limpus, 2014) and has been selected as an index beach for long term monitoring of Flatback turtles within the eAust stock.

Methods specific to Wild Duck Island

Monitoring at Wild Duck Island included the standard 14-day mid-season census period 24 November - 7 December. Additional data on nesting activity were collected on 23 November 2020.

Monitoring of hatchling emergence occurred during 15 - 29 January 2021, with nests being dug to determine incubation and emergence success. This included nests that could be identified by nest tags, but not mapped, and those found opportunistically.

A Hobo MX2201 temperature data logger was placed at 50 cm depth on the upper beach slope to commence monitoring of sand temperature at nest depth in the open sun on the main northern beach.

RESULTS

Nesting activity, nesting success and recruitment

A total of 329 individual Flatback turtles were encountered during the 2020-2021 mid-season census and an additional 37 turtles were recorded for all nights of monitoring (Table, 5.1 5.2). There were 208 first time tagged turtles, which equates to an estimated 63.2% of untagged turtles.

A total of 432 nesting crawls by Flatback turtles were recorded on Wild Duck Island during the two-week census (Table 5.2). Of these, there were 291 successful nests dug with eggs recorded as being laid. This equates to a 75.4% nesting success for the census period (Table 1). Nest success was fairly consistent across the three beach sectors (Figure 5.3)

The mean nightly number of Flatback turtle nesting crawls during the mid-season census period was 30.9 (Table 5.2, Figure 5.4). Most nesting activity during the census occurred in the central area of the north beach in sector 2 with 47.7% of tracks observed there (Figure 5.3).

A total of 219 clutches were laid during the two-week census, these were not mapped, but nest tags were place with the eggs for identification. The mean number of clutches laid per night was 20.8 (Table 5.2).

Nesting females: size, fecundity

The mean CCL of all nesting female Flatback turtles during all monitoring was 93.4 cm (Table 5.3 and Figure 5.5). Newly tagged females were somewhat smaller (92.9 cm) than known remigrants (93.9 cm) (Table 5.3)

Remigration interval, the number of years between recorded breeding seasons, is not accurate at present given only two years of monitoring and a lack of data from when turtles were first tagged. The number of years since last observing turtle ranged from 1 to 38 years (Table 5.3). Two turtles had been originally tagged as different nesting beaches. One was previously seen eight years ago on Avoid Island in 2012. The other turtle was previously seen 38 years ago on Peak Island in 1992.

Renesting intervals between a successful nesting and the subsequent return to lay another clutch were recorded for 13 turtles, which returned 11 to 14 days later (Table 5.3, Figure 5.6). There were 40 encounters with turtles that did not lay during a nesting crawl but returned for another nesting attempt from 0 – 5 days later (average = 1.5 days) (Table 5.3, Figure 5.6).

There was an average of 50.6 (SD = 8.4) eggs per clutch laid for the 455 clutches for which eggs were counted after emergence. Summary data on clutch, egg size and nest depths are given in Table 5.4 and Figure 5.7.

Health and injuries

Two turtles were recorded as having fibropapilloma tumours, one turtle was recorded as having a healed wound from a shark attack and two turtles were recorded as having recent wounds.

On 5 December 2020 Turtle QB5488 died of asphyxiation following inhalation of sand to block the trachea. She had been digging against a sand bank and her head had been buried by falling sand. She died while traveling down the beach retuning to the water. A necropsy showed that her mouth and trachea were compacted with sand.

Sand temperature monitoring

Rainfall and air temperature data recorded at the BOM weather station at Carmilla Beach Road (Figure 5.8) shows intermittent elevated (>60 mm) rainfall events from late December 2020 to early January 2021, and on 20 February. These would have caused a drop in sand temperatures at a time when some clutches were in the critical period of incubation that determines sex.

Based on the period to emergence it appears that a substantial proportion of the clutches would have produced males (Figure 5.9). Of the 59 clutches with a recorded time to emergence, 24 of them (40.7%) took longer than 54 days, suggesting they produced at least some males, and some clutches would have produced predominately males. Wild Duck Island appears to have produced a balance of male and female hatchlings for at least part of the breeding season.

Nest and hatchling disturbance and depredation and island fauna

No clutches were relocated. Seven clutches were recorded as having been dug into by a nesting turtle. One nest had been dug into by a water rat with a direct loss of 15 eggs and failure of the remaining eggs. One nest with a loss of 8 eggs was dug into an unknown predator. No reptilian terrestrial predators of marine turtle eggs or hatchlings were observed disturbing nests. There were observations of deer and deer tracks during the mid-season census.

- 30 November 2020: two deer on South beach
- 1 December: evidence of two deer on the eastern beach
- 3 December: four deer tracks eastern end of North beach
- 4 December: deer tracks along the east coast and on South beach

On 15 January 2021, juvenile bull sharks were observed taking hatchlings in the shallows. On 16 January early morning predation of hatchlings by crows was observed.

Across all clutches dug, two nests had a total of eight eggs predated by crabs. The crab species responsible for this predation was *Ocypode cordimanus*.

Other observations noted that a dead Wedge Tailed Eagle was found on 26 November in Sector 1. The cause of death was not determined.

Estimation of hatchling sex ratio from period to emergence data

The incubation period to hatchling emergence was obtained for 59 clutches from across the entire monitoring period. The average period to emergence was 53.8 days (SD = 3.0, range = 47 - 62) (Table 5.5). Of these clutches, 54% (n = 32) had a period to emergence that was equal to or greater than the pivotal period to emergence of 54 days (Figure 4.12). These data suggest that a substantial proportion of male hatchlings were produced at Wild Duck Island from clutches laid during the 2020-2021 mid-season census period.

Incubation and emergence success

Incubation success and hatchling emergence success was assessed for 461 clutches. Because nest locations were not mapped, nests were found opportunistically after hatchling emergence, which does not account for failed nests or those with very low number of hatchlings emerging (if they occur).

Incubation success was 91.9% (SD = 11.7% and emergence success was 91.2% (SD = 12.3%, Table 5.5). One clutch that had 0% success was found in the nest that had been dug into by a water rat.

DISCUSSION

Wild Duck Island supports the largest population of nesting Flatback turtles for the eAust stock. It serves as a control site for comparative monitoring with respect to the Curtis Island and Peak Island rookeries because it is free of uncontrolled human disturbance of the nesting turtles and the nesting and adjacent inter-nesting habitat has not been modified by anthropogenic activities.

This year's study has completed the second year of monitoring the nesting turtles after 12 years without monitoring, and the first year to collect data on incubation and emergence.

The total number of individually tagged Flatback turtles during the census was 329, which was somewhat lower than the 380 turtles tagged in the 2019-2020 census (Figure 5.4). Previous data from 1992 and 1998 included a complete season census, indicating that an average of approximately 260 turtles nested in each of those years (Limpus 2007). A more recent estimate of the mean adult female population is 473 individuals (Limpus at al. 2013). Mean nightly track counts in 2019-2020 averaged 35.1 and in 2020-2021 the average was 30.9 (Figure 5.4). Previous data collected every year from 1981-2002 fluctuated from 9 – 27 tracks per night, with a trend of fewer tracks for one to three years following years with higher numbers (Limpus

2007). There was an overall trend of increasing tracks per night during that period based on the years with higher track counts.

There were eight turtles that returned to nest after only one year. Given that the most frequent internesting interval at the other eAust rookeries is 2 or 3 years, it will take another few years to determine an accurate internesting analysis for this rookery. Resighting of >1 year of previously tagged turtles, which does not equate to the remigration interval, ranged from 8 - 38 years (mean = 30.9, SD = 6.3, n = 34). Some of these records represent very long breeding histories for this species.

Recruitment rate of first-time tagged females into the adult nesting population was estimated to be 63.2%, which is an expected very high value due the lack of monitoring for 12 years during 200 -2018. It is expected the estimated recruitment rate will drop over the next 4 - 5 years. Previously the recruitment rate for Wild Duck Island was estimated at 10-20% (Limpus 2007).

The size of nesting turtles was 93.4 cm CCL, which is very similar to a previous estimate from Wild Duck of 94.0 cm CCL (SD =. 2.6; n = 133; Limpus 2007). Nesting success (75.4%) was high and similar to that of the Curtis Island and Peak Island rookeries.

Only one turtle had originally been tagged at nearby (25 km distant) Avoid Island, where tagging began in 2007 and continued from 2012-2019. Similarly, only two turtles have been observed nesting at Avoid Island that were originally tagged nesting at Wild Duck Island. A particularly interesting record was of a turtle (A6568) originally tagged at Peak Island (210 km distant) and was last seen in there in 1992, that has provided a 38-year resighting. These data suggest an overall very high fidelity to breed at particular rookeries.

The pivotal temperature, the theoretical temperature that will produce a 50:50 sex ratio, is 29.3^{o}C for the eastern Australian Flatback turtle stock (Limpus, 2007). Warmer nests produce a female bias in the hatchlings, and hatchlings emerge sooner. Flatback eggs incubated at constant temperature of 29.3^{o}C have the hatchlings emerging at approximately 54 days after the eggs were laid (DES, unpublished data). Of the 59 clutches with data on incubation duration, 54% took 54 days or longer, suggesting they produced at least some males, and some clutches would have produced predominately males. Flatback turtle hatchling sex ratio at Wild Duck Island appears to have produced a balance of male and females for much of the peak breeding season and may have produced a greater proportion of males early in the season.

The Wild Duck rookery is not only the largest rookery for the eAUst stock, but the preliminary data suggest it provides an excellent nesting and incubation environment. Additionally, the island at present is not affected by light pollution and there is little direct human impact. Assessment should be made to predict the effects of rising sea levels on this rookery and to obtain data on nest temperatures. It was noted that in comparison to the 2019-2020 season there was a lot more rock exposed at the eastern end of the beach in sector 1, with an estimated 0.5 m of sand eroded. Changes to the beach profile over the next several years will be important.

6. Acknowledgements

All Flatback turtle projects were conducted as part of the Queensland Turtle Conservation Project of the Threatened Species Unit, Department of Environment and Science. The project was funded in part by grants from Gladstone Ports Corporation's Ecosystem Research and Monitoring Program.

The Curtis Island and Peak Island projects received logistical assistance from the Gladstone Queensland Parks and Wildlife Service staff.

These studies could not have been completed without the assistance of the numerous Queensland Turtle Conservation volunteers, who often worked long hours in challenging conditions. The assistance of staff and volunteers is gratefully acknowledged. We particularly thank field volunteers Kymberly Robinson, Tim Byrne, Rachelle Buckley at Peak Island, and Cathy Perkins, Ebony King and Cathy Perkins at Wild Duck and Meran Bull-Watkins, Karen Hedstrom, and Hayley Doblo at Curtis Island.

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TABLES

Table 1. Comparison of reproductive parameters (± standard deviation) recorded for Flatback turtles, *Natator depressus*, nesting at the three central Queensland index rookeries during the 2020- 2021 breeding season, with data on nesting activity from the two-week, mid-census period. Parameters that are considered to be indicative of poor population performance are shaded.

Data Collected	Curtis Island	Peak Island	Wild Duck Island
# turtles – total	67	209	329
Mean tracks/night ± SD	6.8 ± 2.5	23.0 ± 9.5	30.9 ± 13.0
# clutches – total	72	190	291
Nesting success	75.8%	72.8%	75.4%
New recruits to breeding population	13.4%	13.6%	63.2%
Female CCL (cm)	93.7 ± 2.9; n = 66	93.7 ± 2.7; n = 193	93.4 ± 2.6; n = 289
Mean remigration interval (yr)	3.6 ± 1.8; n = 50	3.5 ± 1.5; n = 183	n.a
Mean eggs/clutch	51.7± 7.5; n = 25	49.3 ± 8.2; n = 37	50.6 ± 8.4; n = 455
Mean egg diameter (cm); n = # clutches	5.1 ± 0.13; n = 9	5.2 ± 0.14; n =10	n.a.
Mean egg weight (g); n= # clutches	74.7 ± 4.6, n = 9	74.9 ± 5.1; n = 10	n.a.
Incubation duration n = # clutches	47.9 ± 1.3; n = 61	49.6 ± 1.7; n = 79	53.8 ± 3.0; n = 58
Incubation success; n = # clutches	82.4 ± 21.9%; n = 66	80.5 ± 19.5%; n =107	91.9 ± 11.7%; n = 460*
Emergence success; n = # clutches	80.0 ± 21.6%; n = 66	76.7 ± 21.9%; n = 107	91.2 ± 12.3%; n = 460*

*all nests were found opportunistically, so higher success is partly due to an artefact of sampling

Curtis Island Tables

Table 3.1. Summary of Flatback turtle, *Natator depressus*, tagging census at Curtis Island during the entire 2020-2021 breeding season.

	Flatback turtles	Loggerhead turtles	Green turtles
First time tagged	12	0	2
Remigrant recaptures			
• With tags	60	0	1
• With tag scars only	1	0	0
• Change of colony within the 2020-2021 season	0	0	0
• Change of colony between breeding seasons	0	0	0
Total turtles	**73***	**0**	**4**

* mid-season census = 67

Table 3.2. Nightly count of turtle tracks, tagged turtles, clutches laid and emerged clutches of Flatback turtles, *Natator depressus*, at Curtis Island during the two-week census 24 November -7 December 2020

Date	# tracks	# tagged turtles	# clutches laid	# emerged clutches
24 Nov 2020	7	7	7	0
25 Nov 2020	4	3	4	0
26 Nov 2020	7	5	6	0
27 Nov 2020	9	8	7	0
28 Nov 2020	4	4	3	0
29 Nov 2020	3	3	3	0
30 Nov 2020	9	7	6	0
1 Dec 2020	6	4	4	0
2 Dec 2020	8	4	3	0
3 Dec 2020	13	13	10	0
4 Dec 2020	7	7	6	0
5 Dec 2020	7	7	6	0
6 Dec 2020	5	4	3	0
7 Dec 2020	6	5	4	0
Total	**95**	**67 individuals**	**72**	**0**
Mean (S.D)	**6.8 ± 2.5**	**5.8 ± 2.6**	**5.1 ± 2.0**	**0**

Table 3.3. Size and remigration interval of nesting female turtles at Curtis Island during the entire 2020-2021 breeding season.

	Curved carapace length (cm)			
	Mean	**SD**	**Range**	**N**
Flatback turtles				
• First time tagged females	91.9	3.3	84.3-95.8	10
• Remigrant females	94.0	2.7	85.6-99.3	56
• All females for season	93.7	2.9	84.3-99.3	66
Green turtles				
• All females for season	113.8	0.36	113.5 -114.3	3
	Remigration interval (yr)			
	Mean	**SD**	**Range**	**N**
Flatback turtles- census only	3.6	1.8	2-11	50
Flatback turtles- all season	3.6	1.9	2-11	52
Green turtles	3	-	-	1

Table 3.4. Flatback turtle, *Natator depressus*, clutches, nest descriptions and within season nesting return intervals, at Curtis Island for the entire 2020-2021 breeding season.

	Mean	**SD**	**Range**	**N**
Eggs per clutch- at laying	51.7	7.46	30-69	25
Yolkless eggs per clutch	0.14	0.43	1-3	225
Multi-yolked eggs per clutch	0.0	-	-	225
Renesting interval (d), following a successful nesting	13.0	0.0	13	3
Return interval (d), following an unsuccessful nesting attempt	0.92	0.47	0-2	13
Nest depth, top (cm)	41.0	8.66	17-58	93
Nest depth, bottom (cm)	56.2	9.56	36-72	25
Egg diameter (mean) (cm)	5.11	0.13	4.83-5.48	89 (9 clutches)
Egg weight (g)	74.7	4.59	63.6-87.0	89 (9 clutches)

Table 3.5. Incubation period, incubation success, and emergence success for undisturbed Flatback, *Natator depressus*, and green, *Chelonia mydas*, turtle clutches at Curtis Island during the 2020-2021 breeding season. An undisturbed clutch is defined as one that was not predated by foxes or dogs. Mid-season census and entire season data are included.

	Mean	SD	Range	N
Flatback turtles				
Incubation period (oviposition to emergence)				
• During mid-season census (d)	47.9	1.30	45-50	61 clutches
• entire season (d)	48.2	1.93	44-59	172 clutches
Success of clutches undisturbed by mammals				
• Incubation success, census (%)	82.4	21.9	8.8-100	66 clutches
• Incubation success, entire season (%)	78.0	25.1	0-100	213 clutches
• Emergence success, census (%)	80.0	21.6	8.8-98.2	66 clutches
• Emergence success, entire season (%)	75.1	25.7	0-100	213 clutches
Green turtles (entire season)				
Incubation period to emergence (d)	52.8	0.83	52-54	4 clutches
Incubation success (%)	95.4	4.6	87.5-99.2	4 clutches
Emergence success (%)	90.2	6.5	82.8-99.2	4 clutches

Peak Island Tables

Table 4.1. Tagging history of Flatback turtles, *Natator depressus*, recorded nesting at Peak Island during the two-week census period, 24 November to 7 December 2020

Tagging history of turtles	# turtles
First time tagged females (Primary tagged turtles)	29
Remigrant recaptures	
• Recaptured with tags previously recorded at Peak Island	180
• Recaptured with tag scars only, previously applied tags lost	0
• Recaptured with tags from a different colony between breeding seasons	0
Total turtles	**209**

Table 4.2. Nightly count of turtle tracks, tagged turtles, clutches laid and emerged clutches of Flatback turtles, *Natator depressus*, at Peak Island during the two-week census 24 November - 7 December 2020

Date	# tracks	# turtles	# clutches laid	# emerged clutches
24 Nov 2019	11	9	8	0
25 Nov 2019	8	7	4	0
26 Nov 2019	24	20	13	0
27 Nov 2019	46	39	19	0
28 Nov 2019	17	15	8	0
29 Nov 2019	28	25	17	0
30 Nov 2019	29	27	17	0
1 Dec 2019	26	24	19	0
2 Dec 2019	20	19	14	0
3 Dec 2019	28	25	22	0
4 Dec 2019	17	13	12	0
5 Dec 2019	31	23	15	0
6 Dec 2019	25	23	15	0
7 Dec 2019	12	9	7	0
Total	**322**	**209 individuals**	**190**	**0**
Mean (S.D)	**23.0 ± 9.5**	**19.9 ± 8.4**	**13.6 ± 5.01**	**0**

Table 4.3. Summary of CCL measurements and remigration intervals of nesting Flatback turtles, *Natator depressus*, at Peak Island during the 24 November to 7 December 2020 census period.

	Mean	SD	Min	Max	N
	Curved Carapace Length CCL (cm)				
1st breeding season (primary taggings)	92.3	2.5	87.0	98.3	29
All remigrant turtles	93.9	2.7	83.1	102.7	164
All Turtles	93.7	2.7	83.1	102.7	193
	Observed Remigration Interval (yr)				
All remigrant turtles	3.5	1.5	1	10	183
	Return and renesting intervals (d)				
Return interval (d) following unsuccessful nesting attempt	1.3	0.67	0	3	71
Renesting interval (d) following successful nesting attempt	12.3	0.4	12	13	4

Table 4.4. Flatback turtle, *Natator depressus*, clutches, and nest descriptions at Peak Island, 2020-2021 breeding season.

	Mean	SD	Range	N
Eggs per clutch- at laying	49.3	8.2	31-65	37
Eggs per clutch- at emergence	51.6	7.9	28-77	189
Yolkless eggs per clutch	0.15	0.05	0-2	189
Multi-yolked eggs per clutch	0.03	0.16	0-1	37
Nest depth, top (cm)-at laying	29.2	10.4	5-49	16
Nest depth, bottom (cm)- at laying	48.6	6.4	33-58	25
Nest depth, bottom (cm)- at emergence	58.3	10.4	32-89	189
Egg diameter (cm)	5.2	0.14	4.8-6.1	100 (10 clutches)
Egg weight (g)	74.9	5.1	57.6-84.2	100 (10 clutches)
Eggs/clutch disturbed in an existing clutch by a nesting turtle	0.27	1.6	0-10	37 clutches; 1 disturbed

Table 4.5. Incubation period Incubation and emergence success and for Flatback turtle, *Natator depressus*, clutches at Peak Island during 24 November – 7 December 2020.

	Mean	SD	Range	N
Incubation period (oviposition to emergence) (days)	49.6	1.7	45-56	79
Clutches identified as laid during mid-season census period				
• Incubation success (%)	79.1	19.2	18-100.0	77 clutches
• Emergence success (%)	74.5	22.3	8-100.0	77 clutches
Pooled data for all clutches examined				
• Incubation success (%)	81.8	17.7	3.9-100.0	191 clutches
• Emergence success (%)	77.3	20.8	3.85-100	191 clutches

Wild Duck Island Tables

Table 5.1. Tagging history of Flatback turtles, *Natator depressus*, recorded nesting at Wild Duck Island in the 2020-2021 breeding season.

Tagging history of turtles	# turtles
Breeding Season	2020-2021
First time tagged females (Primary tagged turtles)	208
Remigrant recaptures	
• Recaptured with tags previously recorded at Wild Duck Island	46
• Recaptured with tag scars only, previously applied tags lost or with tags not identified to original tagging site	73
• Recaptured with tags from a different colony between breeding seasons	2
Total Turtles	**329**

Table 5.2. Nightly census of nesting Flatback turtles, *Natator depressus*, at Wild Duck Island during 2020-2021 breeding season: nightly track count, tagged turtles and clutches laid with mean ± SD calculations.

Date	# tracks	# tagged turtles	# clutches laid
Census			
24 Nov	41	34	27
25 Nov	15	15	12
26 Nov	32	25	20
27 Nov	54	39	31
28 Nov	43	37	28
29 Nov	17	16	13
30 Nov	14	14	10
01 Dec	27	26	19
02 Dec	28	26	23
03 Dec	29	27	23
04 Dec	14	14	9
05 Dec	47	47	31
06 Dec	46	44	27
07 Dec	25	23	18
Total Census	432	329 individuals	291
Mean ± SD	*30.9 ± 13.0*	*27.6 ± 10.7*	*20.8 ± 7.3*
Pre-census			
23 Nov	33	9	14
Post-census			
17 Jan	4	5	3
18 Jan	1	1	1
19 Jan	1	1	1
20 Jan	4	3	3
21 Jan	6	6	6
22 Jan	4	4	3
23 Jan	4	4	4
24 Jan	3	3	3
25 Jan	1	0	0
28 Jan	1	1	1
Total pre and post census	62	37	39

Table 5.3. Summary of CCL measurements and remigration intervals of nesting Flatback turtles, *Natator depressus*, at Wild Duck Island during the 24 November to 7 December 2020 census period.

	Mean	SD	Min	Max	N
	Curved Carapace Length (cm)				
1st breeding season (primary taggings)	92.9	2.5	83.8	102.2	187
All remigrant turtles	93.9	2.5	88.1	102.2	102
All Turtles	93.4	2.6	83.3	102.2	289
	Observed Remigration or Re-sighting Interval (yr)				
All remigrant turtles	n/a	n/a	1	38	43
	Return and renesting intervals (days to attempted nesting)				
Return interval (d) following unsuccessful nesting attempt	1.5	1.2	0	5	58
Renesting interval (d) following successful nesting attempt	12.7	0.7	11	14	19

Table 5.4. Summary of clutch and nest data for Flatback turtle, *Natator depressus*, at Wild Duck Island during the 2020-2021 season.

	Mean	SD	Range	N
Eggs per clutch- after emergence	50.6	8.4	23-79	455
Egg diameter (cm) – at laying	-	-	-	-
Egg weight (g) –at laying	-	-	-	-
Yolkless eggs per clutch- on emergence	0.104	0.39	0-3	461
Multiyolk eggs per clutch- on emergence	0	0	0	461
Nest depth, bottom (cm)-on emergence	55.5	6.2	32-75	461

Table 5.5. Summary incubation period to emergence, incubation success and hatchling emergence success for Flatback turtle, *Natator depressus*, clutches at Wild Duck Island during the 2020-2021 season. All nests were found opportunistically, so higher success is partly due to an artefact of sampling.

	Mean	SD	Range	N
Incubation period (period to emergence) (d)				
• Entire monitoring	53.8	3.0	47 - 62	59
Success from all opportunistically found emergent clutches				
• Incubation success (%)	91.9	11.7	0 – 100	460
• Emergence success (%)	91.2	12.3	0 – 100	460

FIGURES

Introduction

Figure 1a. Primary nesting study sites for Flatback turtles, *Natator depressus*, within the eAust genetic stock (orange type).

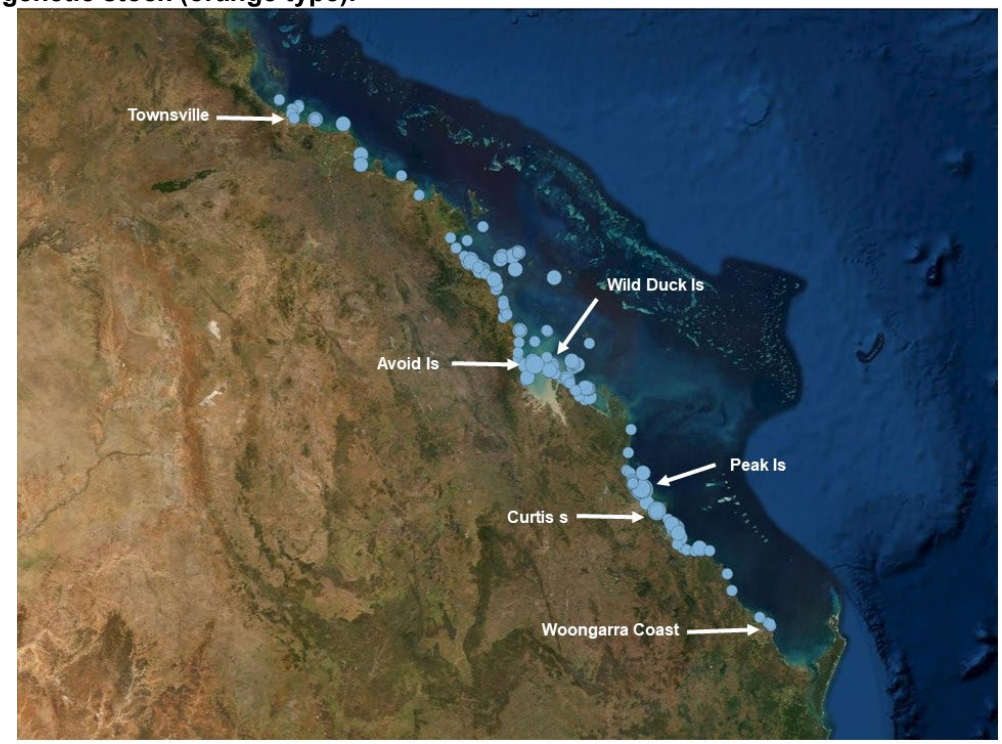


Figure 1b. Distribution of Flatback turtle nesting within the eAust genetic Stock.

Figure 1. The eAust genetic stock of Flatback turtles, *Natator depressus*, breeding range.

Environmental monitoring

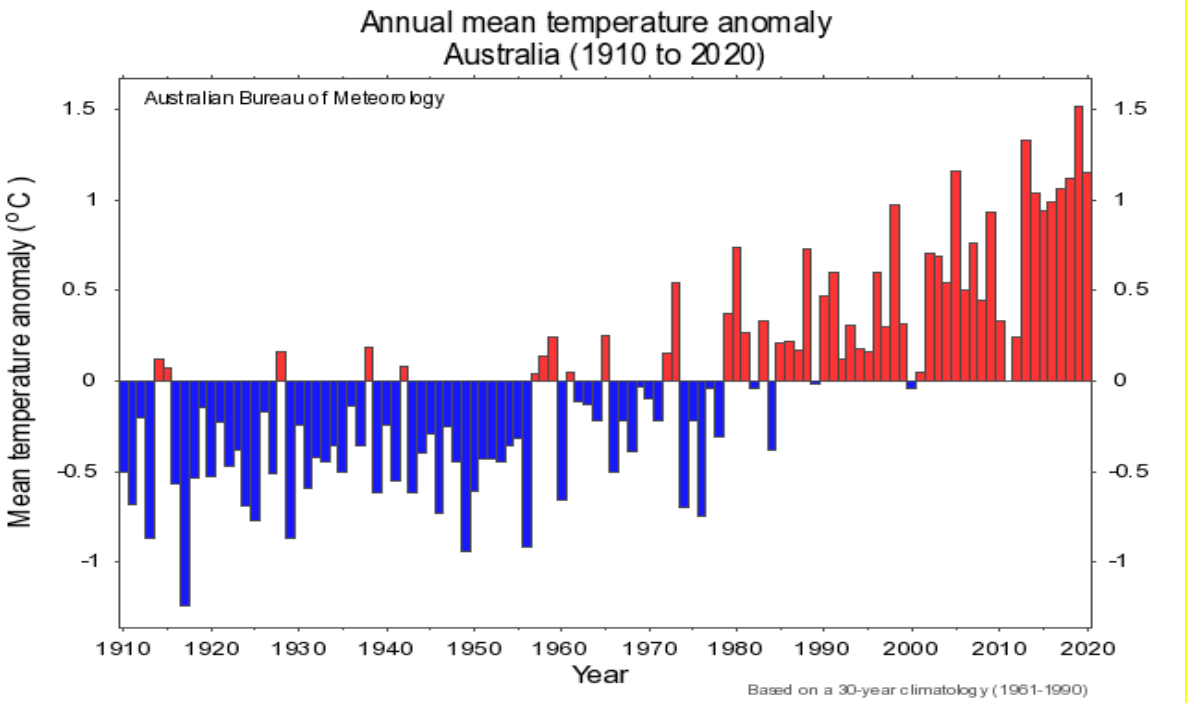


Figure 2. Bureau of Meteorology (2021) annual mean temperature anomaly data. Above average temperatures persisted through the 2020-2021 summer.

Curtis Island Figures

a. Curtis Island.

b. South End Beach, looking south from Connor's Bluff.

Figure 3.1. Location of South End Beach, Curtis Island, in relation to Gladstone, Port Curtis and Port Alma.

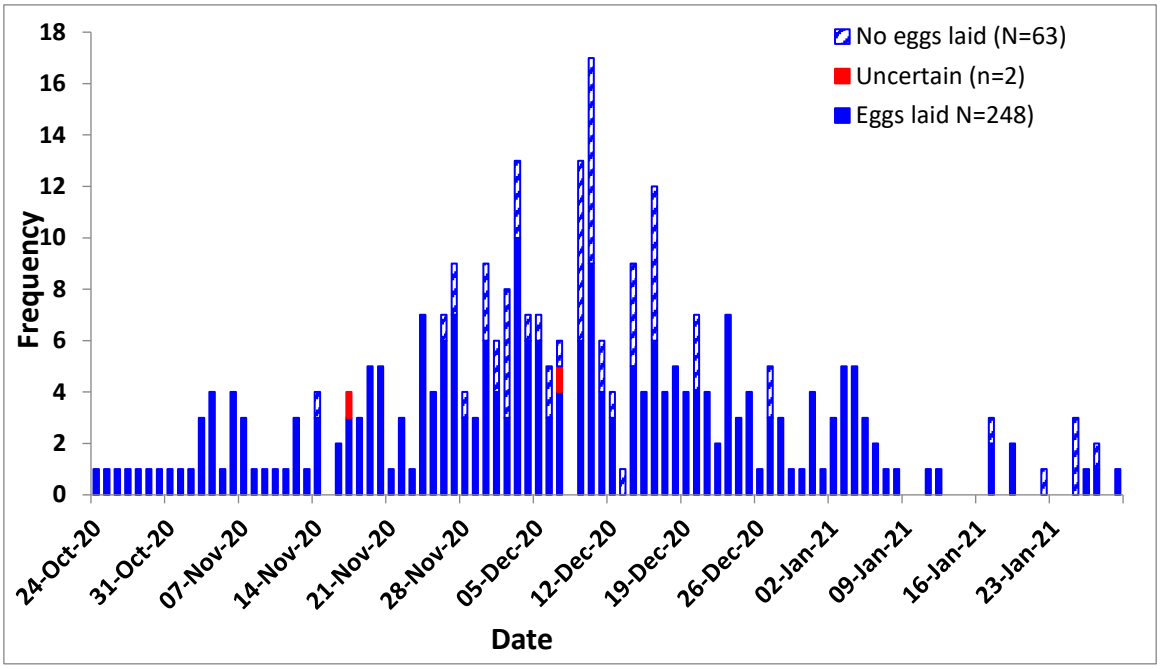


Figure 3.2. Nightly number of Flatback turtles, *Natator depressus*, ashore for nesting on South End Beach, Curtis Island during the 2020-2021 nesting season. Census period was 24 Nov – 7 Dec 2020.

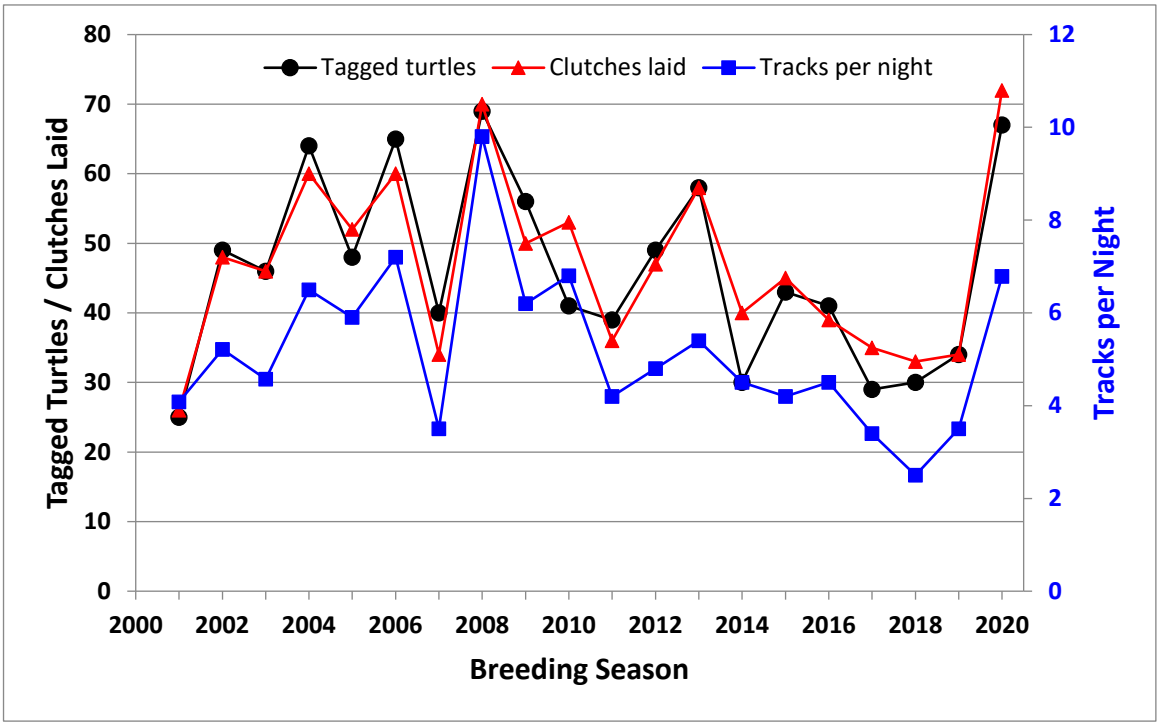


Figure 3.3. Census of Flatback turtle, *Natator depressus*, nesting activity at South End Beach, Curtis Island during the mid-season census population from 2002-2021 including: mean nightly track counts, number of tagged turtles and number of clutches. Note that some clutches were laid by turtles that were not encountered.

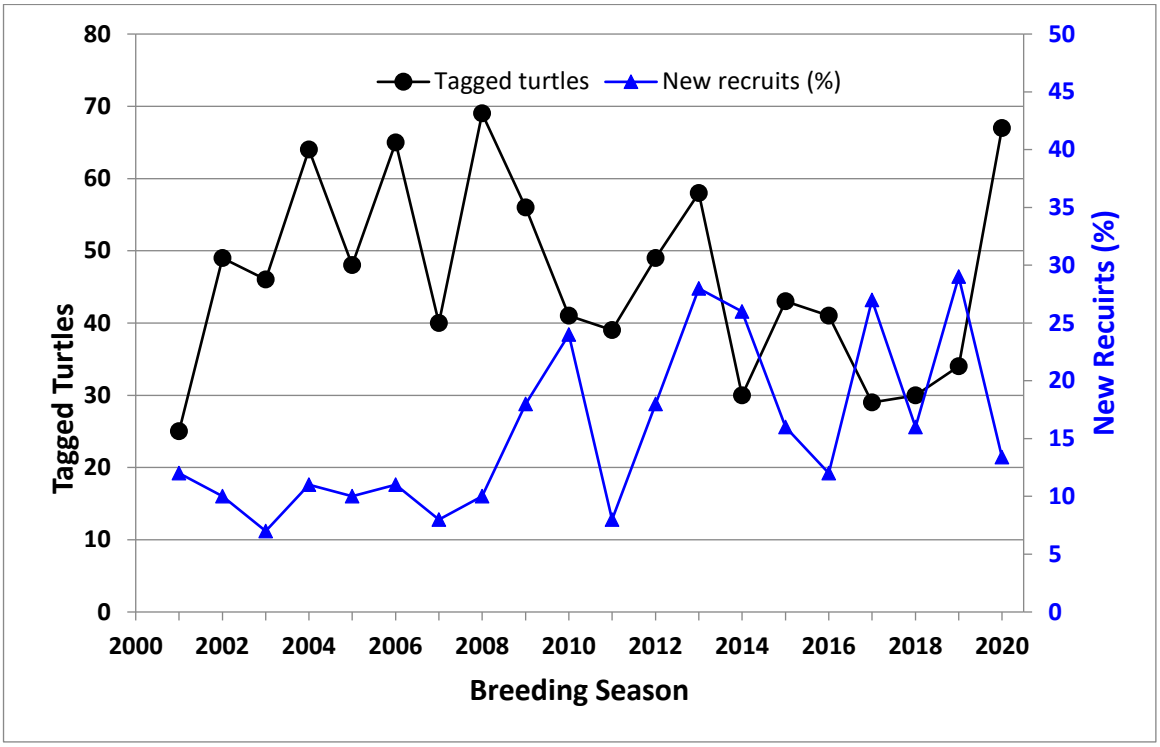


Figure 3.4. Census of Flatback turtle, *Natator depressus*, nesting activity at South End Beach, Curtis Island during the mid-season census population from 2002-2021 including; the number of tagged turtles and the proportion of new recruits into the annual breeding population.

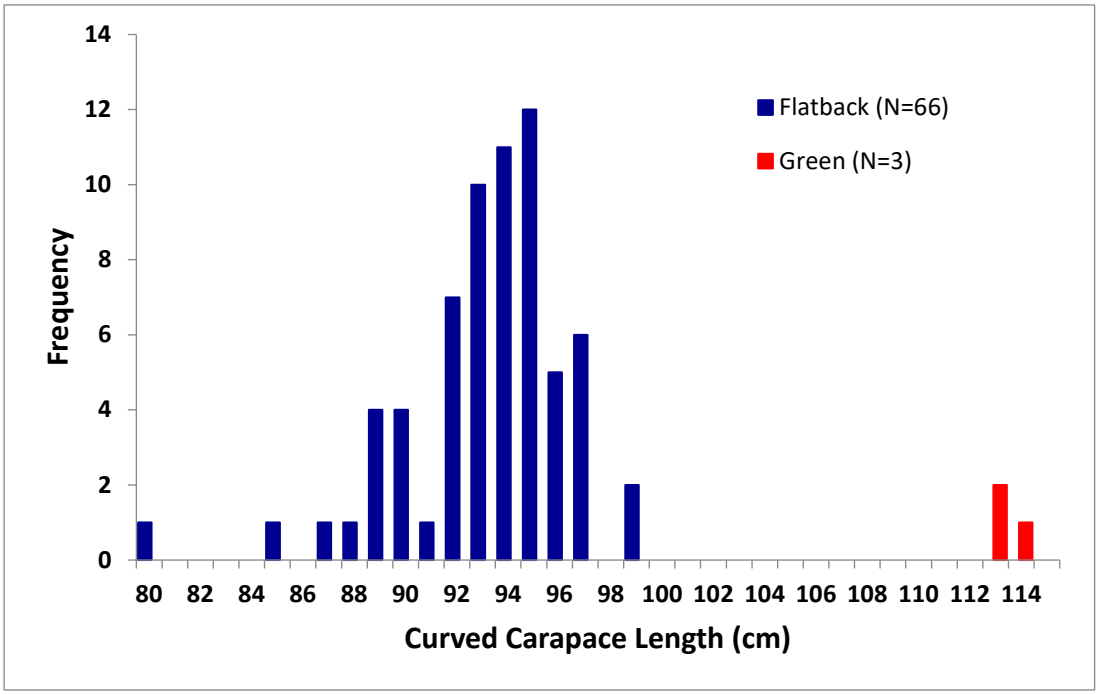


Figure 3.5. Size of nesting Flatback, *Natator depressus*, and Green, *Chelonia mydas,* turtles nesting at South End Beach, Curtis Island during the 2020-2021 breeding season.

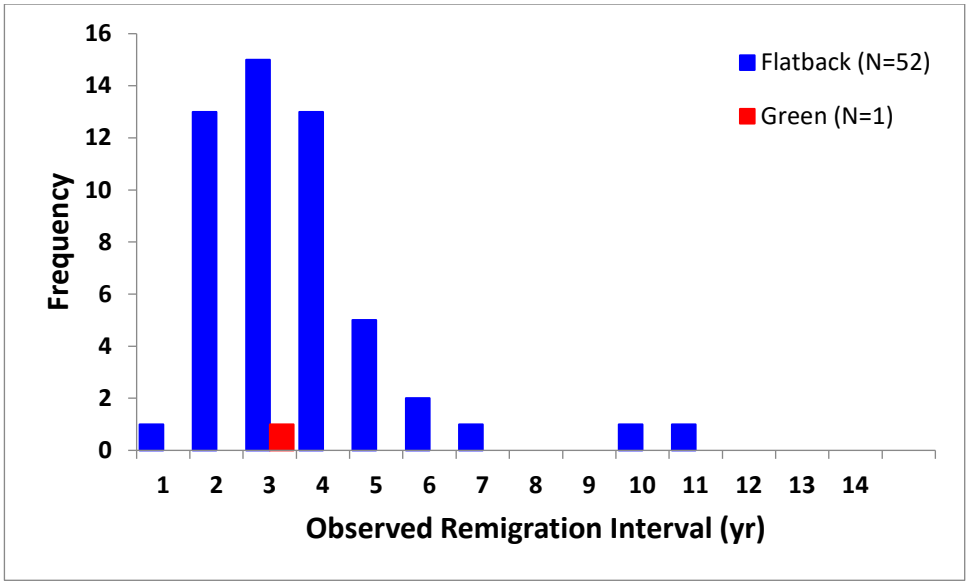


Figure 3.6. Observed remigration intervals recorded for nesting Flatback, *Natator depressus*, and Green, *Chelonia mydas,* turtles nesting at South End Beach, Curtis Island during the 2020-2021 breeding season.

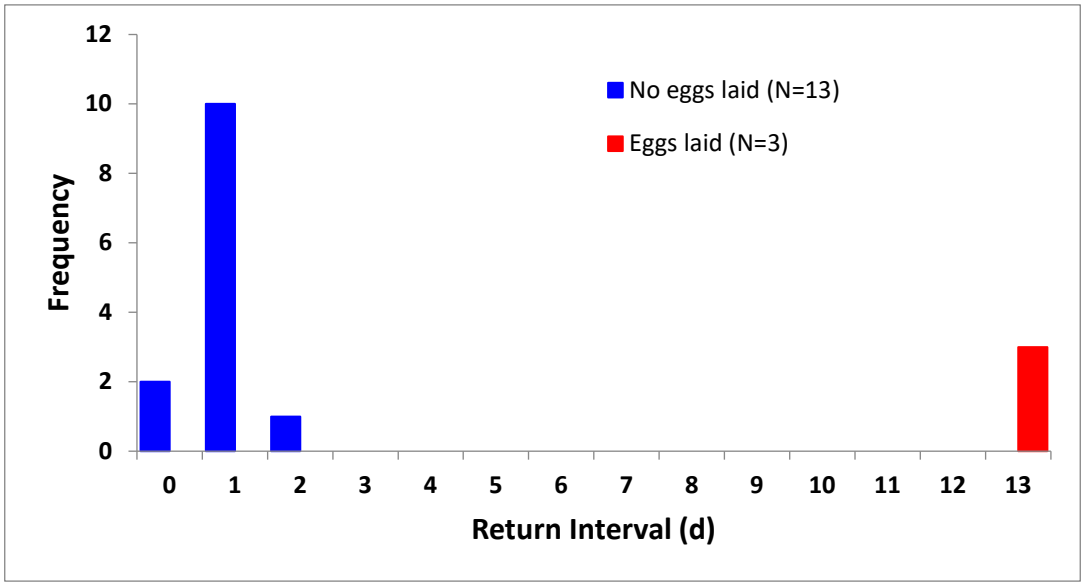


Figure 3.7. Return intervals recorded for nesting Flatback turtle, *Natator depressus,* following both successful and unsuccessful nesting attempts at South End Beach, Curtis Island during the 2020-2021 breeding season.

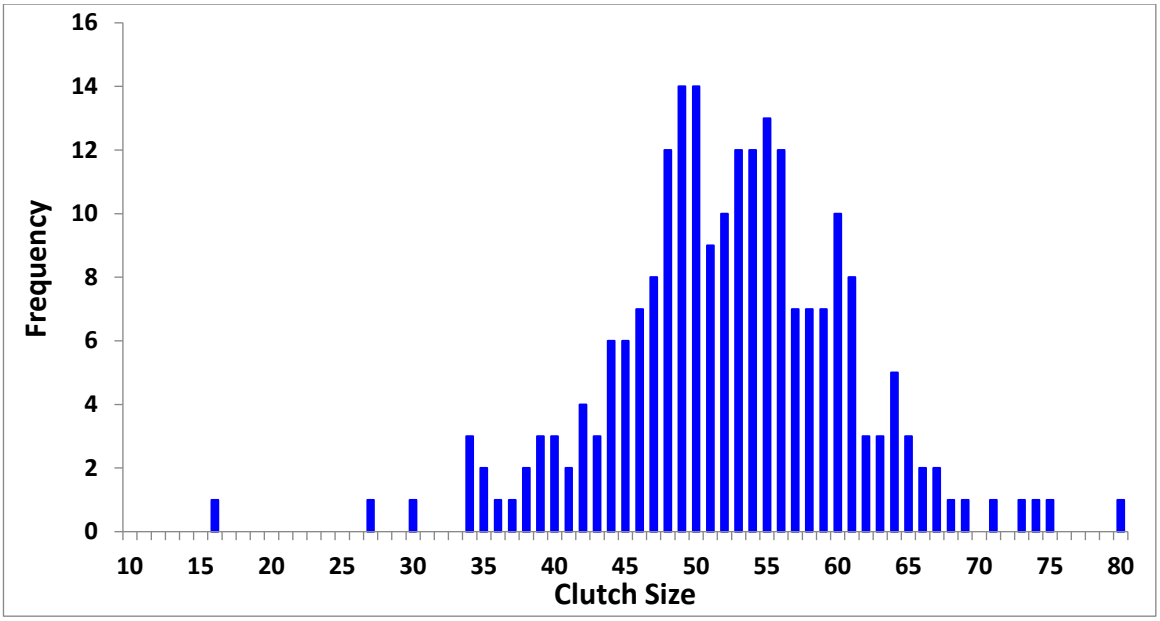


Figure 3.8. Frequency distribution of the number of eggs per clutch of Flatback turtles, *Natator depressus*, recorded nesting at South End Beach, Curtis Island during the mid-season census period, 24 November – 7 December 2020.

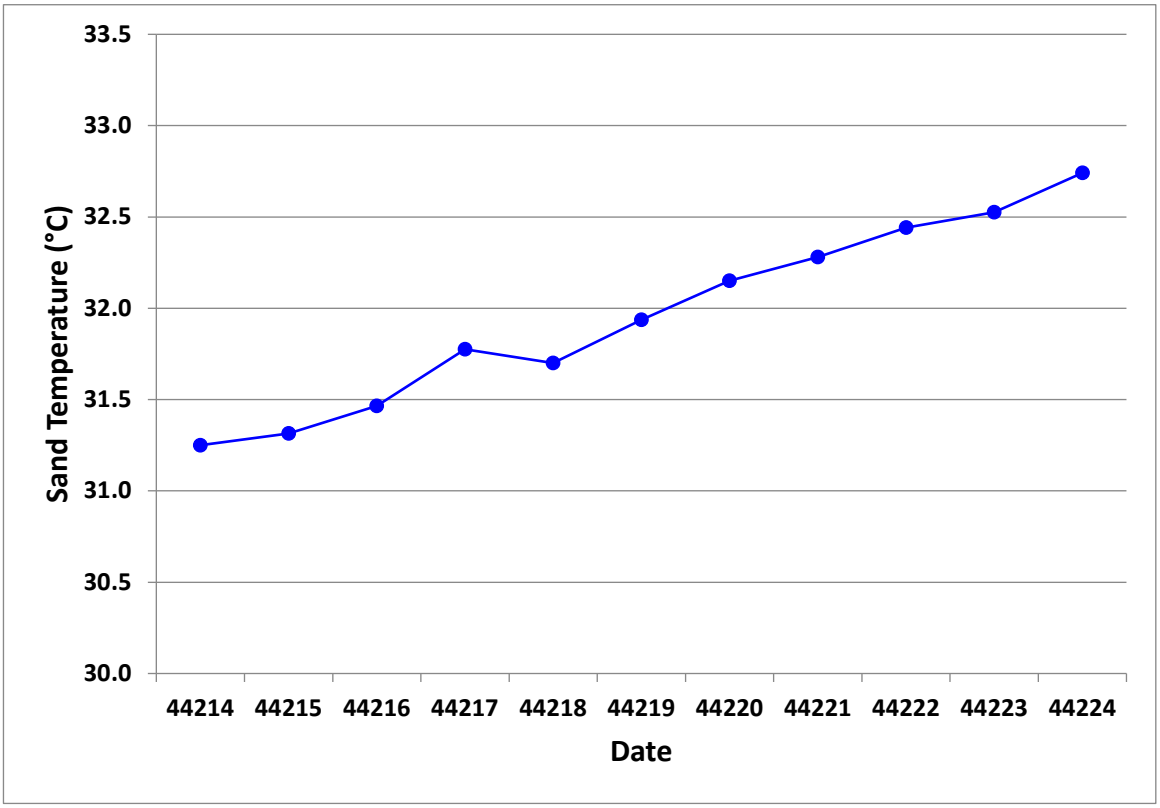


Figure 3.9. Sand temperatures (°C) at nest depth in the open sun at noon recorded from 18-28 January 2020 at the South End Beach, Curtis Island.

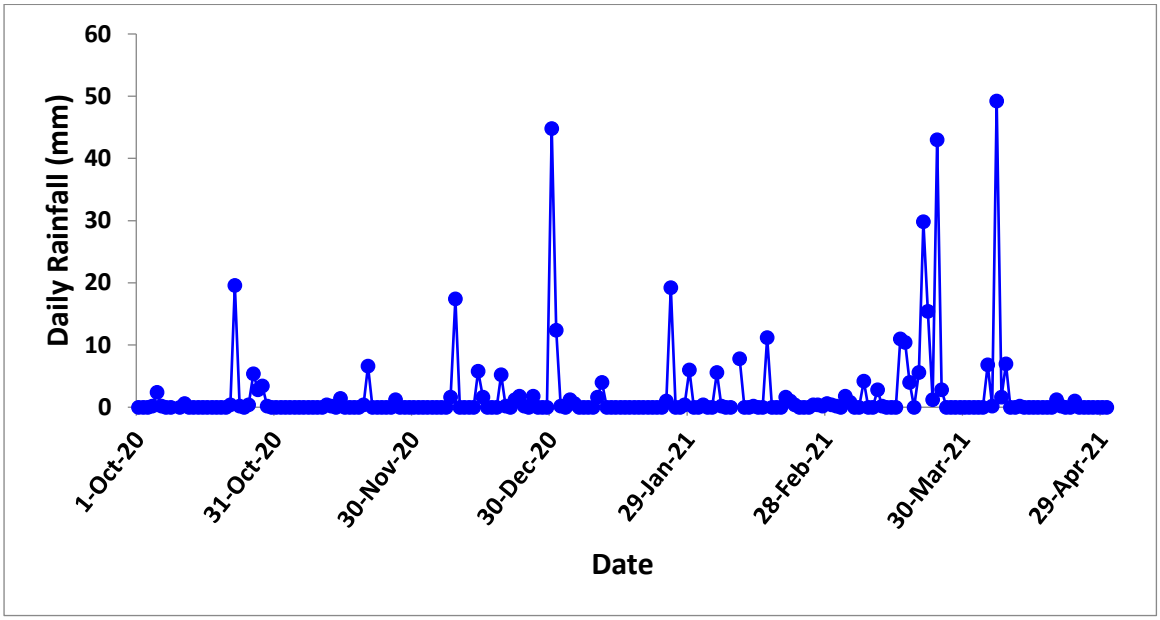


Figure 3.9. Daily rainfall, 1 October 2020 – 30 April 2021, recorded at the Gladstone Airport; Australian Bureau of Meteorology station number 39326, 23.87°S, 151.22°E.

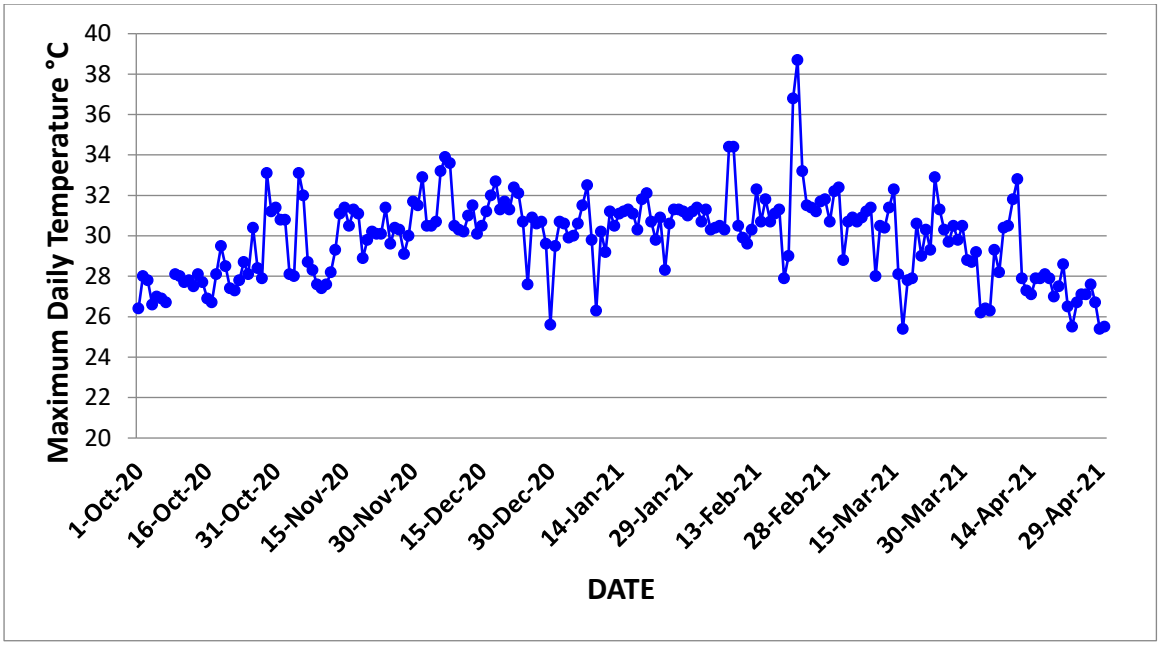


Figure 3.10. Maximum daily temperature, 1 October 2020 – 30 April 2021, recorded at the Gladstone Airport; Australian Bureau of Meteorology station number 39326, 23.87°S, 151.22°E.

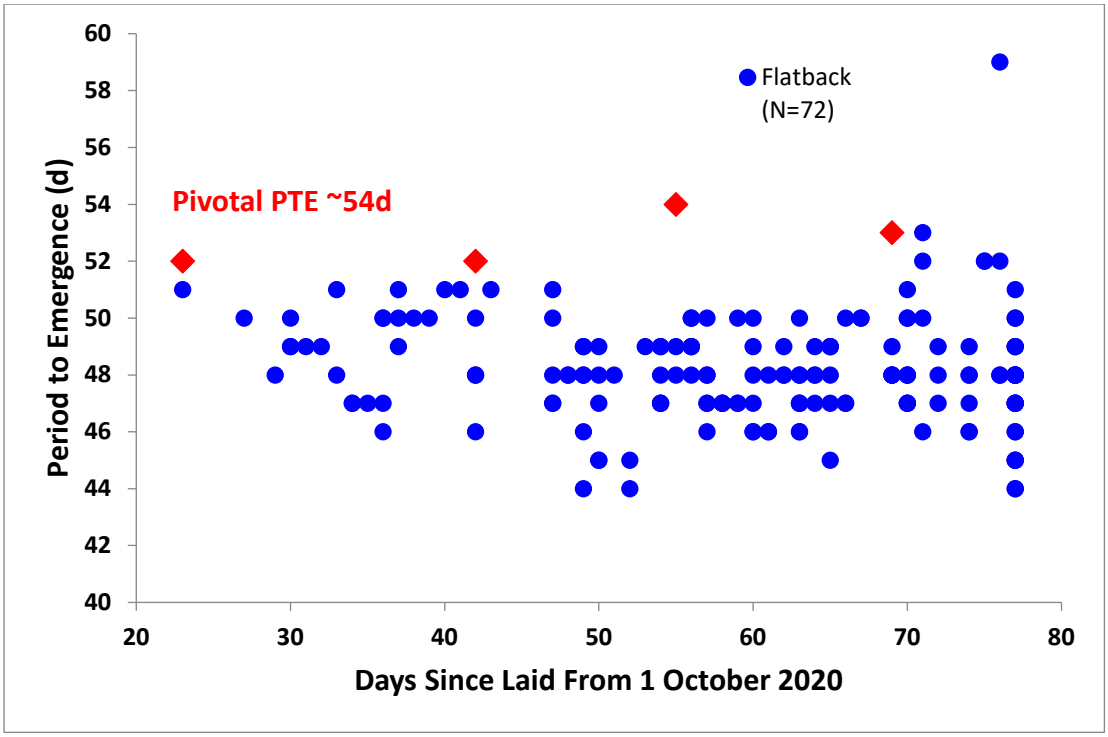


Figure 3.11. Seasonal variation in period to emergence (period from laying to hatchling emergence to the beach surface) for Flatback, *Natator depressus,* and Green, *Chelonia mydas*, clutches laid on South End Beach, Curtis Island, 2020-2021 season. Pivotal PTE of ~54 days indicates clutches emerging in fewer days produce a greater proportion of females and vice versa.

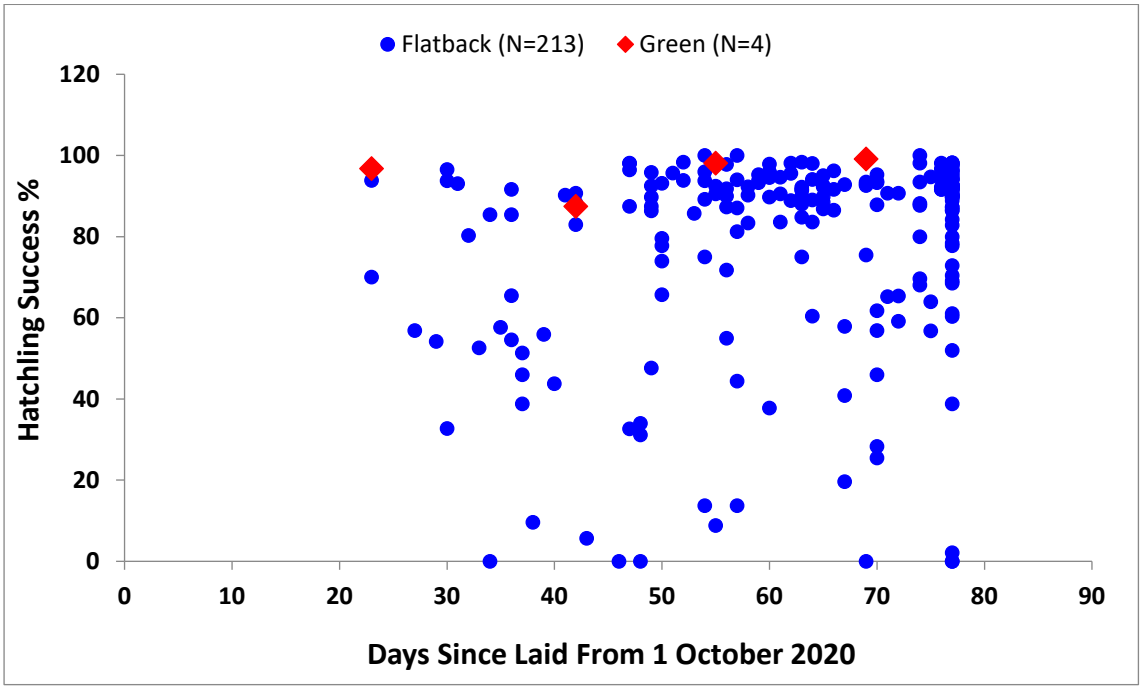


Figure 3.12. Comparison of incubation success (%) for Flatback, *Natator depressus,* and green, *Chelonia mydas*, clutches laid on South End Beach, Curtis Island, 2020 – 2021 season.

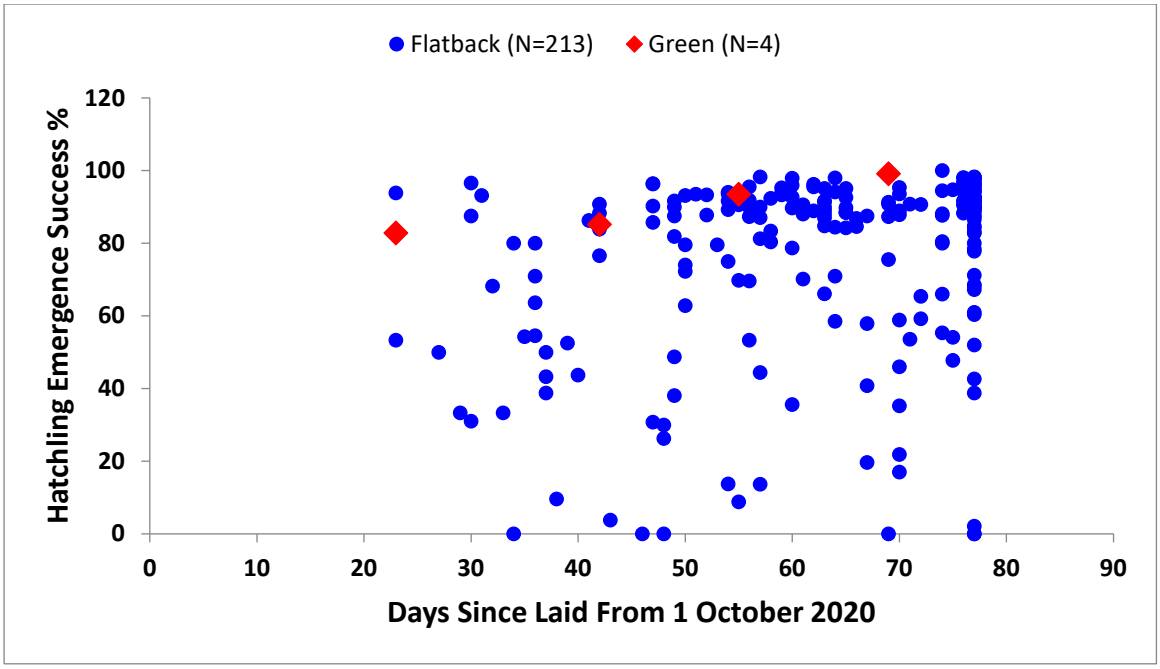


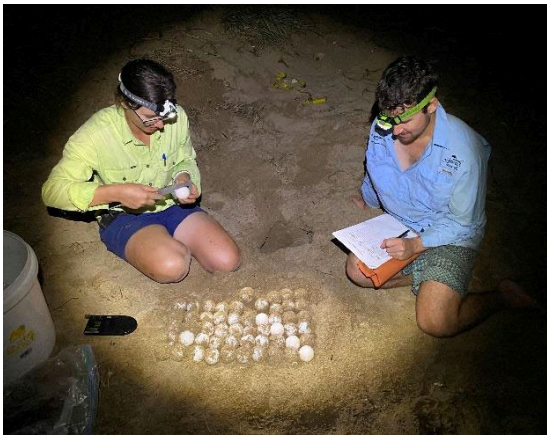
Figure 3.13. Comparison of hatchling emergence success (%) for the 2020-2021 breeding season for Flatback, *Natator depressus,* and green, *Chelonia mydas*, clutches laid on Curtis Island.

Peak Island Figures

a. Peak Island and surrounding areas

b. Peak Island

c. Peak Island National Park sign



d. Measuring eggs

e. Removal of Crotolaria from Sector 1

Figure 4.1. Images of Peak Island, including work done in the 2020-2021 turtle breeding season.

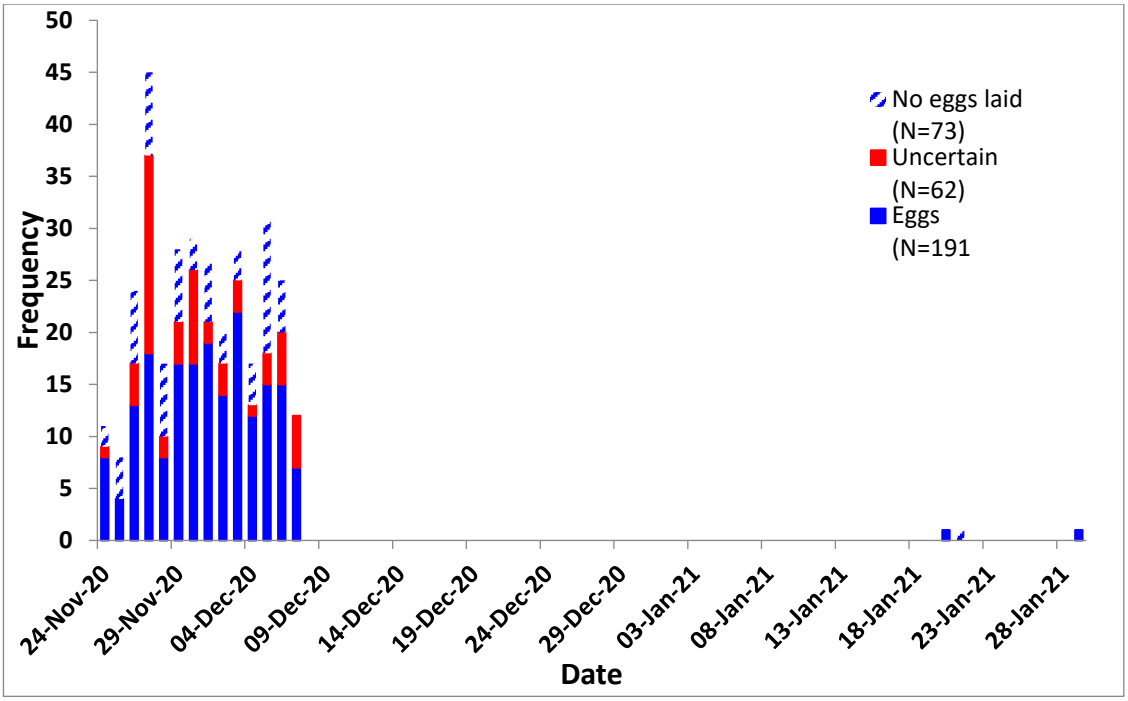


Figure 4.2 Nightly number of Flatback turtles, *Natator depressus*, ashore for nesting on Peak Island during the 2020-2021 nesting season. Census period was 24 Nov – 7 Dec 2020.

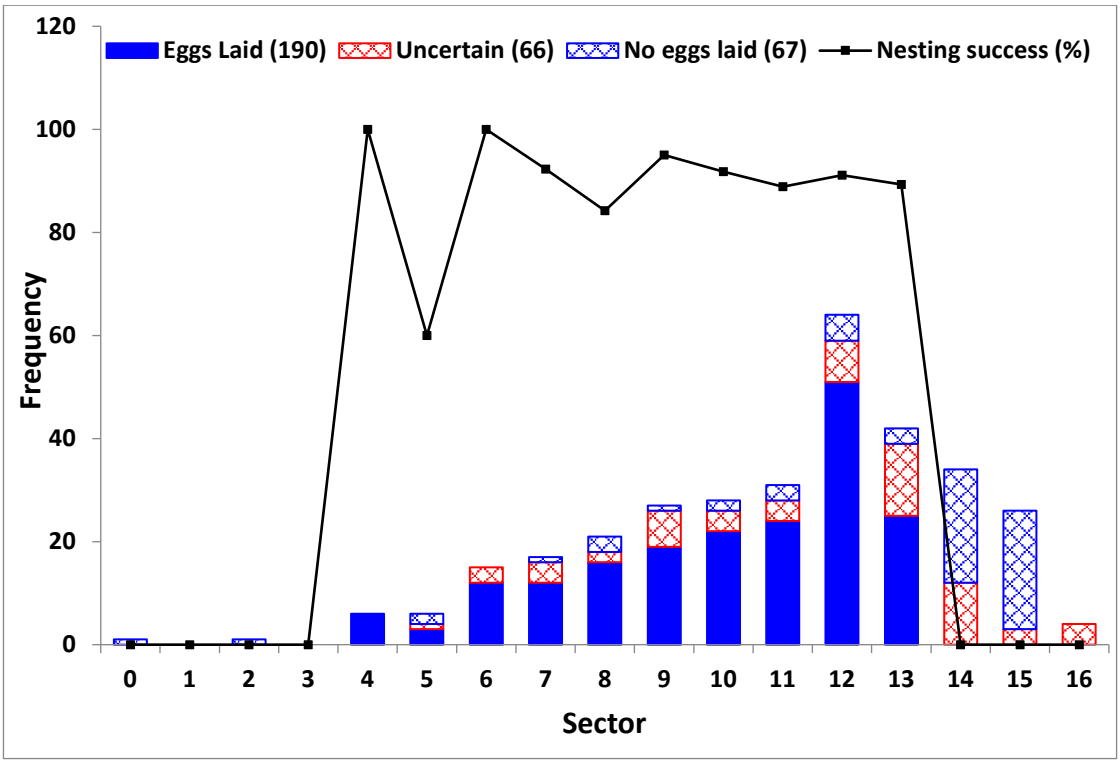


Figure 4.3. Frequency distribution of Flatback turtle, *Natator depressus,* nesting activity and nesting success (not considering uncertain events) by beach sectors, Peak Island during 24 November – 7 December 2020.

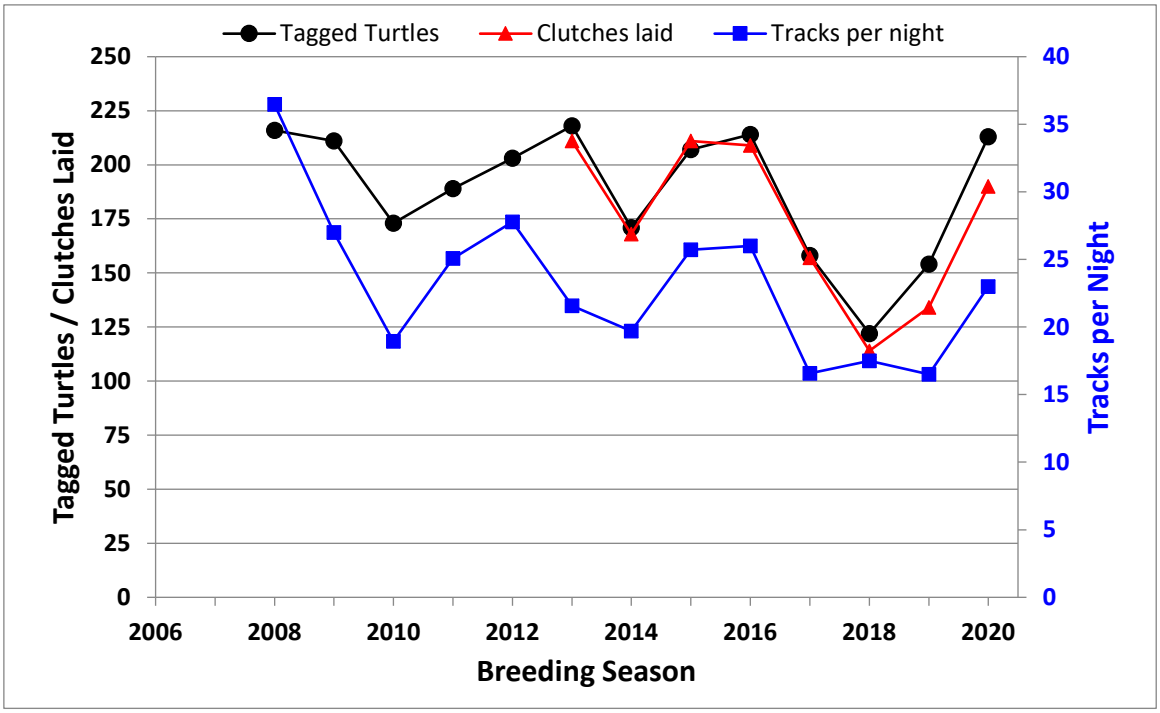


Figure 4.4. Census of Flatback turtle, *Natator depressus*, nesting activity at Peak Island during the mid-season census population from 2008-2021 including: mean nightly track counts, number of tagged turtles and number of clutches. Note that some clutches were laid by turtles that were not encountered.

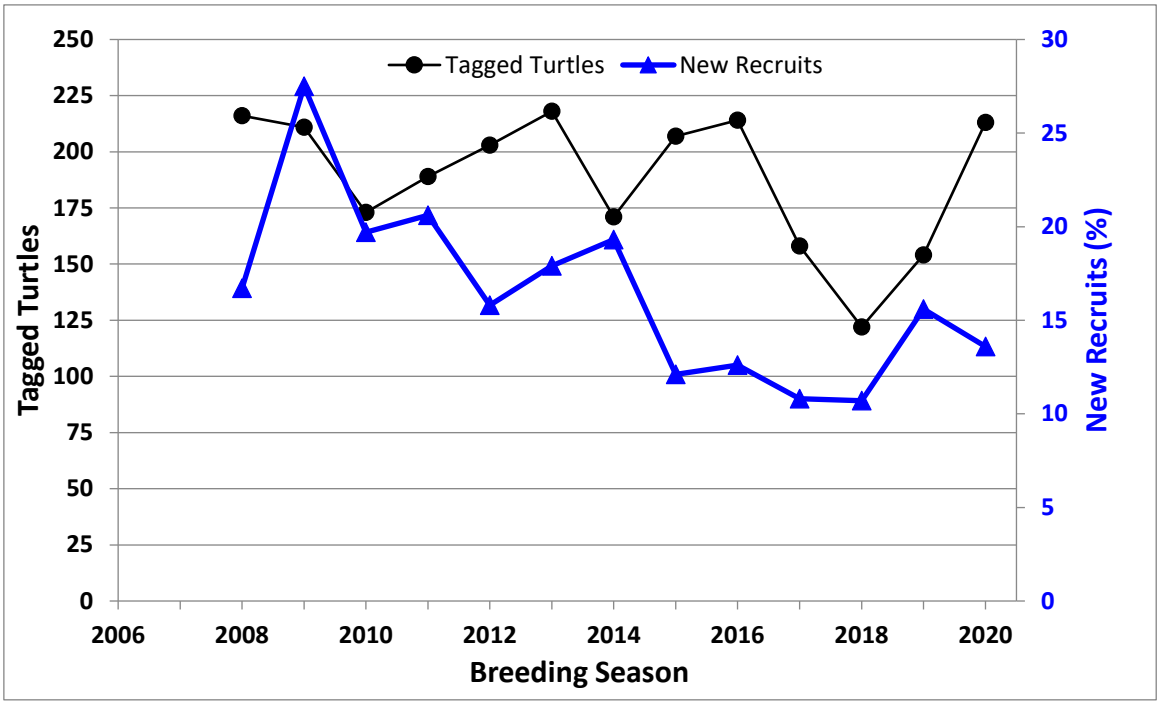


Figure 4.5. Census of Flatback turtle, *Natator depressus*, nesting activity at Peak Island during the mid-season census population from 2008-2021 including; the number of tagged turtles and the proportion of new recruits into the annual breeding population.

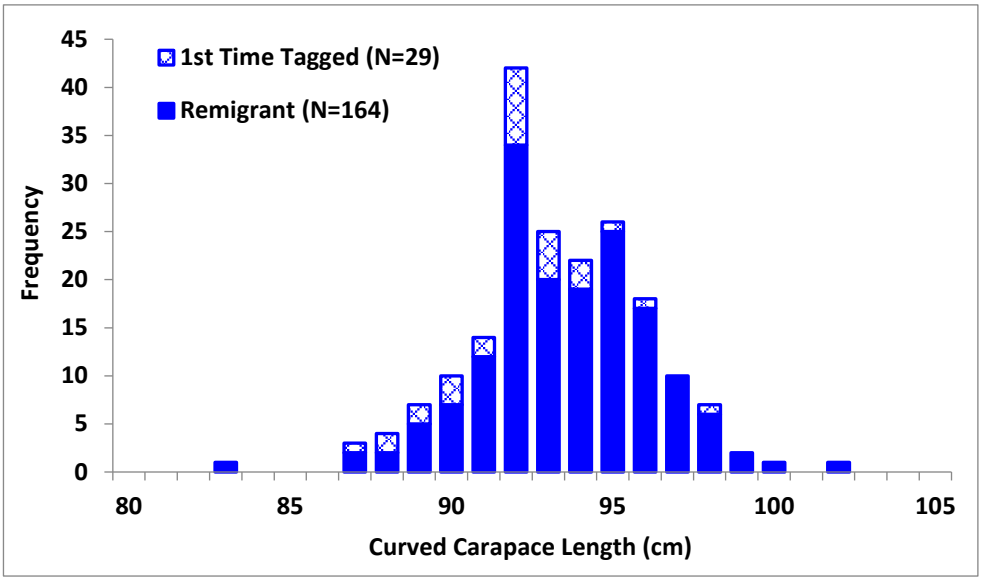


Figure 4.6. Frequency distribution of curved carapace length by breeding experience of Flatback turtles, *Natator depressus*, recorded nesting at Peak Island during the 24 November – 7 December 2020.

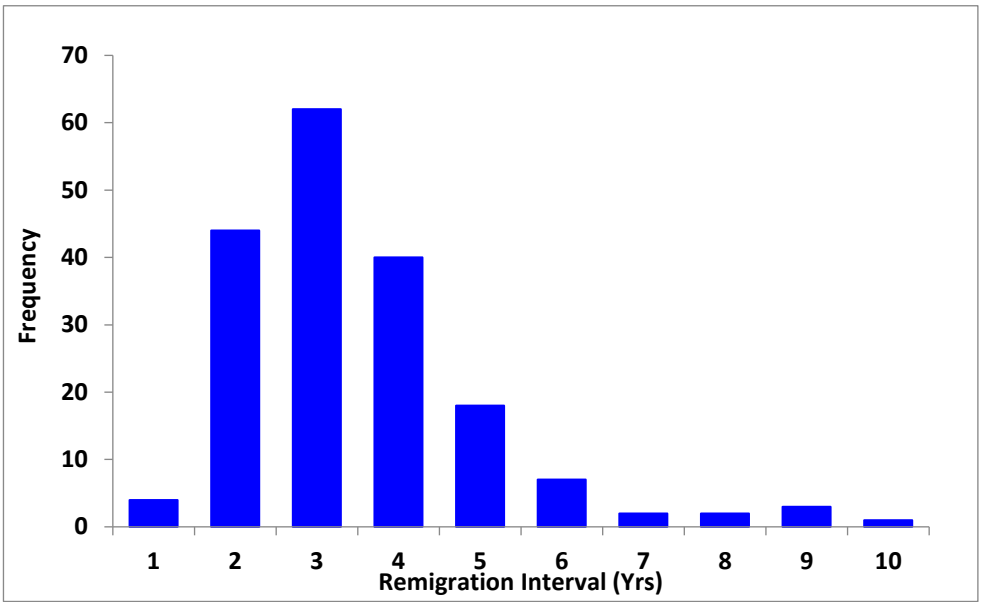


Figure 4.7. Frequency distribution of observed remigation intervals (N = 183) of Flatback turtles, *Natator depressus*, recorded nesting at Peak Island during the 2020-2021 breeding season.

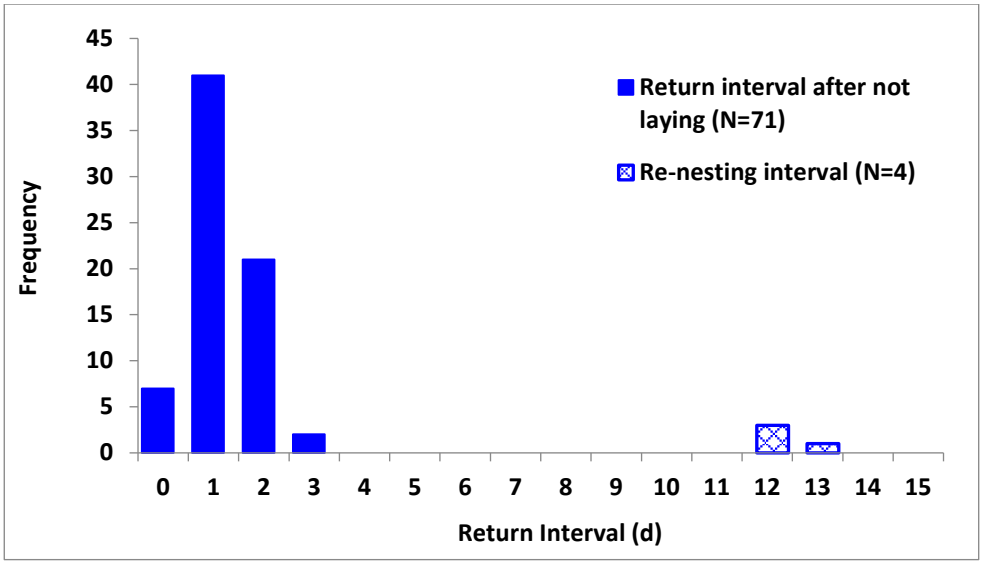


Figure 4.8. Return intervals recorded for nesting Flatback turtle, *Natator depressus,* following both successful and unsuccessful nesting attempts at Peak Island during the 2020-2021 breeding season.

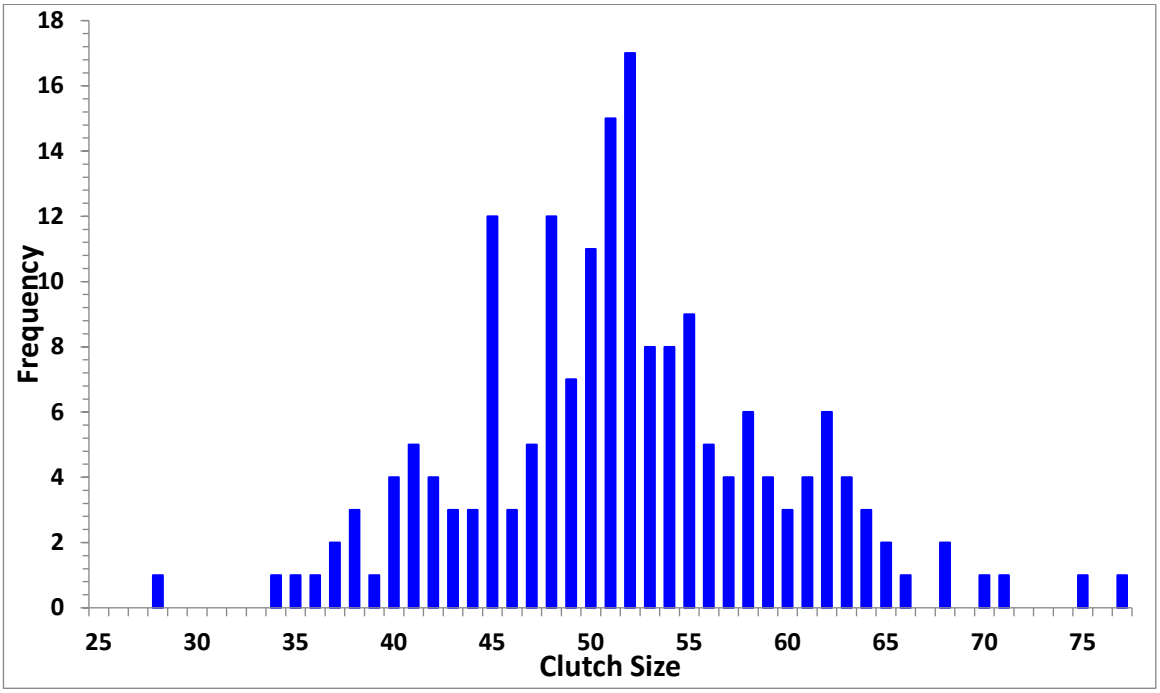


Figure 4.9. Frequency distribution of the number of eggs per clutch of Flatback turtles, *Natator depressus*, recorded nesting at Peak Island during the mid-season census period, 24 November – 7 December 2020.

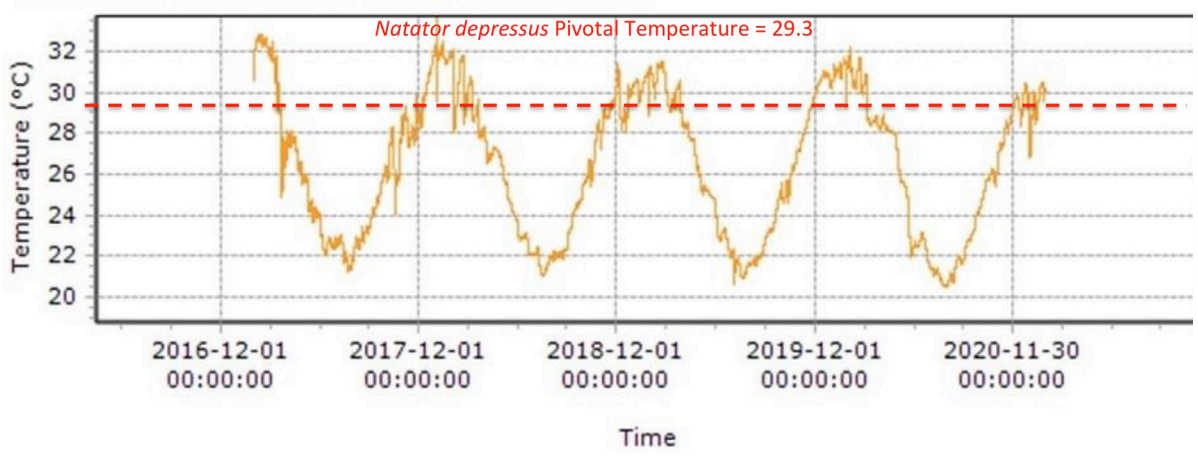


Figure 4.10. Sand temperatures measured at 50 cm depth within the turtle nesting habitat (dune at post 10) in open sun using Vemco Minilog II temperature data logger at Peak Island from 1 February 2017 - 7 December 2020.

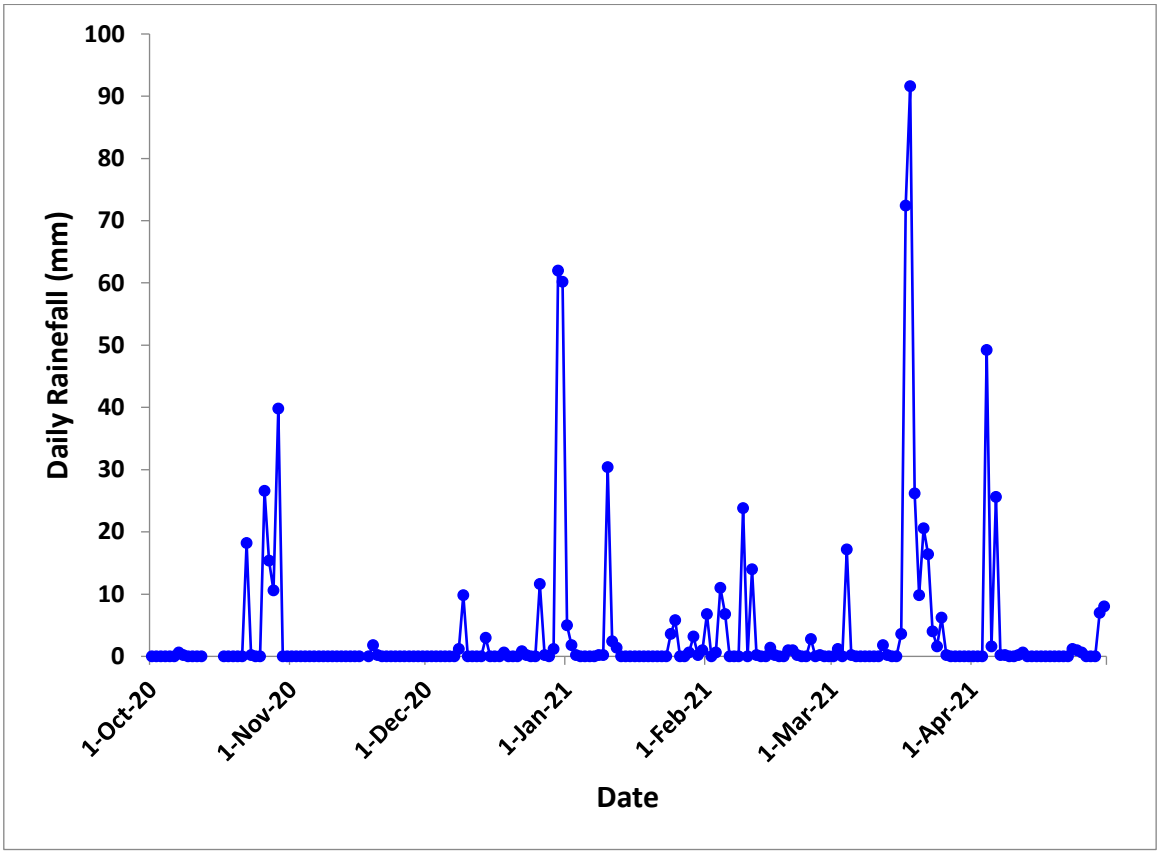


Figure 4.11. Daily rainfall, 1 October 2020 – 30 April 2021, recorded at Yeppoon the Esplanade; Australian Bureau of Meteorology station number 33294, 23.14°S, 150.75°E.

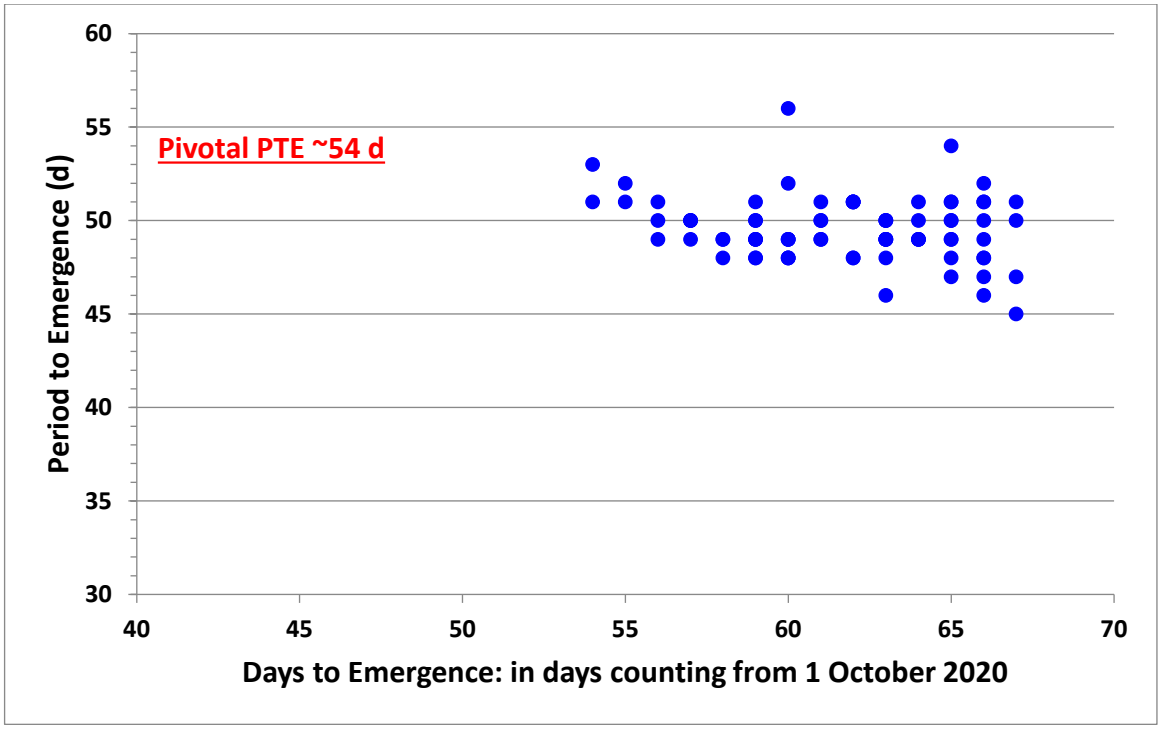


Figure 4.12. Seasonal variation in period to emergence (period from laying to hatchling emergence to the beach surface, n = 79) for Flatback, *Natator depressus,* clutches laid on Peak Island, 2020-2021 season. Pivotal PTE of ~54 days indicates clutches emerging in fewer days produce a greater proportion of females and vice versa

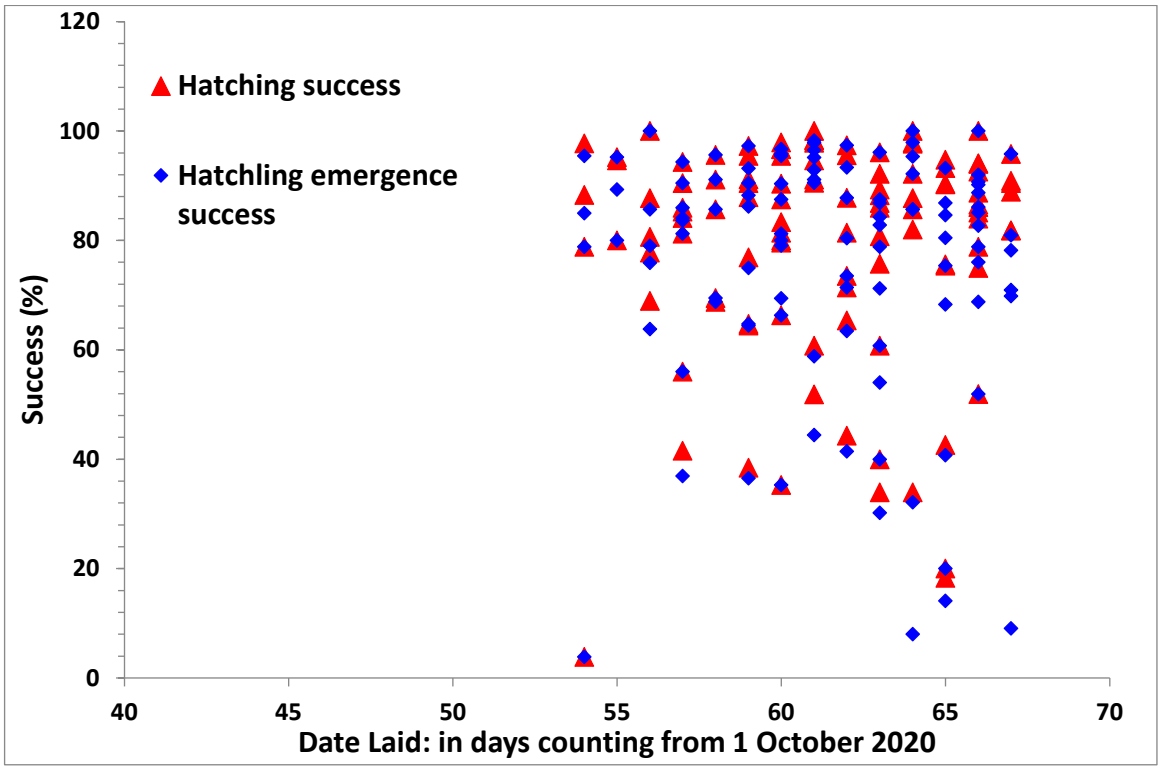
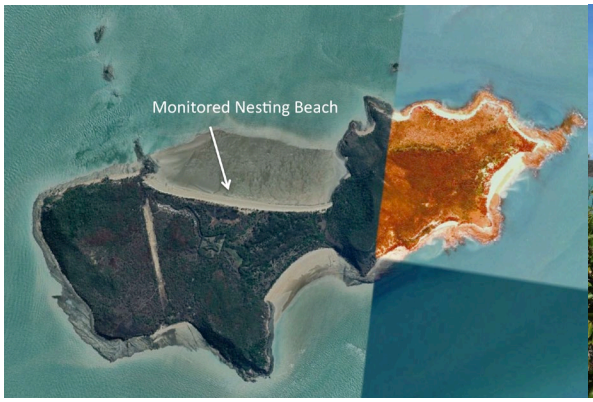


Figure 4.13. Incubation and emergence success for Flatback turtle, *Natator depressus*, clutches (n = 77) recorded when laid on Peak Island during the mid-season census period, 24 November - 7 December 2020.

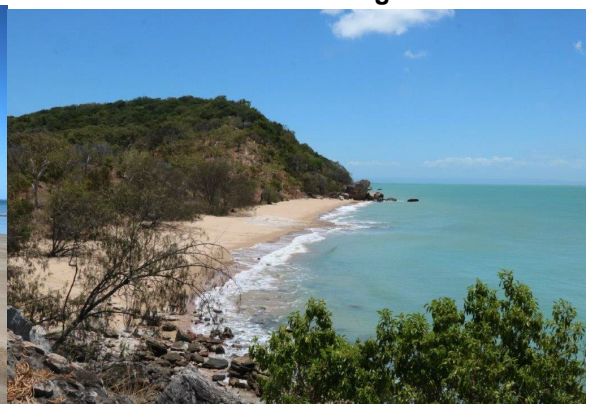
Wild Duck Island Figures



a. Wild Duck Island (Goggle Earth image)

b. North Beach- main nesting beach

c. South Beach



d. West Beach

e. Camp

f. Measuring eggs

Figure 5.1. Images of Wild Duck Island, including work done in the 2020-2021 turtle breeding season.

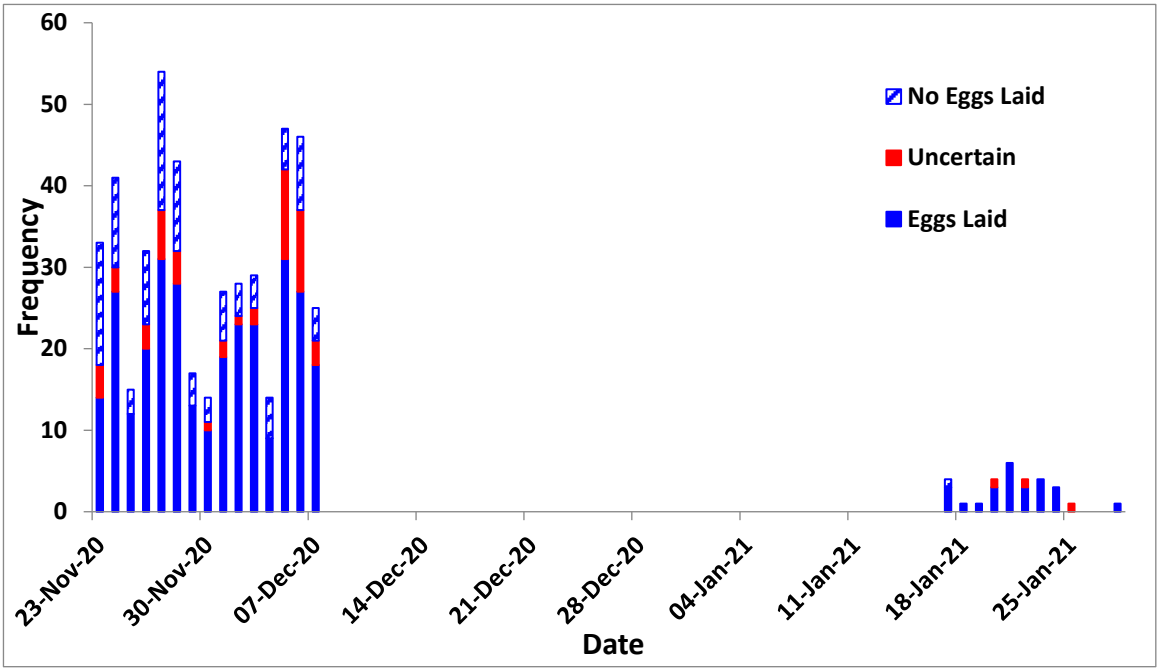


Figure 5.2. Nightly number of Flatback turtles, *Natator depressus*, ashore for nesting on Peak Island during the 2020-2021 nesting season. Census period was 24 November – 7 December 2020, additional data were collected from 17-28 January 2021.

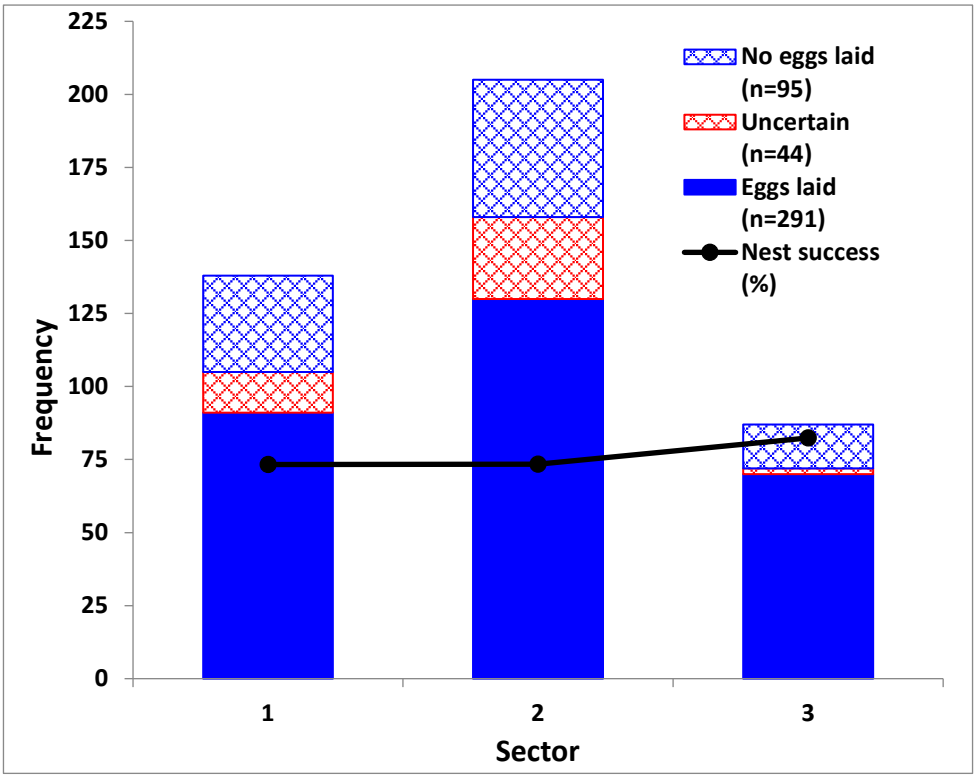


Figure 5.3 Frequency distribution of Flatback turtle, *Natator depressus,* nesting activity and nesting success (not considering uncertain events) by beach sectors, Wild Duck Island during 24 November – 7 December 2021.

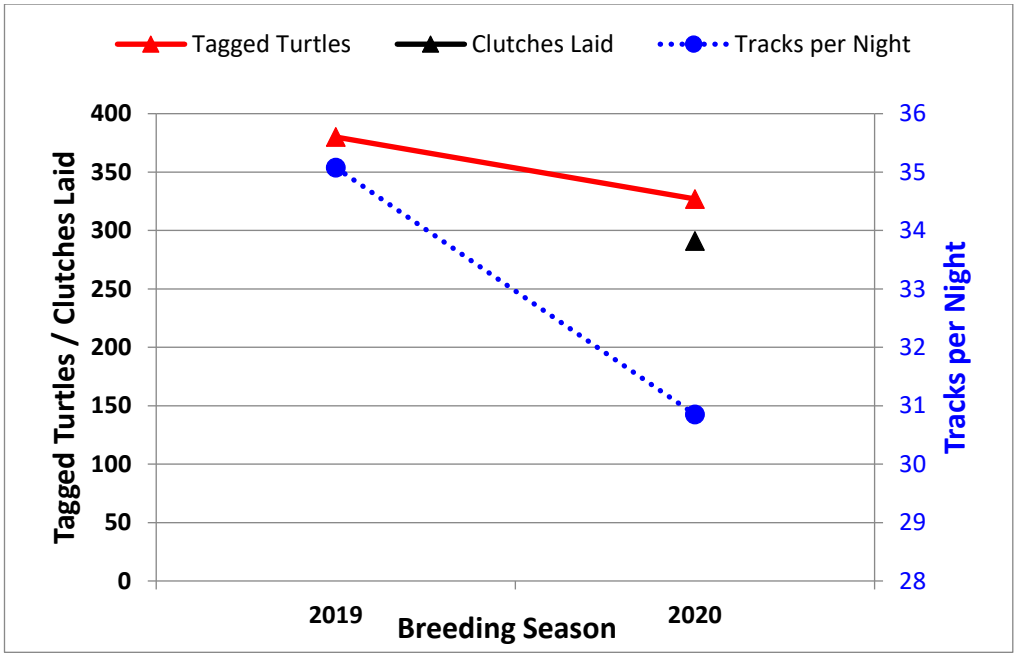


Figure 5.4. Comparison of total number of tracks, tagged females, total clutches laid and mean track count, mean number of turtles and mean number of clutches per night during the standard mid-season nesting census across breeding seasons at Wild Duck Island.

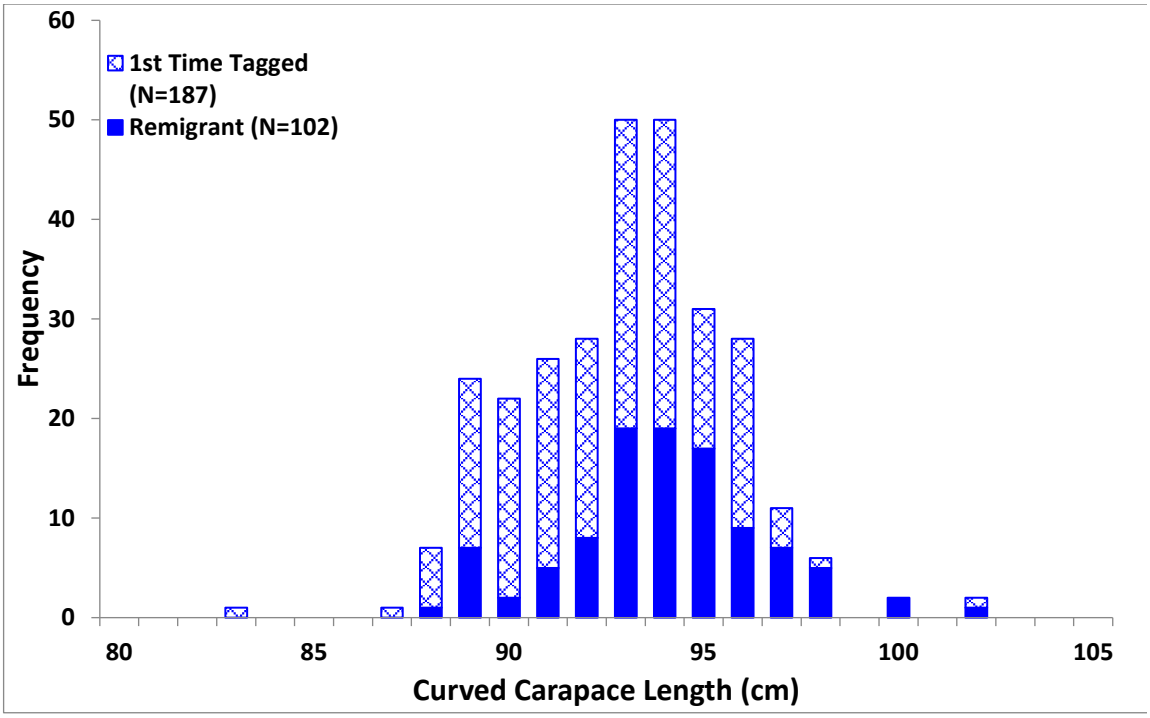


Figure 5.5. Size frequency distribution of nesting Flatback turtles, *Natator depressus*, at Wild Duck Island during the 2020-2021 breeding season.

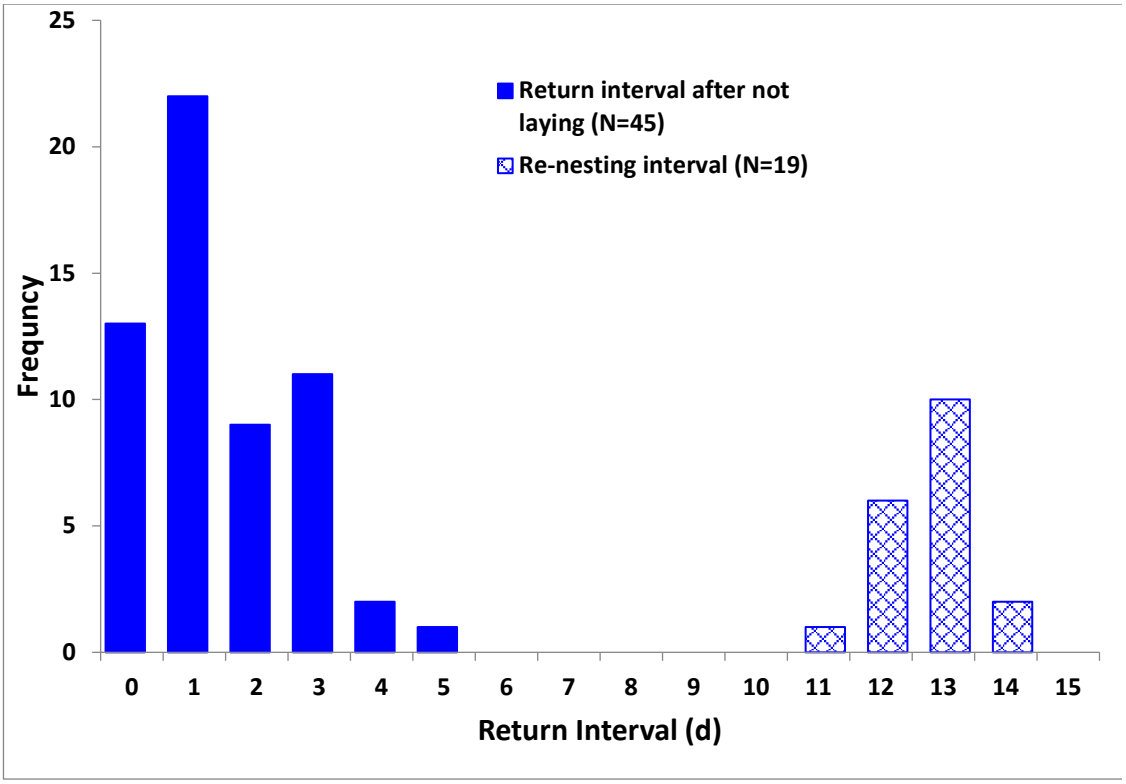


Figure 5.6. Number of days to attempted nesting following an unsuccessful emergence or after a successful nesting of Flatback turtles nesting at Wild Duck Island in the 2020-2021 breeding season.

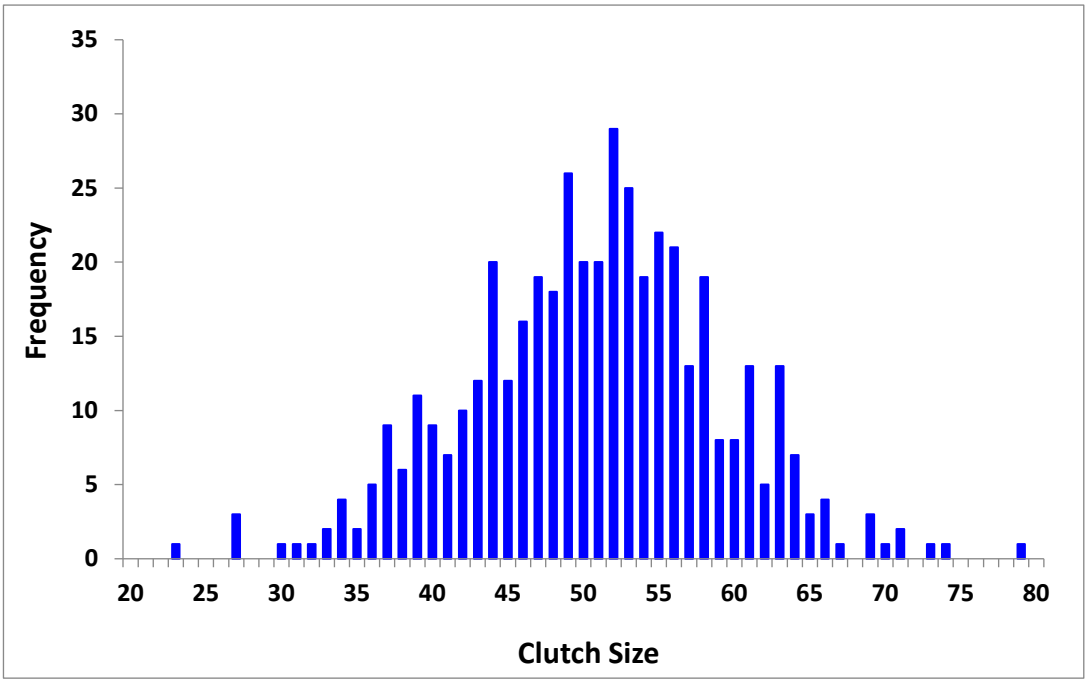


Figure 5.7. Frequency distribution of the number of eggs per clutch of Flatback turtles, *Natator depressus*, recorded nesting at Wild Duck Island during the mid-season census period, 24 November – 7 December 2020.

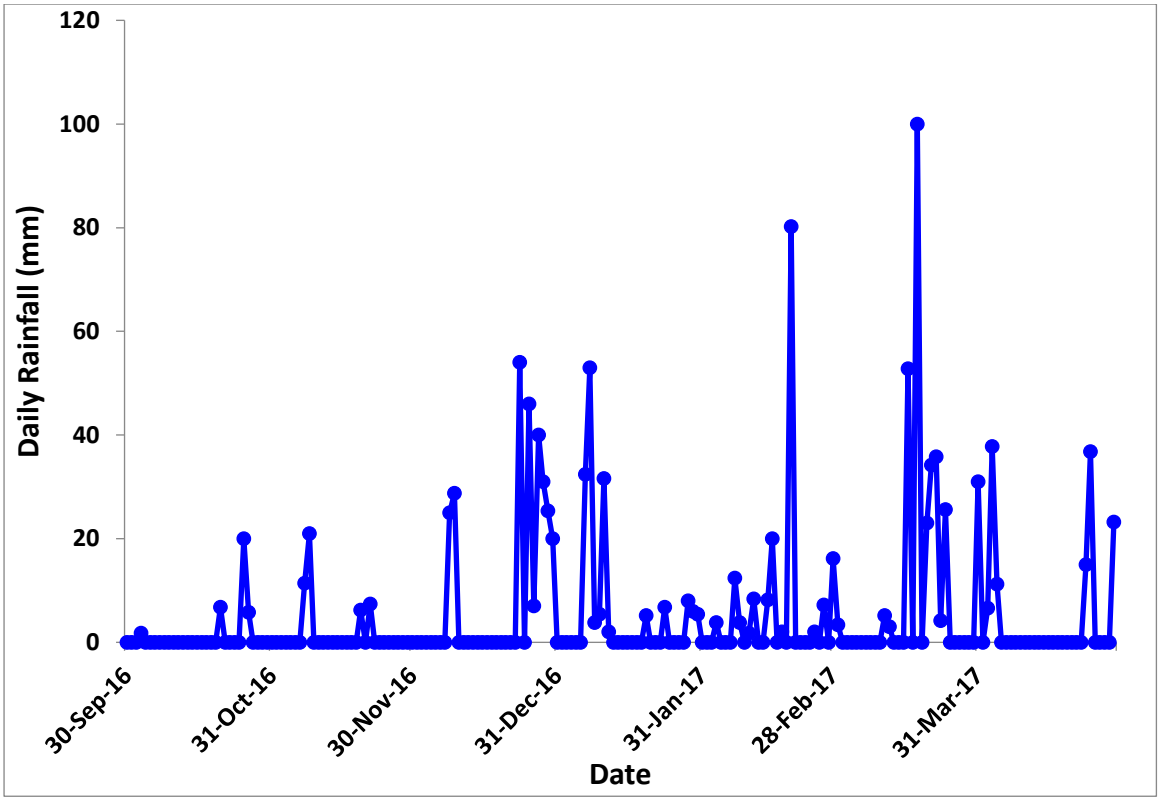


Figure 5.8. Daily rainfall, 1 October – 30 April 2021, recorded at Carmila Beach Road (Bureau of Meteorology station number 033186; 21.92°S, 49.44°E) during the 2020-2021 Flatback turtle, *Natator depressus*, breeding season.

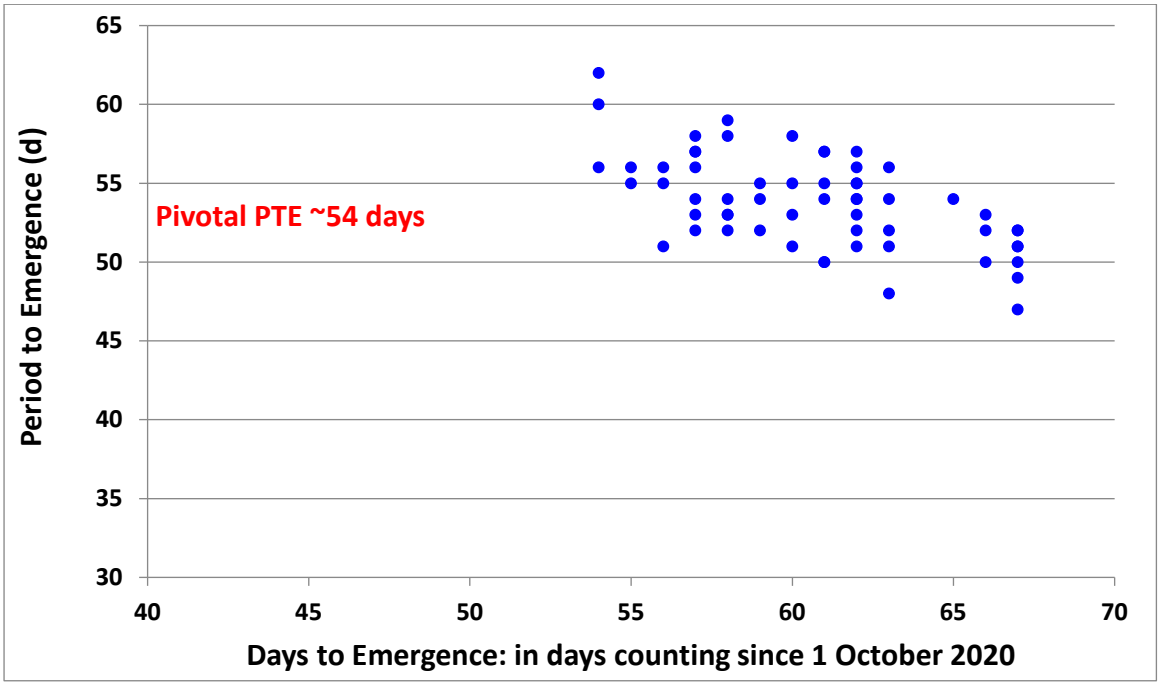


Figure 5.9. Seasonal variation in period to emergence (period from laying to hatchling emergence to the beach surface, n = 59) for Flatback, *Natator depressus,* clutches laid on Wild Duck Island, 2020-2021 season. Pivotal PTE of ~54 days indicates clutches emerging in fewer days produce a greater proportion of females and vice versa