Data Report for Marine Turtles on the Woongarra Coast

2024-2025 Breeding Season

Queensland Turtle Conservation Project

DELIVERING FOR QUEENSLAND

Queensland Government

Prepared by: Aquatic Research and Monitoring,
Threatened Species Operations
Department of the Environment, Tourism
Science and Innovation.

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Cover Image: Loggerhead turtle *Caretta caretta,* nesting at Mon Repos – Kyle Debets

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Citation

Debets,K., Latter, M., McNeil, M., Prince, L., Anderson, D., McLaren, Gatley, C., and Finlayson, K. (2025) Queensland Turtle Conservation Project: data report for marine turtles on the Woongarra Coast, 2024-2025 breeding season. Brisbane: Department of the Environment, Tourism, Science & Innovation, Queensland Government.

Acknowledgements

Queensland Parks and Wildlife, Threatened Species Operations recognizes that its success is made possible by the unwavering dedication of Volunteers, Citizen Scientists, and First Nations People. Their time, commitment, and hard work have been invaluable in supporting the program's efforts for more than 50 years.

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Executive Summary

During the 2024–2025 turtle nesting season, a total of 541 individual marine turtles from three species were recorded nesting along the Woongarra Coast. This included 525 loggerhead turtles (*Caretta caretta*), 13 flatback turtles (*Natator depressus*), and 3 green turtles (*Chelonia mydas*), marking the second-largest nesting season since monitoring began in 1968.

Loggerhead Turtle Nesting Characteristics

- Nesting loggerhead turtles displayed a mean curved carapace length (CCL) of 95.46 cm, consistent with the eastern Australian population from previous years.
- On average, females laid 3.87 clutches, with 121.82 eggs per clutch. Clutch size and frequency tended to increase with the age of nesting females, while the interval between breeding seasons decreased as reproductive age advanced.
- Loggerhead turtles exhibited strong site fidelity to Mon Repos Beach, with 83.3% of nesting females exclusively nesting there. Other beaches demonstrated lower site fidelity, likely due to the impacts of artificial lighting and coastal development. Mon Repos remains the primary nesting site for loggerhead turtles on the Woongarra Coast.

Conservation Efforts

In the largest relocation effort to date, 1,076 at-risk clutches were moved to elevated incubation sites to reduce losses from erosion and flooding, or to darker beaches to lower the risk of hatchlings being disoriented by coastal lighting. These efforts were critical in mitigating environmental and anthropogenic threats to nesting success.

Concerns for Loggerhead Nesting Population Trends

Recruitment of new adult females into the nesting population has declined by approximately 50% over the past two decades, with the annual recruitment rate for the 2024–2025 season recorded at 27.4% ± 3.8%. This trend raises concerns about the long-term sustainability of the population.

Incubation and Hatchling Emergence Success

- The mean period to emergence for loggerhead turtle clutches incubated in natural dune habitats was 54.85 days, indicating a strong female-biased sex ratio due to sand temperatures exceeding the pivotal incubation temperature of 28.6°C for most of the season.
- Artificial light pollution (e.g., skyglow) remains a significant threat to hatchling orientation and ocean-finding behaviour along the Woongarra Coast.

- Of the 1,945 loggerhead clutches recorded, 1,553 clutches (79.84%) were assessed for hatchling emergence success.
- Hatchling emergence success from clutches incubating naturally in vegetated dune habitats at key nesting beaches was below 80% (e.g., Mon Repos: 79.40%). This reduced success was likely due to elevated sand temperatures exceeding 31°C during late January 2025.
- Relocated clutches showed improved hatchling emergence success, with 81.44% success at Mon Repos, highlighting the effectiveness of conservation interventions.

Conclusion

The 2024–2025 nesting season demonstrates both the success of long-term conservation efforts and the challenges facing loggerhead turtle populations. While the season recorded a high number of nesting individuals, concerns remain regarding declining recruitment, the impacts of elevated sand temperatures, and threats from artificial light pollution. Continued monitoring, habitat restoration, and targeted conservation actions are essential to ensure the long-term sustainability of loggerhead turtles on the Woongarra Coast.

1. Introduction

This report addresses the results of the 57th summer of annual study of marine turtle breeding on the Woongarra Coast. The Woongarra Coast is a primary index site for monitoring and researching the loggerhead turtle, *Caretta caretta*, within the South West (SW) Pacific genetic stock and a secondary index site for nesting flatback turtles, *Natator depressus*, within the eAust genetic stock (Department of Environment and Science, 2021). Systematic monitoring of these turtles commenced in 1968.

The loggerhead turtle is listed as *endangered* under both Queensland and Commonwealth conservation legislation while the flatback turtle is listed as *vulnerable.* International Union for Conservation of Nature (IUCN) lists the loggerhead turtle population of the South Pacific as critically endangered and the flatback turtle as data deficient. While the studies commenced with an emphasis on defining the biology of the flatback turtle (Bustard and Limpus, 1969), loggerhead turtles dominate the current conservation considerations for marine turtles on the Woongarra Coast.

Loggerhead turtle breeding within the South Pacific Ocean forms an independent genetic stock that does not interbreed with other loggerhead turtles elsewhere within the Pacific or Indian Oceans (FitzSimmons and Limpus, 2014. Figure 1). Loggerhead turtle breeding within the South Pacific Ocean is restricted to eastern Australia and New Caledonia, with most of the nesting occurring in eastern Australia.

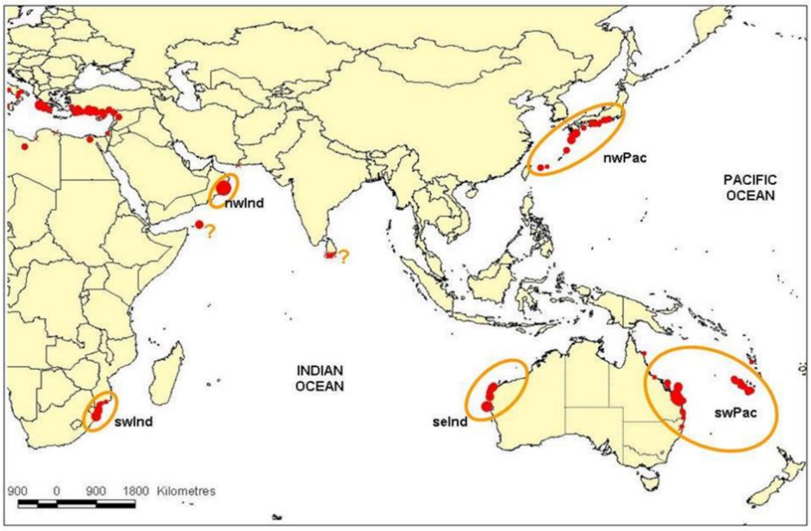


Figure 1. Genetic stocks (management units) of loggerhead turtles, *Caretta caretta*, within the Pacific and Indian Oceans (FitzSimmons and Limpus, 2014).

There are five significant concentrations of loggerhead turtle breeding in eastern Australia (Figure 2; Limpus *et al*. 2013): Woongarra Coast and Wreck Rock Beaches on the mainland and Wreck, Tryon, and Erskine Islands within the Capricornia region of the southern Great Barrier Reef (GBR). The Woongarra Coast is estimated to currently support approximately 50% of annual loggerhead turtle breeding in eastern Australia (Limpus *et al*., 2013).

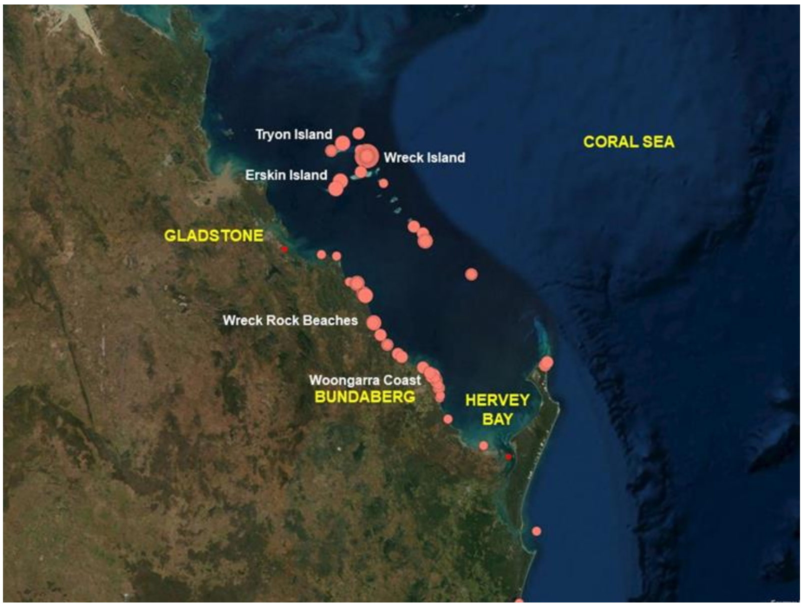


Figure 2. Nesting distribution of loggerhead turtles, *Caretta caretta*, in central-south Queensland with the five principal nesting sites identified (TurtleNet, 23 Oct 25).

The functioning of loggerhead turtle nesting in eastern Australia needs to be understood within the context of the complex life history that takes this population into diverse habitats throughout the South Pacific region and the associated diversity of threats to which it is exposed (CMS, 2014; Figure 3). While breeding success at the nesting beaches contributes to the functioning of the next generation that will return to breed in about 30 years' time, good population functioning within each life history phase is required for this genetic stock of loggerhead turtles to survive. At each of these key life history phases loggerhead turtles may be exposed to diverse anthropogenic threats, including ingestion of floating plastic debris, fishery bycatch (longline, gillnet, crabbing and trawling), boat strike and declines in quality of foraging habitat in response to extreme weather events.

In response to the diverse threats to the loggerhead turtle, spanning multiple national jurisdictions across the entire South Pacific, the United Nations Environment Programme (UNEP) Convention for Conservation of Migratory Species (CMS) approved in 2014, the *Single Species Action Plan for the Loggerhead Turtle (Caretta caretta) in the South Pacific Ocean* (UNEP/CMS/Resolution 11.21; UNEP/CMS/COP11/Doc 23.2.2/Rev.1/Annex 2) (CMS, 2014). As a signatory state to CMS, the Australian Government is expected to implement this Action Plan. This report summarises part of the Queensland Government's contribution to implementation of the Single Species Action Plan for the Loggerhead Turtle in the South Pacific Ocean.

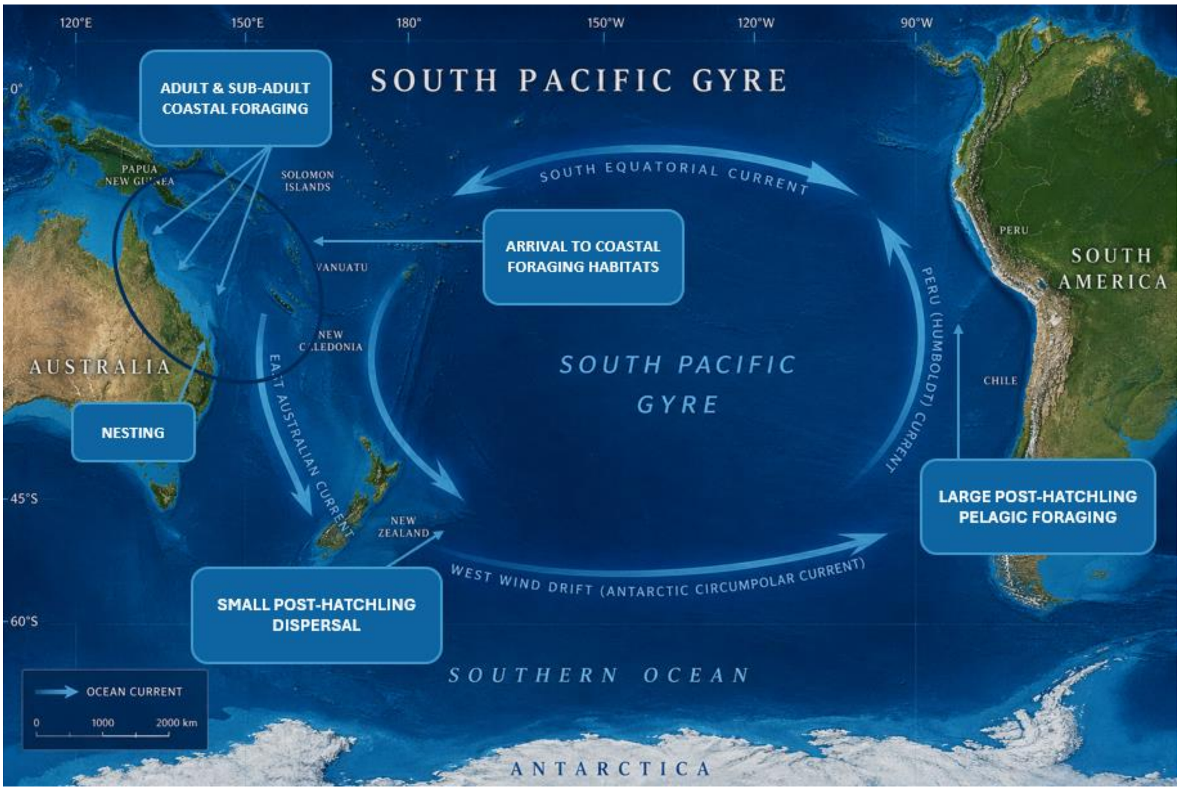


Figure 1. Summary of the life history dispersal of the SW Pacific genetic stock of loggerhead turtles. Generated using historic CMS (2014) resources.

2. Study Area and Methods

The Woongarra Coast supports nine small crescent sand beaches in an otherwise 22 km of rocky coastline between the Burnett and Elliott Rivers in the Bundaberg Region South Queensland (Figure 4). The intertidal areas of these beaches and the majority of the adjacent sub-tidal waters are within the Great Sandy Marine Park. The longest of these beaches is Mon Repos Beach (1.6 km) where the nesting habitat occurs mostly within the Mon Repos Conservation Park that is managed by Queensland Parks and Wildlife Service (QPWS) within the Queensland Department of the Environment, Tourism, Science and Innovation (DETSI). The remaining beaches are principally within esplanades managed by the Bundaberg Regional Council, except for Kellys Beach where the nesting habitat extends into the seaward margin of privately owned properties.

Standard methodologies of the DETSI Queensland Turtle Conservation Project (QTCP) within Threatened Species Operations (TSO) (Limpus *et al*., 1983; Limpus, 1985; Limpus *et al.* 2023) were followed for this project that monitored nesting females and their clutches. Proportional data were presented as the value ±95% confidence interval. Monitoring teams consisted of QPWS staff and QTCP volunteers who were trained in the methods. DETSI TSO extends its gratitude to the dedicated local volunteers, managed by the Burnett Mary Regional Group (BMRG), for their tireless efforts in patrolling beaches outside Mon Repos Conservation Park and contributing to the collection of project data from Burnett Heads, Bargara, and Elliott Heads beaches.

Figure 2. Map of the locations of the marine turtle nesting beaches on the Woongarra Coast.

The Queensland Marine Turtle Strategy 2021-2031 (Department of Environment and Science, 2021) sets a management goal to "Maintain, adapt and strengthen existing direct management efforts at key individual nesting beaches and foraging grounds for each genetic stock to implement management practices that promote:

- Nesting success > 80%
- successful hatching of at least ≥ 70% of clutches laid (including rescuing doomed eggs where feasible); and
- mean hatchling emergence success in excess of ≥ 80% from clutches producing hatchlings.
- the production of male hatchlings to achieve ecologically appropriate sex ratios

Data management

DETSI TSO maintains the QTCP database which collates data on marine turtle tagging and sightings from nesting beaches, foraging grounds, and stranded turtles. The data is coded into a relational database to facilitate statistical analysis. The data is routinely analysed to investigate:

- distribution and abundance of nesting by beaches
- trends in size of nesting populations and other demographic parameters
- description of population characteristics by study year
- threatening processes.

Nesting activity

Nesting activity was recorded at all nesting beaches along the Woongarra Coast during the entire breeding season from early October 2024 to May 2025. Monitoring of nesting occurred nightly and additionally during the cooler hours of the day. The assessment of incubation success was conducted between late January and May. Procedures included:

- Flipper tagging following the standard methods reported by Limpus (1992). Adult turtles left the beach with a minimum of two titanium tags manufactured by Stockbrands Australia in the front left and right flippers, generally proximal to the flipper scute closest to the body. If scar tissue from previous tagging made this position unsuitable, tags were applied distally to this scute or on hind flippers.
- Flipper tagging using monel tags for this nesting population commenced in 1968, but these tags only lasted a few years before they were lost to corrosion. The introduction of double tagging with titanium tags in 1981 has enabled long term recognition of the individual nesting turtles (Limpus, 1992). Past studies have established that since 1982, any turtle nesting on the Woongarra Coast that is untagged and shows no visible scarring from losing previously applied tags, has a 98% probability of being a first-time breeding turtle. This has enabled the assignment a year for commencement of breeding to these first-time tagged females with a high level of confidence.
- Passive Integrated Transponder (PIT) tags manufactured by Animal Electronic I.D. Systems were injected into the upper left (or occasionally right) shoulder (just below the carapace) of nesting flatbacks, greens and a limited number of high priority loggerhead turtles.
- 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 *Chelonibia* 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 when feasible.
- 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.
- A subset of clutches was counted, and ten 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).
- When clutches were counted, nest depths from the beach surface to the top of the eggs and to the bottom of the nest were measured with fibreglass flexible tape measures (± 1 cm).
- Nest locations were recorded by triangulation measurements from pairs of numbered posts along the crest of the upper dune and extending for the full length of Mon Repos Beach, Oaks Beach, and Archies Beach. No surface markers were placed on individual nests.

Rescuing of doomed eggs

Since the late 1980s, it has been standard management for the majority of clutches of eggs that are laid below or close to the high tide level on the Woongarra Coast to be relocated to more secure incubation sites higher up the dunes. This relocation was completed within two hours of the eggs being laid and with the minimum of rotation of the eggs (Limpus *et al*. 1979; Pfaller *et al* 2008). The relocation of clutches was primarily managed by DETSI staff and trained volunteers.

Because of the high risk of hatchlings heading inland from Nielson Park, Bargara and Kellys Beaches, the majority of clutches of eggs laid on these beaches were relocated to a darker beach, either Mon Repos or Archies Beaches, on the night that they were laid or approximately three weeks later.

Shaded cages and hatcheries

QPWS maintains four standard shaded, predator-proof cages (Figure 5A) and two shaded, open-sided hatcheries (Figure 5B) on Mon Repos Beach, to provide some clutches with a cooler incubation environment. The shading on the cages and hatcheries was provided by 70% shade cloth. The predator-proof cages were enclosed in aluminium mesh with 70 mm diameter mesh size allowing self-release of hatchlings emerging from the enclosed nests.

Additional shaded predator-proof cages have been installed at Archies Beach, Elliott Heads Beach, Moore Park Beach and at Wreck Rock with the assistance of the Bundaberg Regional Council, Sea Turtle Alliance and Gidarjil Land and Sea Rangers to provide increased protection of eggs from potential fox, dog and varanid depredation.

Location of incubation cages and hatcheries at Mon Repos Beach, 2024-2025 breeding season:

- Cage 1: Sector 1, top of 2nd dune, shaded by *Casuarina* from approximately midday onward.
- Cage 2: Sector 8, 1st dune, shaded by *Casuarina* from approximately 2:00 pm onward.
- Cage 3: Sector 10, 1st dune, not shaded by the forest until after approximately 5:00 pm.
- Cage 4: Sector 14, 2nd dune, shaded by *Pandanus sp* after approximately 2:00 pm (cage location changed from 14B in 2023).
- Hatchery 1: Sector 9C, 1st dune, receives shade from the forest after approximately 4:30 pm.
- Hatchery 2: Sector 13C, 1st dune, receives shade from *Casuarina* after 3:30 pm (Wood *et al*. 2014).

Clutches were relocated and buried at 60 cm spacing and at a depth to the bottom of the artificial nest of 60 cm into the cages and hatcheries from different distances along Mon Repos Beach. Ropes with knots at 60 cm spacing were placed across the ground within each cage and hatchery to guide the positioning of the relocated clutches. A nest tape with tag number and date laid was placed within each clutch of eggs with a second one tied to the knot on the rope above.

The cages on Mon Repos Beach have space for approximately 30 relocated clutches while each hatchery can accommodate up to 100 clutches at a time.

Figure 5A. Relocation cage (RC3), sector 10A, dune crest.

Figure 5B. Open hatchery (RH1), North Beach, sector 9C.

Figure 3. Shaded incubation structures on Mon Repos Beach.

Hatching success and hatchling emergence success

Nests were excavated for assessing incubation success and hatchling emergence success after hatchlings had emerged to the beach surface. Previously marked nests were relocated using triangulation measurements from marker posts and confirmed by the presence of nest tags. Nests were excavated no sooner than 24 hours after hatchling emergence or at 9 weeks if hatchlings had not emerged. Procedures included:

- Where logistically feasible, 10 hatchlings from all flatbacks, greens and high priority loggerheads (+ any live-in-nest) were weighed (± 0.1 g), measured (± 0.1 mm) with vernier callipers and the scale pattern counted and photographed.
- Observations of heat stress were noted that included:
  - dead hatchlings that had emerged but died in the vicinity of the nest, with no signs of predation.
  - dead hatchlings in the neck of the nest that were not otherwise trapped by roots from emerging.
  - elevated numbers of dead pipped eggs.
- 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.
- Unhatched eggs were opened to determine the phase to which the embryo had developed or whether it appeared to be undeveloped.
- Hatchling incubation success was calculated as: (hatched eggs/estimated clutch count) x 100%.

- Emergence success was calculated as:

(hatched eggs – [live + dead 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.

Hatchling sex ratio theory

The sex of marine turtle hatchlings is determined by the temperature of the nest presumably within the middle third of incubation (Reed, 1980; Yntema and Mrovosky, 1980, 1982). The pivotal temperature (the theoretical temperature that will result in equal proportions of male and female hatchlings) for the SW Pacific loggerhead turtle population has been quantified at 28.6°C (Limpus *et al*. 1985), with higher temperatures producing predominantly females and lower temperatures producing predominantly males. If loggerhead eggs incubate at a constant temperature of 28.6°C:

- Hatching should occur approximately 58 days after the eggs were laid (Limpus *et al*. 1985).
- Allowing for 2-3 days for the hatchlings to dig to the beach surface for emergence, the incubation period from laying to hatchling emergence to the beach surface should be approximately 60-61 days.

Thus, incubation duration can be informative regarding the sex ratio of hatchlings. However, heavy rainfall during the mid incubation period will also influence the sex ratio (Reed, 1980), as cool rain results in a decline in sand temperatures with a corresponding potential to produce more male hatchlings. In contrast, sand temperatures increase in the short term in the absence of rain and as a result of reduced evaporative cooling within the sand. The warmer sand temperatures during mid incubation can be expected to result in an elevated proportion of female hatchlings.

Extreme weather and environmental monitoring

There is a continuing challenge to assess the environment within which populations of long-lived migratory turtles are functioning in the context of fluctuating annual weather within a trend for global warming.

The BOM annual report for 2024 (5 November 2025, https://www.bom.gov.au/climate/current/annual/aus/#tabs+Key-points) summarised that:

- Australia recorded its second warmest year on record, with the national annual average temperature 1.46 °C warmer than the long-term (1961–1990) average (Figure 6A).
- The national average maximum temperature was 1.48 °C above the long-term average, the fourth warmest on record. The national average minimum temperature was 1.43 °C above the long-term average, and the warmest on record.
- Warmth was persistent throughout the year. Nationally, summer 2023–24 was the third warmest on record, winter was the second warmest on record and spring was the warmest on record.
- Low-to-severe intensity heatwave conditions affected large parts of Australia during early 2024 and from September to December.

- Australia's national, area-averaged rainfall total was 596 mm, 28% above the 1961–1990 average of 466 mm. It was the wettest year since 2011 and Australia's eighth-wettest recorded year.
- Annual sea surface temperatures for the Australian region for 2024 were the warmest on record, and 0.89 °C above the 1961–1990 average. Global sea surface temperatures in 2024 were the warmest on record (Figure 6B).
- Globally, 2024 was the warmest year on record, with the World Meteorological Organization reporting an average global temperature of 1.55 ± 0.13 °C above the pre-industrial (1850–1900) baseline. Global sea surface temperatures were also the warmest on record, and 0.79 °C above the average.
- 21 February 2025 Tropical Cyclone (TC) Alfred, category 4, developed east of Cooktown and progressed slowly southward along the eastern coastline of Queensland making landfall across the Southeast Queensland/New South Wales North coast as a sub-tropical cyclone on 8 March 2025 (Figure 7). This system generated elevated coastal erosion, heavy rainfall, and widespread flooding, which significantly affected marine turtle nesting habitats across the region. Cyclone track data for TC Alfred were sourced from the Australian Bureau of Meteorology (BOM) website (https://www.bom.gov.au/cyclone/history/Alfred2025.shtml).

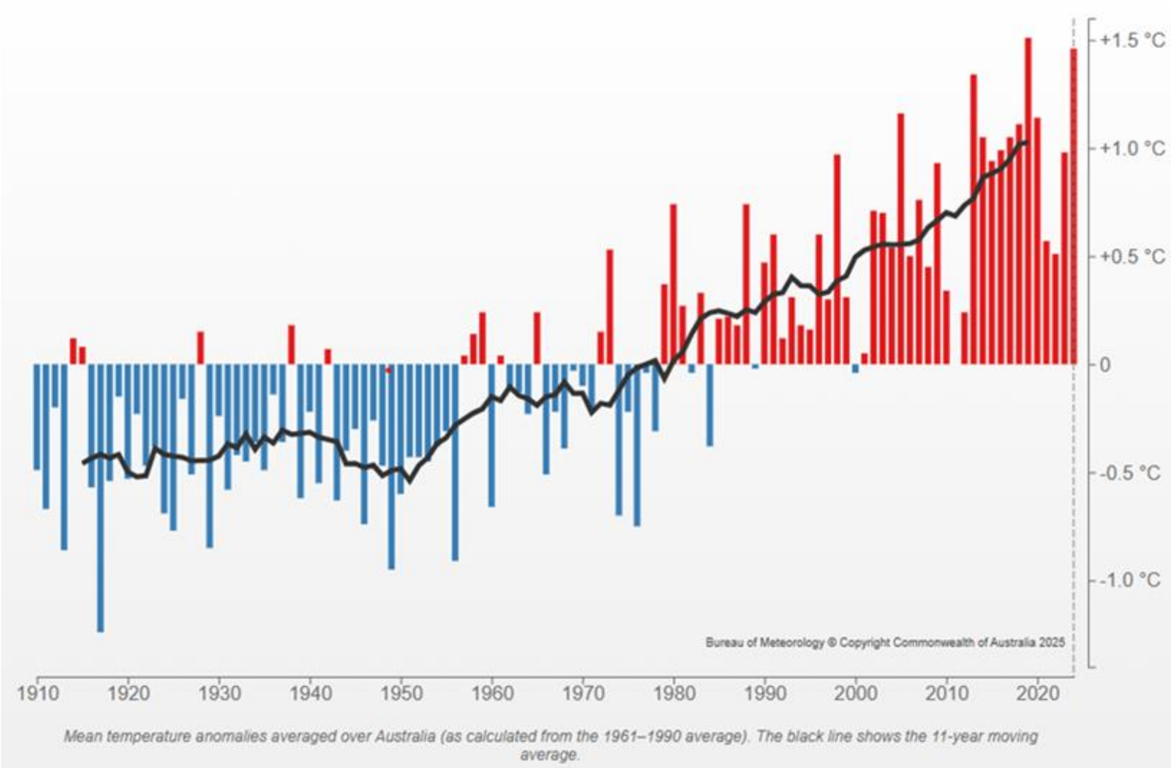
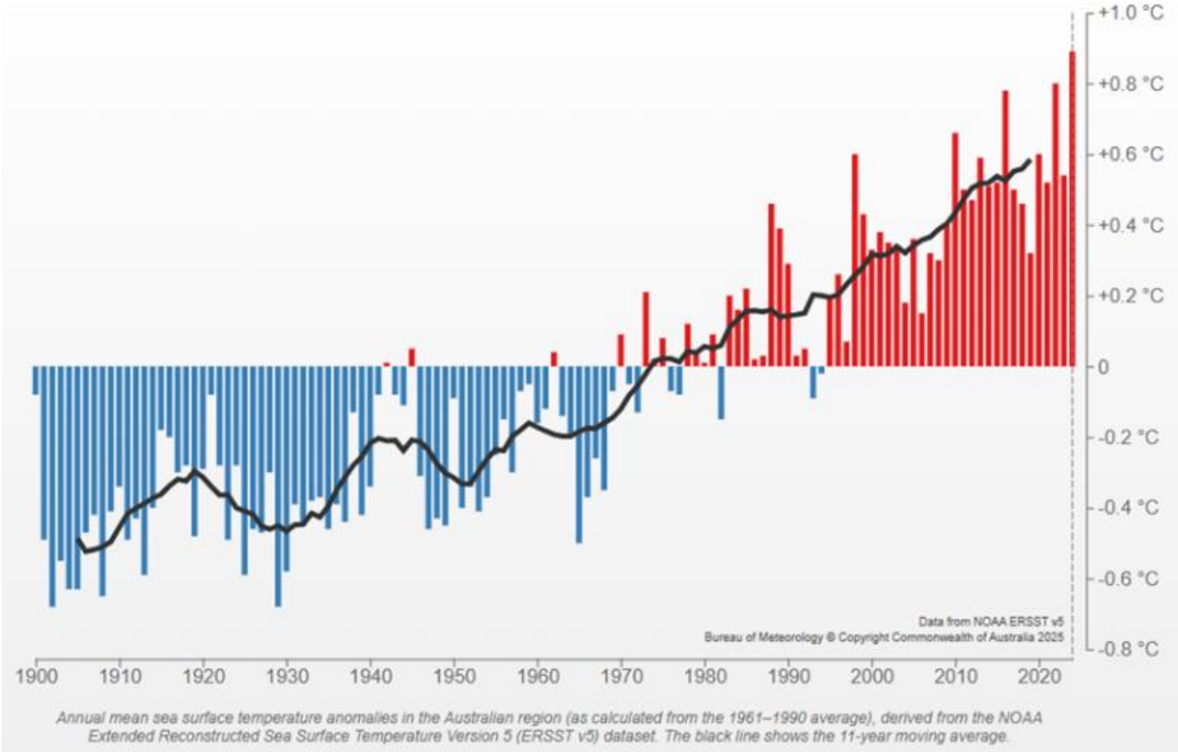


Figure 6A. Bureau of Meteorology (2024) annual mean temperature anomaly data. In 2024, the mean temperature was 1.46°C higher than in the 1961–1990 average and was considered the second warmest year on record since 1910. Accessed 27 October 2025 http://www.bom.gov.au/climate/current/annual/aus/#tabs=Temperature

Figure 6B. Bureau of Meteorology (2024) annual mean sea surface temperature anomaly data. In 2024, the



mean sea surface temperature was 0.89°C higher than in the 1961–1990 average and was considered the warmest on record since. Accessed 27 October 2025 http://www.bom.gov.au/climate/current/annual/aus/#tabs=Oceans-and-atmpsphere&oceans=Oceans.

Figure 6. Bureau of Meteorology (2024) annual means for land and sea surface temperatures

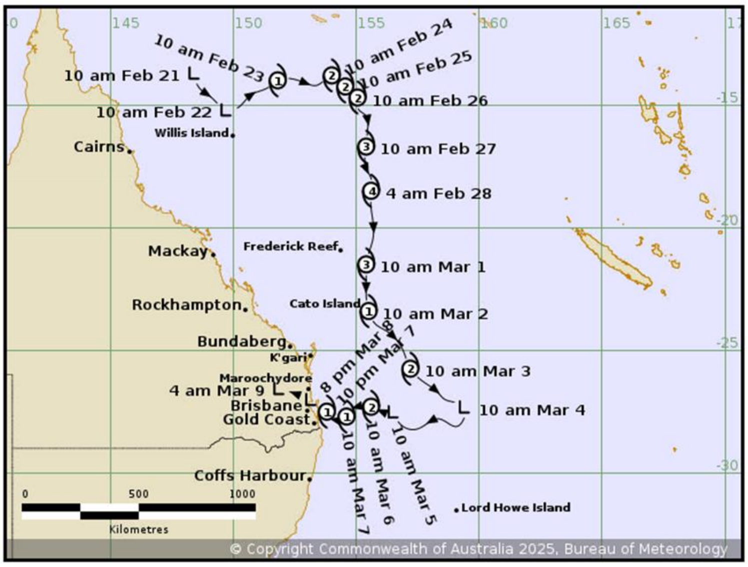


Figure 7. BOM tracks of TC Alfred in the Coral Sea region during the 2024-2025 summer.

Accessed from: https://www.bom.gov.au/cyclone/history/Alfred2025.shtml

The Woongarra Coast lies within the region for Australia in which a rising trend in air temperatures of 0.2-0.3°C per decade has been recorded since 1970 (Figure 8). To record long term sand temperature data at nest depth, Hobo MX2201 and MX2204 WiFi linked temperature data loggers have been deployed at selected sites on Mon Repos Beach commencing during the 2021-2022 breeding season. These data loggers can record temperature data continuously for up to five years and are replaced as required. Sand temperature at 50 cm depth has been recorded at 30-minute intervals within the turtle nesting habitat at standard temperature monitoring locations:

- In front of **sector post 3**, on 1st dune grassy habitat in open sun but exposed to afternoon shade from the forest inland of the turtle nesting habitat from mid-afternoon onward.
- In front of **sector post 6**, on 1st dune bare sand habitat in open sun but exposed to shade from the forest inland of the turtle nesting habitat from approximately midday onwards.
- **Sector 9C**, on the crest of the 2nd dune in open sun and only exposed to shade from the adjacent forest in the late afternoon.
- **Sector 14A**, on 1st dune grassy habitat in open sun but exposed to afternoon shade from the forest inland of the turtle nesting habitat.
- Within the centre of each of the two shaded, open sided hatcheries on Mon Repos Beach.
- Within the centre of each of the four shaded predator-proof incubation cages on Mon Repos Beach.

The recorded sand temperature measurements provide an index of sand temperature at approximately nest depth for loggerhead and flatback turtles in the absence of metabolic heating that commences to increase during the temperature sensitive incubation phase, during mid-incubation, when gender of the embryo is determined (Reed, 1980; Yntema and Mrosovsky, 1982).

Graphical summaries of the sand temperatures at 50 cm depth are presented from temperature data loggers at Mon Repos within:

- natural nesting habitat in sectors 3, 6, 9C, 14A (Figure 9; Figure 10).
- centre of shaded predator-proof cages (RC): RC1, RC2, RC3, RC4 (Figure 9; Figure 10).
- centre of each of two shaded hatcheries (RH): northern RH1 and southern RH2 (Figure 9; Figure 10).

Sand temperature at natural nest depth within the nesting habitat at 3, 6, 9C and 14A were above the pivotal temperature of 28.6°C for loggerhead turtles (PTLT) for the majority of the nesting season and can be expected to have produced a strong female biased hatchling sex ratio (Figure 9).

Sand temperatures at relocated nest depth (55-60 cm) for shaded hatcheries and cages remained below the PTLT until mid-January when elevated temperatures indicated a 2+°C increase in temperatures at nest depth (Figure 9). Elevated rainfall events over December and early January resulted in pronounced cooling spikes in sand temperature at nest depth for all ten sites (Figure 11). Clutches at mid-incubation during these cooling spikes particularly the shaded hatcheries and cages, are expected to produce less female hatchling bias. When these cooling spikes produce sand temperatures approaching 2°C below the pivotal temperature, the clutches at mid-incubation can potentially produce 100% male hatchlings (Reed, 1980).

Overall, the mean sand temperatures at nest depth within the shaded predator-proof cages and shaded hatcheries were lower than those at the control sites, with RC1 and both shaded hatcheries recording mean temperatures below the PTLT (Figure 9B).

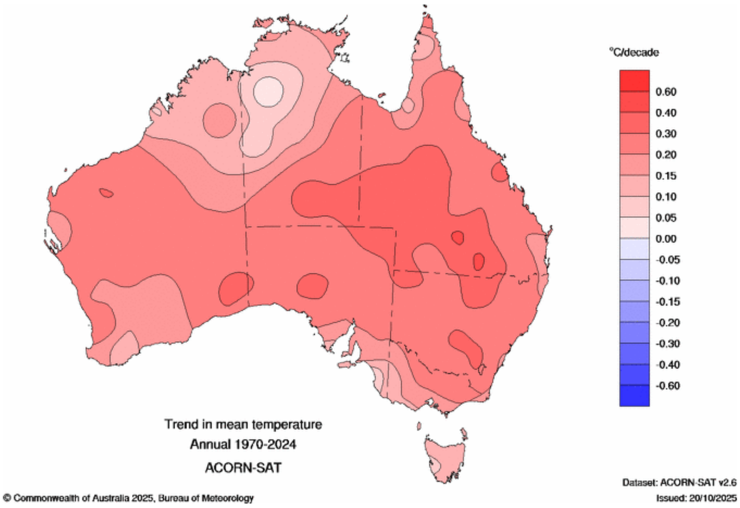


Figure 8. Bureau of Meteorology (2024) annual air temperature data. Accessed 15 April 2026 (https://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

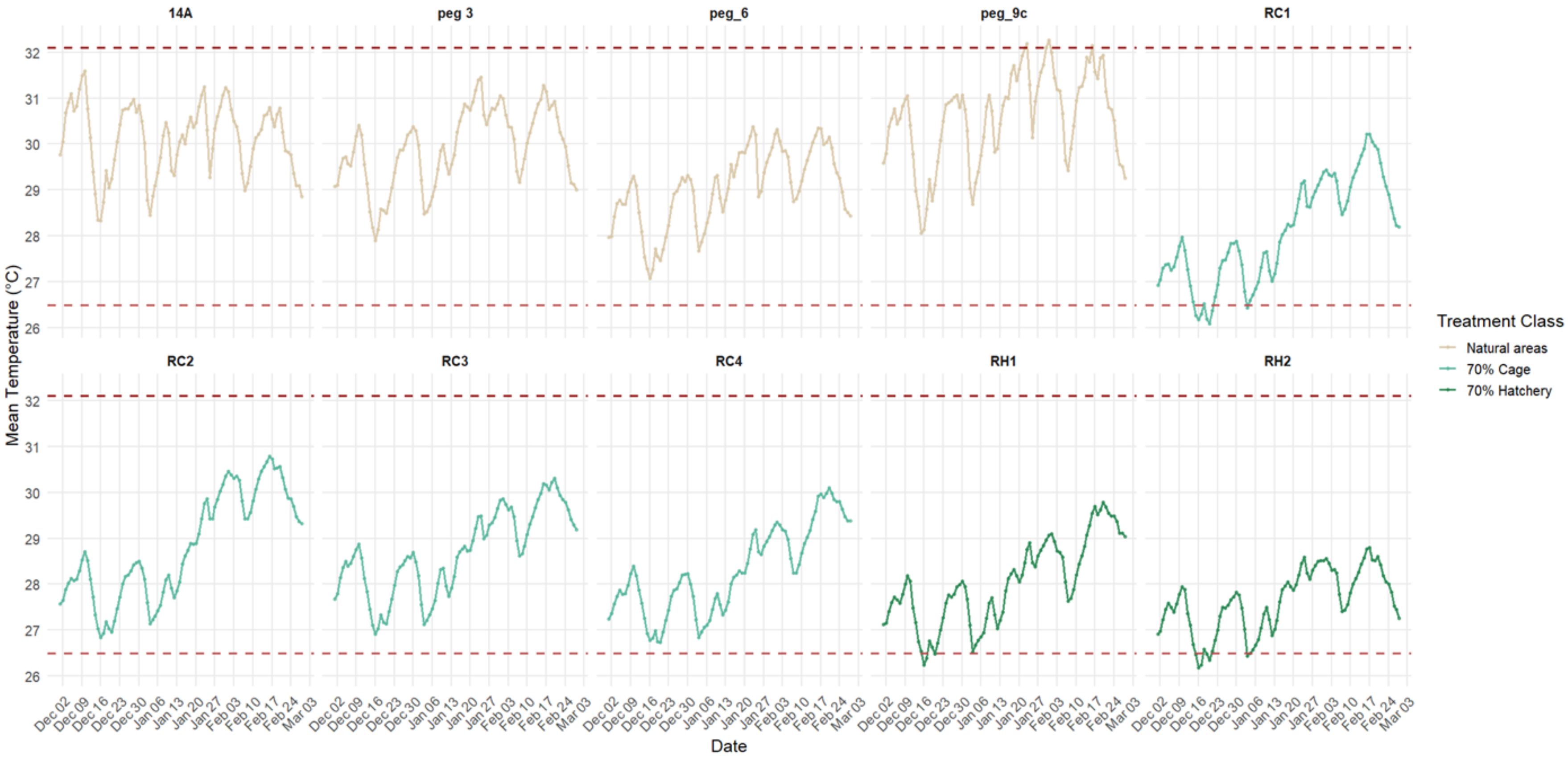


Figure 9. Plots of daily sand temperature data recorded at 50cm depth in sand at standard recording sites on Mon Repos Beach during the 2024-2025 breeding season. The dashed lines represent incubation limits (26.5 °C – 32.1 °C).

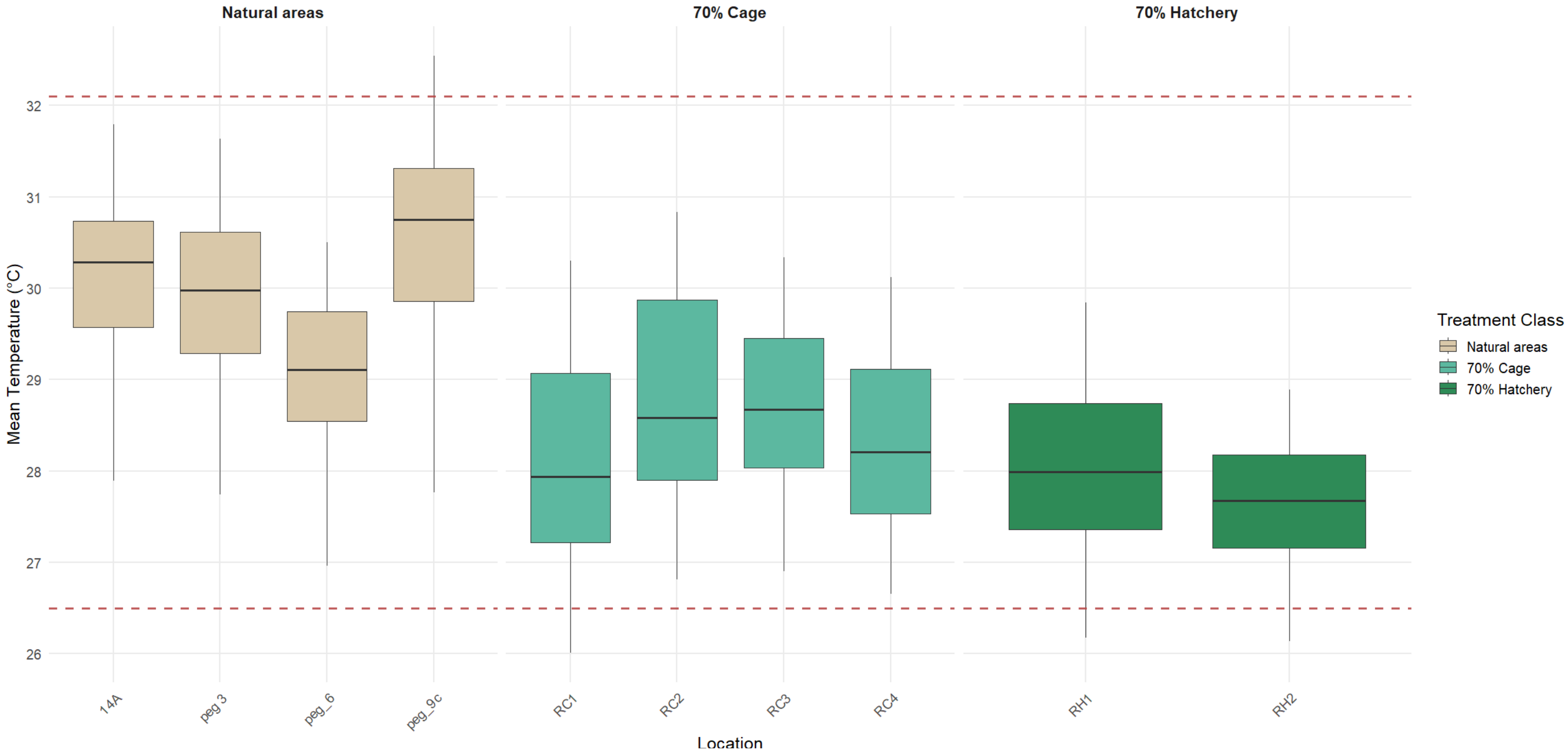


Figure 10. Plots of mean daily sand temperature data recorded at 50cm depth in sand at standard recording sites on Mon Repos Beach during the 2024-2025 breeding season. The dashed lines represent incubation limits (26.5 °C – 32.1 °C).

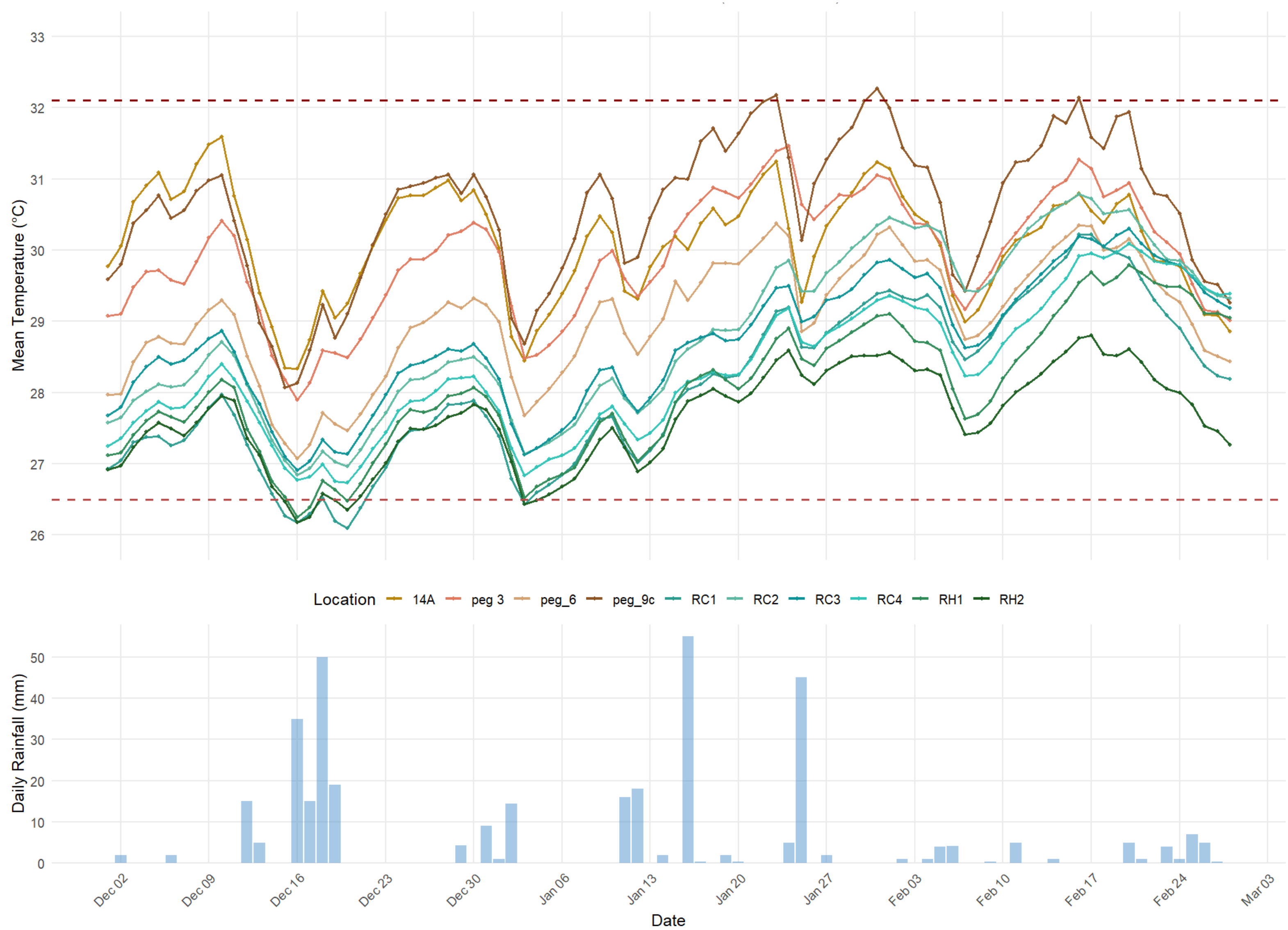


Figure 11. Comparison between mean daily sand temperature at standard recording sites and daily rainfall at Mon Repos Beach during the 2024-2025 breeding season. The dashed lines represent incubation limits (26.5 °C – 32.1 °C).

3. Results

Marine turtle nesting populations on the Woongarra Coast, 2024-2025

In this season, turtle nesting on the Woongarra Coast commenced on 19 October 2024 and continued until the last nesting on 31 March 2025 (Table 1).

The marine turtle hatchling emergence from nests on the Woongarra Coast commenced on 27 December 2024 and ceased on 08 May 2025 (Table 1).

Based on the whole of nesting season capture-mark-recapture nightly tagging of all turtles encountered, a total of 541 individual marine turtles of three species were recorded ashore for nesting on the Woongarra Coast beaches during the 2024-2025 breeding season (Table 2).

During the 2024–2025 breeding season, relocated clutches represented 54.3 ± 2.2% of the total marine turtle egg production recorded along the Woongarra Coast. Clutches identified as being at high risk from seasonal erosion, artificial light pollution (skyglow), and other anthropogenic threats were strategically relocated to elevated incubation sites or to beaches with minimal light exposure. These interventions aimed to enhance incubation success and improve hatchling emergence outcomes at the following beaches:

- **Mon Repos**, 825 clutches: 596 higher on dunes, 116 to shaded hatcheries, 113 to predator-proof cages
- **Oaks Beach**, 82 clutches: 43 higher on dunes, 39 to predator-proof cage
- **Nielson Park**, 40 clutches: 13 higher on dunes; 27 to predator-proof cage at Archies Beach
- **Bargara,** 11 clutches: 1 higher on dunes; 10 to predator-proof cage at Archies Beach
- **Kellys Beach**, 44 clutches: 5 higher on dunes; 37 to predator-proof cage at Archies Beach; 2 to predator- proof cage/Hatchery at Mon Repos
- **Archies Beach**, 54 clutches: 23 higher on dunes, 31 to predator-proof cage
- **Rifle Range Beach**, 1 clutch: 1 higher on dunes
- **Innes Park**, 8 clutches: 8 higher on dunes
- **Elliott Heads**, 12 clutches: 2 higher on dunes, 10 to predator-proof cage.

Table 1: Summary of the duration of the 2024-2025 marine turtle nesting and hatchling emergence seasons on the Woongarra Coast

	Caretta caretta Loggerhead turtle	*Chelonia mydas* Green turtle	*Natator depressus* Flatback turtle
First nesting crawl	31 October 2024	12 November 2025	19 October 2024
Last nesting crawl	31 March 2025	04 February 2025	04 January 2025
First hatchlings	27 December 2024	missed	12 December 2024
Last hatchlings	08 May 2025	01 April 2025	28 February 2025

Table 2: Summary of the breeding history of the marine turtles nesting on the Woongarra Coast, 2024-2025 breeding season.

	Caretta caretta Loggerhead turtle	*Chelonia mydas* Green turtle	*Natator depressus* Flatback turtle
Primary			
1st time tagged turtles	141	2	3
Ex feeding / nesting study	3	-	-
Recaptures			
Migration from foraging and 1st time breeding	-	1	-
• **Returns from previous season to Woongarra Coast**	351	-	9
• **Remigrants with lost tags**	20	-	1
• **Changing nesting colony** ○ **between seasons**	6	-	-
• **Changing nesting colony** ○ **within season**	4	-	-
TOTAL	**525**	**3**	**13**

3.1 Loggerhead Turtles, *Caretta caretta*

Breeding population size

The 2024–2025 season recorded an above average increase in nesting loggerhead turtles with 525 recorded nesting on the Woongarra Coast beaches, representing the second largest nesting season since the program commenced in 1968. Long-term trends in the annual nesting census data (Figure 12) from the 1970s to 2000, illustrates the major decline in annual numbers of nesting Loggerhead turtles attributed primarily to otter trawl by-catch mortality. The compulsory use of Turtle Exclusion Devices (TEDs) has been regulated under Australian and Queensland fisheries regulations across northern Australia, Torres Strait and eastern Queensland since 2001 (Limpus, 2008). By 2009, loggerhead turtle nesting numbers on the Woongarra Coast had recovered to a population comparable to those documented in the late 1970's. In parallel with this recovery, the Queensland Turtle Conservation Project implemented long-term management actions, including the relocation of doomed clutches as a targeted effort to enhance hatchling production in response to population declines. The relocation of doomed clutches has been maintained for more than three decades and is responsible for increased hatchling production from clutches that would otherwise be lost to tidal inundation or lighting impacts from coastal development.

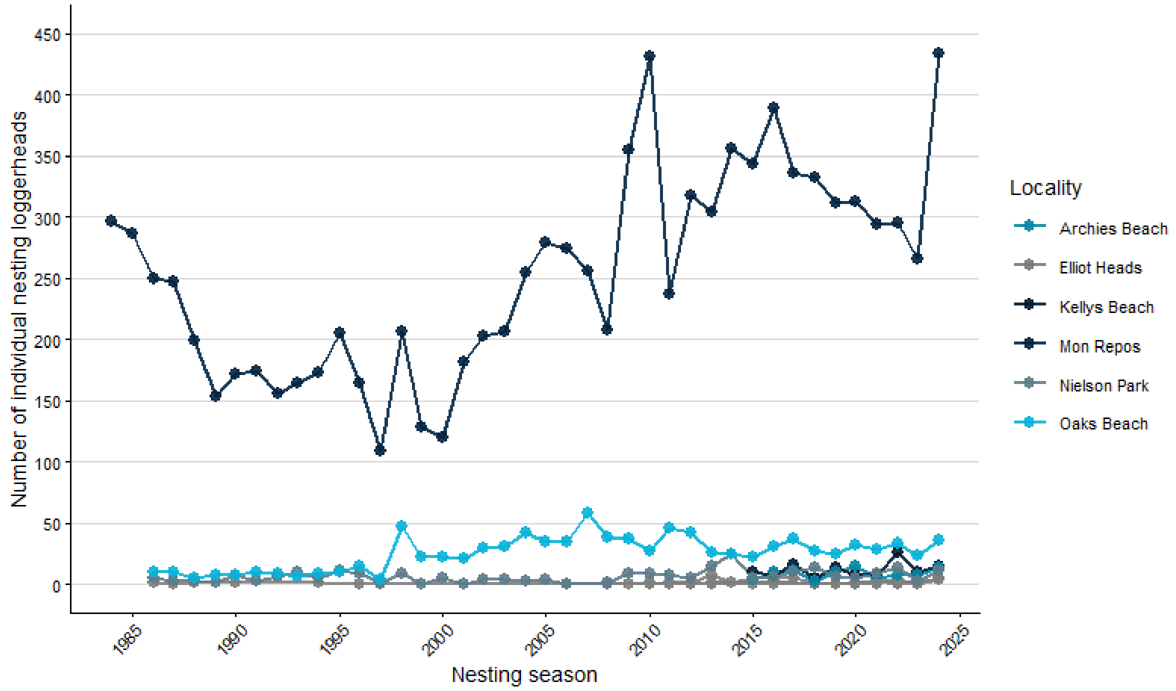


Figure 12: Summary of changing breeding numbers of loggerhead turtles, *Caretta caretta*, on the Woongarra Coast, 1985-2024.

Increased numbers of breeding loggerhead turtles observed this season may be related to above-average annual water temperatures (BOM) in key foraging regions over 2024, which may have altered reproductive phenology (Patel et al., 2021). This increase may also relate to ongoing ecological improvements within major foraging habitats such as Moreton Bay and the Great Sandy Marine Park. These regions have experienced significant environmental stress over recent decades due to recurrent flooding events, which have impacted coastal seagrass and other benthic habitats (Smith et al 2025, Udy et al 2024), known foraging areas for loggerhead turtles. Of the 11 individual loggerhead turtles with known foraging areas that nested on the Woongarra Coast during the 2024–2025 season, 81.82% are known to forage within Moreton Bay (Table 3). Rather than relocating during periods of habitat degradation, loggerhead turtles are known to endure temporary reductions in foraging habitat (Shimada et al., 2020), which can reduce breeding frequency and extend the remigration interval between breeding seasons. However, recent assessments of flood recovery in Moreton Bay and the Great Sandy Marine Park indicate signs of ecological recovery, including improved seagrass coverage and benthic stability as of 2024 (Smith et al 2025, Udy et al 2024). Further research and continued monitoring are needed to understand these patterns and determine whether the recent increase reflects natural variability or signals a meaningful shift in the population's long-term trajectory.

Although the 2024-2025 breeding season showed an increase in nesting individuals, the recruitment into the nesting population along the Woongarra Coast has exhibited a consistent decline over the past two decades (Figure 13). The underlying causes remain unclear, and are likely linked to site-specific environmental pressures, climate change, marine pollution and other anthropogenic disturbance. This regional disparity warrants consideration when interpreting long-term population trends and assessing broader conservation outcomes.

The annual recruitment rate of loggerhead turtles (= proportion of turtles recorded breeding for the first time on the Woongarra Coast) was 27.4% ± 3.8% for the 2024-2025 breeding season. While this index of recruitment into the adult female breeding population has declined by approximately 50% over the last two decades (Figure 13), there has been some improvement in recruitment of new adults into the breeding population in the last three seasons. The increase in proportion of first-time breeding females on the Woongarra Coast in recent years is encouraging and may be attributed to the relocation efforts of doomed clutches in the late 1990s.

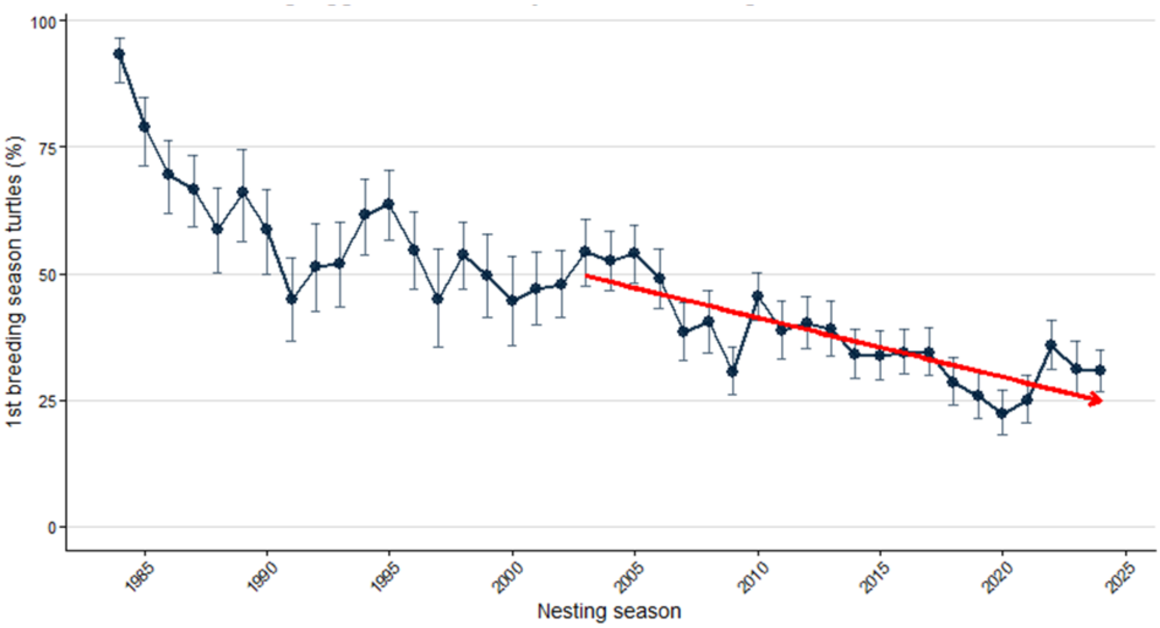


Figure 13: Proportion of primary first-time nesting female loggerhead turtles, *Caretta caretta*, within the annual breeding population displaying a steady decline on the Woongarra Coast, based on capture-mark-recapture analysis.

Table 3: Summary of Loggerhead turtle, *Caretta caretta* nesting on the Woongarra Coast, 2024-2025 breeding season, with known foraging grounds.

Primary Tag	Loggerhead Turtles with known foraging grounds		
	Breeding Age (yrs)	Breeding Seasons	Foraging Ground
X-8558	47	12	Howick Reefs (nGBR)
T14914	41	10	Moreton Bay
T53343	0	1	Moreton Bay
T75757	10	3	Moreton Bay
T79314	9	4	Moreton Bay
T93076	20	4	Moreton Bay
K7518	5	2	Moreton Bay
K15655	16	5	Swains Reefs (sGBR)
K17074	15	7	Moreton Bay
K38424	0	1	Moreton Bay
K64753	0	1	Moreton Bay

Reproductive parameters

The size range of the nesting loggerhead turtles are summarised in Table 4; Figure 14. The mean CCL of 95.46 cm is typical of the eastern Australian loggerhead nesting population. Nesting females tended to increase in carapace length with increasing number of breeding seasons recorded as an index of reproductive age (Table 4). The nesting loggerhead turtles averaged 3.87 clutches laid per female for the summer (Table 4; Figure 15). Nesting females tend to increase the number of clutches laid per season with increasing number of breeding seasons recorded (Table 6). The nesting loggerhead turtles averaged 121.82 eggs per clutch (Table 4). The occurrence of yolkless and multi-yolked eggs in clutches was uncommon (Table 4). Nesting females tended to increase the number of eggs per clutch with increasing number of breeding seasons recorded (Table 7; Figure 16). The nesting loggerhead turtles averaged approximately 3.97 yrs between breeding seasons (Table 4). Older females tended to breed more frequently, decreasing the number of years between breeding seasons with increasing reproductive age (Table 8; Figure 17).

Table 4: Summary of reproductive parameters of Loggerhead turtle, *Caretta caretta,* nesting on the Woongarra Coast, 2024-2025 breeding season, with data pooled across the age classes.

	MEASUREMENT				Sample size
	Mean	SD	Minimum	Maximum	
Curved carapace length (cm)					
1st time tagged	94.29	4.01	82.40	103.60	137
Remigrant turtles	96.15	4.77	80.60	110.50	341
All turtles	95.46	4.62	80.60	110.50	509
Remigration interval (yr)	3.97	2.26	1	14	355
Eggs & clutches					
Number of clutches laid per season per female	3.87	1.20	0	7	516
Eggs per clutch	121.82	21.92	43	207	1061
Yolkless eggs per clutch	2.33*	4.81	1	33	46
Multiyolked eggs per clutch	1.17*	0.48	1	3	24
Mean egg diameter (cm)	4.04	0.10	3.87	4.31	400 eggs 40 clutches
Mean egg weight (g)	36.98	2.86	32.73	43.70	400 eggs 40 clutches
Nest depth to top egg	34.83	9.11	10	64	841
Nest depth to bottom	56.86	7.04	30	88	870
Hatchlings					
Mean hatchling length (cm)	4.34	0.14	3.97	4.56	353 hatchlings 41 clutches
Mean hatchling weight (g)	18.71	1.44	15.20	21.87	353 hatchlings 41 clutches
Incubation period to hatchling emergence (d)	55.76	4.40	42	79	1056

*Calculated from nests containing yolkless or multiyolk eggs

Table 5: CCL by age class of Loggerhead turtle, *Caretta caretta,* nesting on the Woongarra Coast, 2024-2025 breeding season.

Age class Breeding season	CURVED CARAPACE LENGTH (cm)				Sample size
	Mean	SD	Minimum	Maximum	
1st	95.19	4.34	82.40	105.50	172
2nd	94.11	4.41	80.60	103.8	76
3rd	94.83	4.28	83.90	106.20	66
4th	97.39	4.49	86.30	106.20	51
5th	95.49	5.26	81.90	110.50	37
6th	97.30	4.33	89.20	106.20	22
7th	96.07	4.31	87.00	102.00	10
8th	98.12	3.52	93.40	103.10	14
9th	98.32	4.86	92.20	106.20	13
10th	98.69	3.06	92.30	102.3	9
11th	99.24	3.01	96.50	104.40	5
12th	99.97	2.60	97.30	103.20	7
13th	100.43	3.61	95.30	105.50	6
14th	94.50	***NaN	94.50	94.50	1
15th	102.15	2.90	100.10	104.20	2
18th	101.10	***NaN	101.10	101.10	1

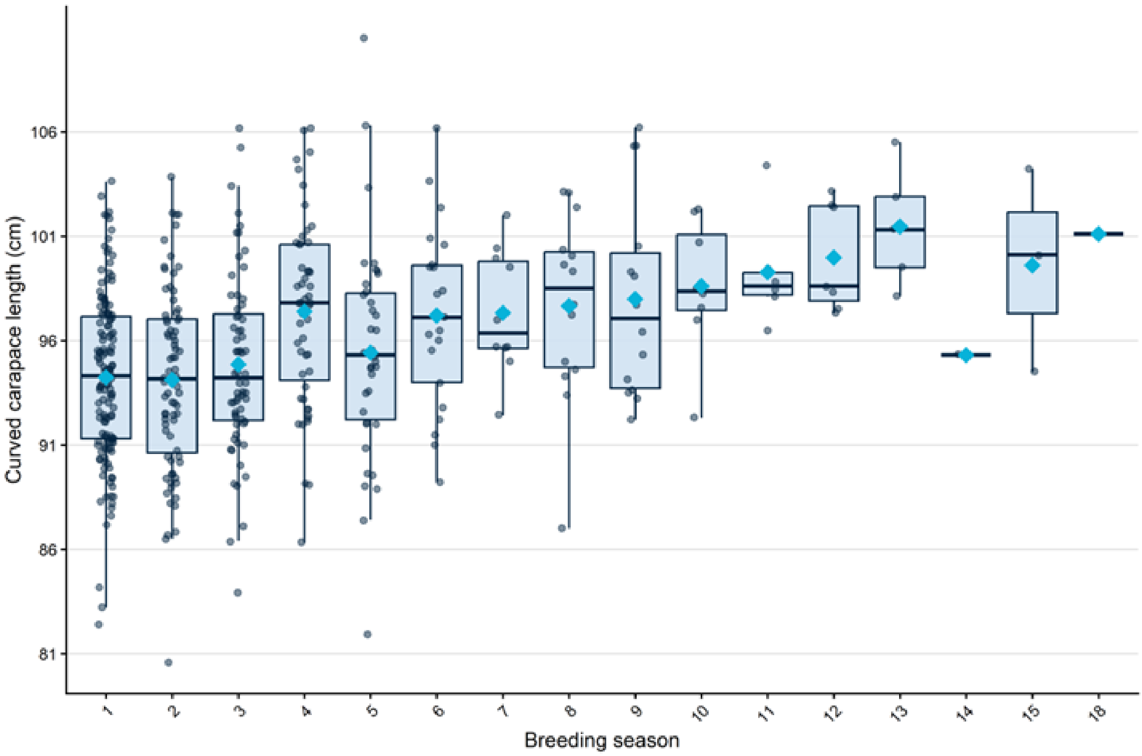


Figure 14. CCL for the total annual nesting population.

Table 6: Number of clutches laid per season by age class of loggerhead turtle, *Caretta caretta,* nesting on the Woongarra Coast, 2024-2025 breeding season.

Age class Breeding season	CLUTCHES per AGECLASS				Sample size
	Mean	SD	Minimum	Maximum	
1st	3.66	1.28	1	7	173
2nd	3.91	1.27	1	7	79
3rd	4.04	0.98	1	6	69
4th	4.00	0.94	2	7	51
5th	4.32	1.03	1	6	37
6th	4.04	0.88	2	5	23
7th	4.00	1.56	1	6	10
8th	4.57	0.85	3	6	14
9th	3.77	1.36	1	6	13
10th	4.22	0.97	3	6	9
11th	4.60	1.14	3	6	5
12th	4.43	0.98	3	6	7
13th	3.83	1.17	2	5	6
14th	5.00	***NaN	5	5	1
15th	3.50	0.71	3	4	2
18th	7.00	***NaN	7	7	1

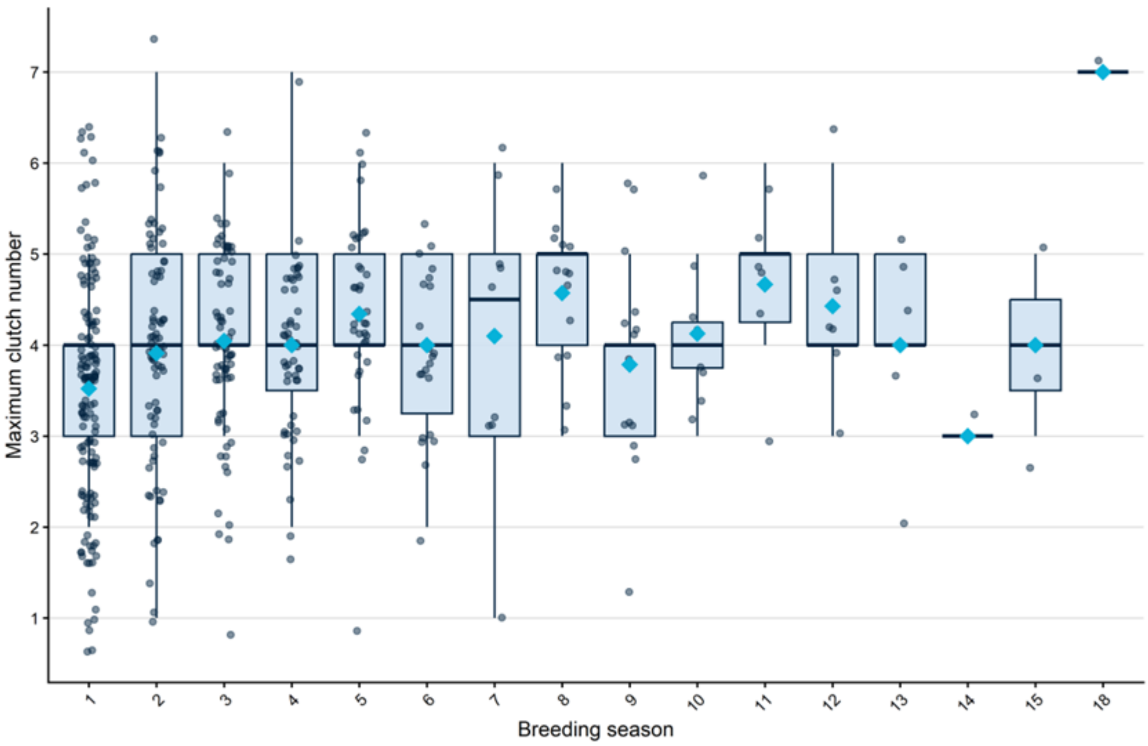


Figure 15. Number of clutches of eggs laid recorded for each female within the breeding season. Each point represents an individual, boxes represent first quartile, median and third quartile, and mean values are represented by light blue diamonds.

Table 7. Number of eggs per clutch by age class of Loggerhead turtle, *Caretta caretta,* nesting on the Woongarra Coast, 2024-2025 breeding season.

Age class Breeding season	EGGS per CLUTCH				Sample size
	Mean	SD	Minimum	Maximum	
1st	119.94	20.19	45	167	350
2nd	117.11	19.22	43	161	164
3rd	119.75	23.10	52	176	141
4th	132.08	20.92	82	177	89
5th	128.17	20.88	84	188	70
6th	125.55	20.62	80	174	49
7th	130.65	13.57	110	158	20
8th	139.55	20.28	110	177	20
9th	119.86	26.87	77	169	22
10th	126.06	28.80	45	154	16
11th	128.06	22.06	100	153	10
12th	135.25	13.77	111	156	12
13th	136.07	13.80	112	159	15
14th	137.00	2.83	135	139	2
15th	129.00	***NaN	129	129	1
18th	134.67	13.32	120	146	3

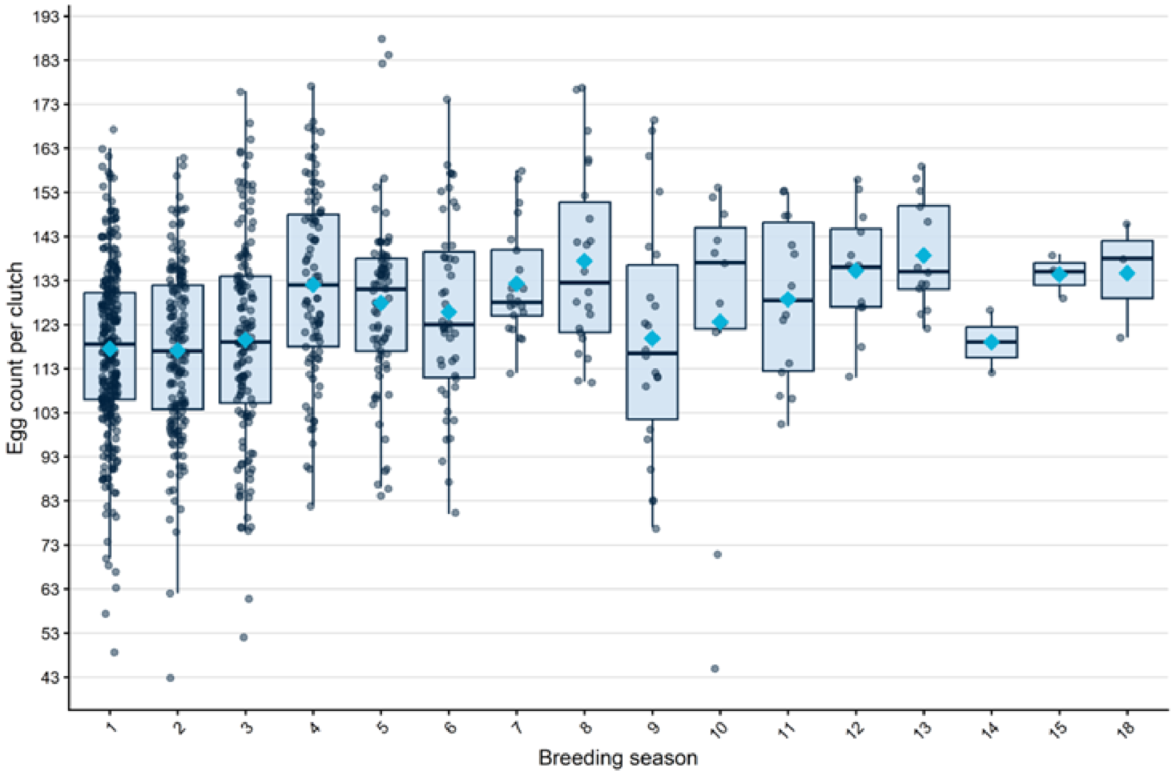


Figure 16. Number of eggs per clutch of eggs. Partial clutches with <10 eggs were excluded

Table 8: Remigration interval by age class of Loggerhead turtle, *Caretta caretta,* nesting on the Woongarra Coast, 2024-2025 breeding season.

Age class Breeding season	REMIGRATION INTERVAL (yr)				Sample size
	Mean	SD	Minimum	Maximum	
1st	-	-	-	-	-
2nd	4.71	2.57	1	13	79
3rd	4.26	2.19	2	13	69
4th	4.10	2.56	1	14	51
5th	3.46	1.32	1	7	37
6th	3.91	1.93	1	8	23
7th	3.30	1.42	1	6	10
8th	2.57	1.16	1	5	14
9th	3.00	1.22	1	5	13
10th	2.67	0.71	2	4	9
11th	2.00	0.71	1	3	5
12th	2.86	2.04	1	7	7
13th	3.50	2.07	1	6	6
14th	1.00	***NaN	1	1	1
15th	1.50	0.71	1	2	2
18th	7.00	***NaN	7	7	1

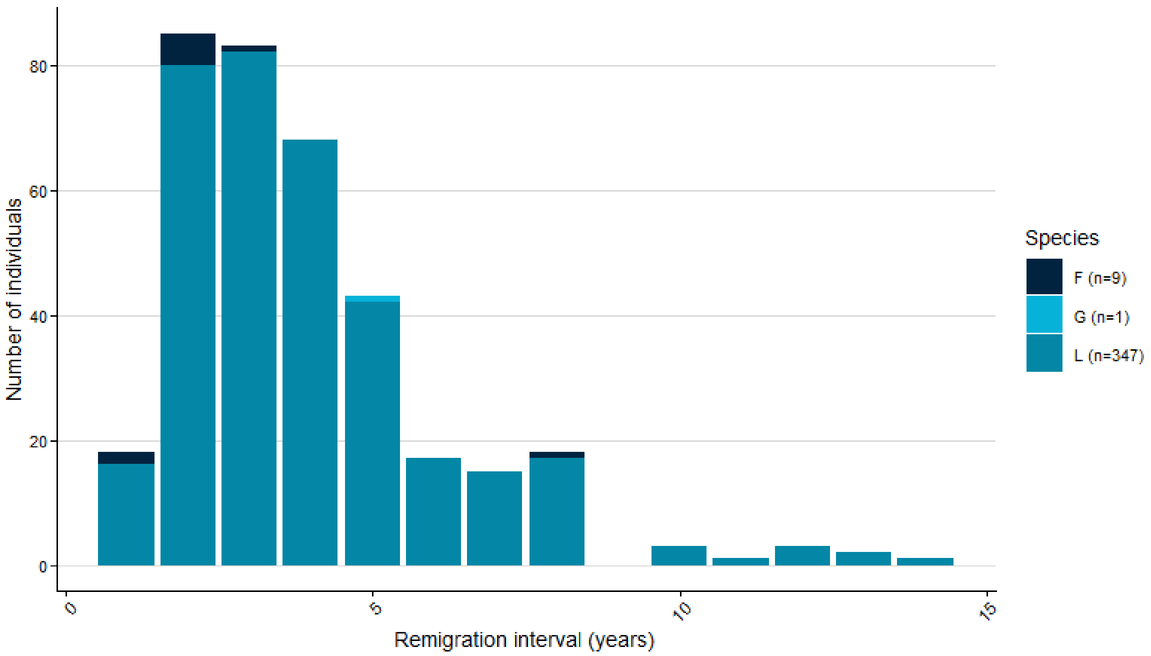


Figure 17. Remigration interval (years between successive breeding seasons). Only individuals with a recorded remigration interval are included.

Nesting behaviour

The proportion of marine turtle nesting crawls and nesting success by Woongarra Coast beaches during the 2024-2025 breeding season are summarised in Table 9.

The majority (83.8 ± 1.3%) of the loggerhead turtle nesting attempts occurred on Mon Repos Beach and the remaining 13.1% of the nesting crawls were spread over the remaining seven beaches (Table 9). Mon Repos has been the primary beach supporting loggerhead turtle nesting on the Woongarra Coast in all years since systematic monitoring of turtle nesting began in 1968 (Figure 18).

Loggerhead turtles exhibited strong site fidelity to Mon Repos Beach, with 83.3% of nesting females exclusively nesting at this location (Table 10). In contrast, the remaining Woongarra Coast beaches demonstrated low site fidelity to an individual beach, with particularly low fidelity observed at Nielson Park, Kellys Beach, and Archies Beach. This reduced fidelity is likely attributed to the impacts of lighting and increased coastal development (Table 10).

Table 9. Loggerhead turtle, *Caretta caretta*, nesting distribution on the Woongarra Coast, 2024-2025 breeding season.

Beach	NESTING CRAWLS (tracks)				
	Nesting Success (%) (± 95% CI)	Laid	Did Not Lay	Uncertain Nesting Success	Total Tracks (% by beach ± 95% CI)
Oaks	46.4% ± 7.0%	90	104	0	194 (5.8% ± 0.8%)
Mon Repos	59.2% ± 1.8%	1661	1003	143	2807 (83.8% ± 1.3%)
Nielson Park	40.5% ± 8.9%	47	63	6	116 (3.5% ± 0.6%)
Bargara	30.6% ± 15.0%	11	25	0	36 (1.1% ± 0.4%)
Kellys	61.8% ± 10.9%	47	29	0	76 (2.3% ± 0.5%)
Archies	73.3% ± 10.0%	55	20	0	75 (2.2% ± 0.5%)
Rifle Range	25.0% ± 30.0%	2	6	0	8 (0.2% ± 0.2%)
Innes Park	60.0% ± 24.8%	9	6	0	15 (0.4% ± 0.2%)
Elliott Heads	68.2% ± 19.5%	15	6	1	22 (0.7% ± 0.3%)
TOTAL	**57.8% ± 1.7%**	**1937**	**1262**	**150**	**3349**

Table 10. Fidelity to individual beaches on the Woongarra Coast.

Beach	Loggerhead			Flatback			Green		
	Total turtles using this beach at least once	Total turtles that only used this beach	Fidelity to an individual beach (%) (± 95% CI)	Total turtles using this beach at least once	Total turtles that only used this beach	Fidelity to an individual beach (%)	Total turtles using this beach at least once	Total turtles that only used this beach	Fidelity to an individual beach (%)
Oaks	49	13	26.5% ± 12.2%	-	-	-	-	-	-
Mon Repos	491	409	83.3% ± 3.3%	11	11	100%	2	2	100%
Neilson Park	22	0	0%	-	-	-	-	-	-
Bargara	6	1	16.7% ± 29.8%	-	-	-	-	-	-
Kellys Bch	28	0	0%	1	0	0%	-	-	-
Archies Bch	35	3	8.6% ± 9.6%	1	0	0%	1	1	100%
Innis Park	3	2	66.7% ± 53.4%	-	-	-	-	-	-
Elliott Heads	6	3	50% ± 40%	-	-	-	-	-	-

Loggerhead turtles with the longest recorded reproductive life span that bred on the Woongarra Coast during the 2024-2025 season:

- **X8558:** 47-year reproductive life span, commenced breeding in the 1983-1984 season, with 12 recorded breeding seasons. This turtle has been satellite tracked and forages on Switzer Reef, Howicks, Northern Great Barrier Reef.

Loggerhead turtles of special interest that bred on the Woongarra Coast during the 2024-2025 season:

- **T93076:** Marked hatchling that emerged on Mon Repos beach during the 1975-1976 season and has a known life age of 49-years. This individual has a 20-year reproductive life span, commenced breeding in the 2004-2005 season, with 4 recorded breeding seasons. This individual was captured as a sub-pubescent foraging on the Moreton Banks, Moreton Bay in 1997 and has since been captured in the same foraging grounds in 1998, 2000, 2001, 2015 and 2021.
- **K36230:** Marked hatchling that emerged on Mon Repos beach during the 1974-1975 season and has a known life age of 50-years. This individual has a 24-year reproductive life span, commenced breeding in the 2000-2001 season, with 10 recorded breeding seasons. Foraging area unknown.
- **T53343:** First captured as a sub-pubescent (CCL: 84.4) foraging on Moreton Banks, Moreton Bay in 1991 and again in 1999. First recorded breeding (CCL: 91.1) at Mon Repos in the 2024-2025 season. 35-year interval between sub-pubescent and breeding adult life stages.

- **K38424:** First captured as a sub-adult (CCL: 72.4) foraging on Moreton Banks, Moreton Bay in 2002. First recorded breeding (CCL: 90.8) at Mon Repos in the 2024-2025 season. 22-year interval between sub-adult and breeding adult life stages.
- **K64753:** First captured as a sub-adult (CCL: 74.8) foraging on Moreton Banks, Moreton Bay in 2004. First recorded breeding (CCL: 91.5) at Mon Repos in the 2024-2025 season. 20-year interval between sub-adult and breeding adult life stages.

The eastern Australian loggerhead turtle nesting population was decimated largely as result of trawl fishery bycatch mortality in eastern and northern Australia. Recovery of the annual nesting numbers commenced following the compulsory regulation of the use of TEDs in the prawn trawl fisheries of northern Australia, Torres Strait, and eastern Queensland in ~2001. However, the voluntary use of TEDs was common practice within some of these fisheries up to three years earlier. As a consequence, 441 (94.6%) of the loggerhead turtles with a known reproductive life span commenced their breeding life since 2001 (Figure 19). The excessive loggerhead turtle mortality across decades throughout the majority of the foraging distribution prior to 2001 is interpreted as the underlying reason for there being only 5.4% of turtles with >24 yr reproductive life still migrating to this major breeding site.

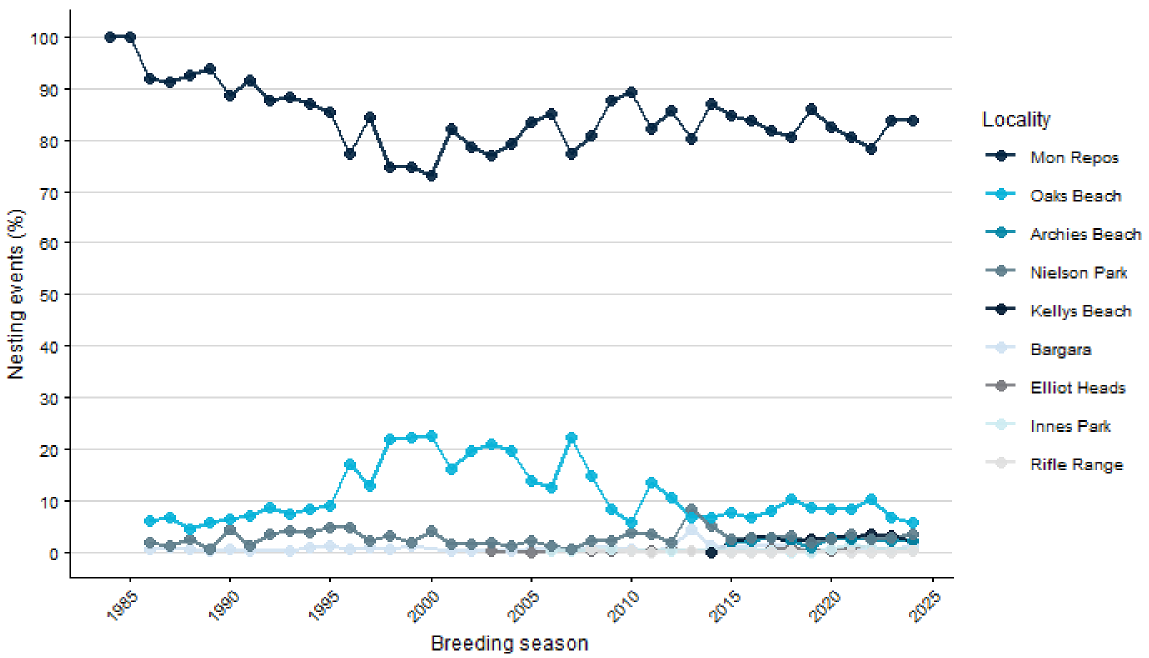


Figure 18: Distribution of Loggerhead turtle, *Caretta caretta*, nesting crawls by principal nesting beaches within the Woongarra Coast, 1985 – 2024 breeding seasons.

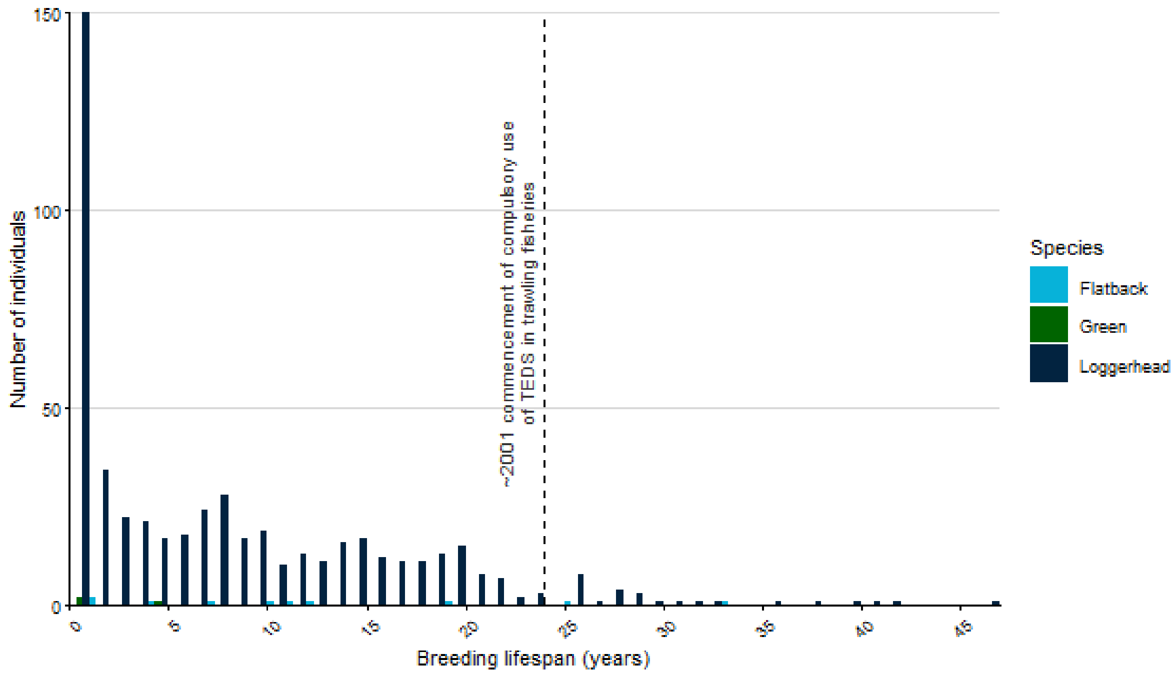


Figure 19: Reproductive life span as breeding adults

Health observations

- No loggerhead turtles were recorded with fibropapilloma tumours throughout the 2024-2025 nesting season.
- Primary loggerhead turtle QB2896 was recorded with fresh propeller damage after laying her first clutch on 21 November 2024.

Rescued turtles

On 14 January 2025, loggerhead turtle QB36272 in her first breeding season was rescued from private property north of Mon Repos Beach (sector -4) after becoming disoriented and moving inland towards the lights of Bundaberg.

Human interactions

More than six negative human interactions involving nesting turtles, hatchlings, and incubating clutches were observed or reported across the Woongarra Coast during the 2024–2025 nesting season. The rise of technology and social media has contributed to increased public awareness, often resulting in large crowds of over 150 people gathering when nesting or hatchling turtles were present. This was especially evident during daylight hours at Mon Repos and at night on other beaches. This raises future concerns for the nesting success of marine turtles, particularly on beaches outside Mon Repos Conservation Park.

Loss of clutches

There was a total of 35 separate reports of fox activity along the Woongarra Coast with at least nine clutches depredated across the 2024-2025 breeding season.

Collectively, for all beaches on the Woongarra Coast, no marine turtle eggs were destroyed by dogs. The use of predator-proof cages at Archies and Elliott Heads Beaches contributed to this result.

A number of clutches were lost to erosion caused by heightened wind and surge conditions during the January spring tides, as well as additional weather-driven surges associated with Cyclone Alfred, which tracked along the coast from late February into March. Throughout the season, 932 clutches (47.91% of clutches laid) were relocated to habitat higher up the dunes in anticipation of potential erosion/storm surge conditions. This relocation of doomed eggs greatly minimised the negative impact of erosion and high tide flooding of nests laid on the lower areas of the beaches.

There were at least 66 clutch destructions of incubating eggs by the nesting activities of loggerhead turtles. All clutch destructions by nesting turtles were reported from Mon Repos Beach. In each case, only part of the incubating clutch was destroyed by the nesting turtle. Clutch destruction by nesting turtles represents a small proportion of egg loss and does not significantly impact loggerhead egg production on the Woongarra Coast.

Incubation success and hatchling emergence

Of the 1945 recorded loggerhead clutches laid on the Woongarra Coast during the 2024-2025 breeding season, 1553 (79.84%) clutches were counted and assessed for hatchling emergence success. The high number of unaccounted clutches are likely the result of faulty triangulation measurements when the eggs were laid and clutches lost through erosion during extreme weather events. Figure 20 summarises the frequency distribution of PTE for naturally incubating loggerhead clutches laid at Mon Repos. Hatchling emergence periods strongly biased below 60 days. These PTE values were within the emergence range that is expected to produce a high proportion of female hatchlings. This summary does not include data from relocated clutches laid on Mon Repos beach.

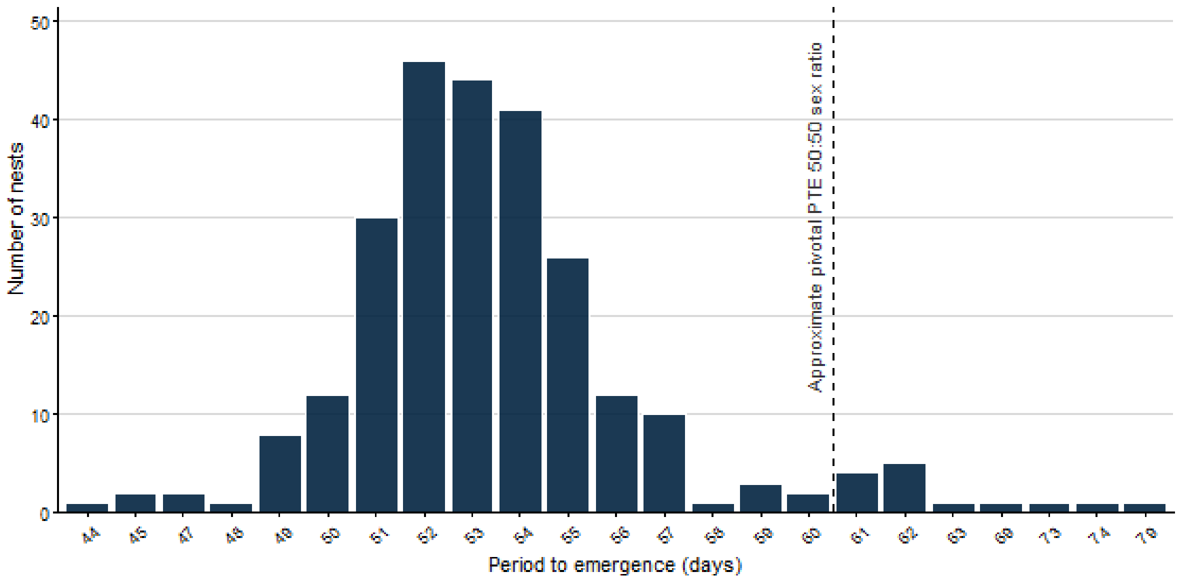


Figure 20. Frequency distribution of PTE for naturally incubating (clutches not relocated) Loggerhead turtle, *Caretta caretta,* eggs laid on Mon Repos beach during the 2024-2025 nesting season. These PTE values are compared to the pivotal incubation period (60-61 days) that is expected to give a 50:50 hatchling sex ratio with constant temperature incubation. The Pivotal Temperature PTE is estimated from Limpus *et al*. 1985). Only nests with PTE between 43 and 80 days are included.

Table 11 summarises the PTE for loggerhead clutches laid on Woongarra Coast beaches, categorised by species, egg relocation history, and exposure to artificial shade. Figures 21 and 22 compare the PTE of clutches incubated in the natural dune habitat at Mon Repos Beach with those relocated to shaded hatcheries and shaded predator-proof cages across the Woongarra Coast. The mean PTE for clutches relocated to Hatchery 1, Hatchery 2, and Cage 1 at Mon Repos indicates a male-biased sex ratio, with clutches emerging within 60–62 days. In contrast, clutches relocated to all other cages across the Woongarra Coast are expected to exhibit a female-biased sex ratio, with a PTE of less than 60 days (Table 11). Additionally, the mean PTE for clutches incubated in the natural dune habitat across the entire Woongarra Coast was 54.85 days, further indicating a strong female-biased sex ratio among hatchlings for the entire 2024-2025 nesting season. This bias is likely due to the mean sand temperatures for natural dune habitat exceeding the pivotal incubation temperature of 28.6°C (Figure 9; Figure 10).

Table 11: Summary of PTE (days) from eggs being laid to hatchlings emerging from nests on the Woongarra Coast beaches by species and relocation history of the eggs, 2024-2025 breeding season * min 42 days, max 80 days

Beach	Subset	Period to Emergence (d)			
		Mean	SD	Range	Sample size
GREEN					
Combined beaches	Natural dune	56.57	8.92	49-76	7
	Cage 4 & 5	51.50	0.70	51-52	2
FLATBACK					
Combined beaches	Natural dune	52.75	4.02	47-61	12
	Hatchery 1 & 2	59.66	3.78	57-64	3
	Cage 3 & 5	54.66	5.03	50-60	3
LOGGERHEAD					
Combined beaches	Natural dune	54.85	4.12	42-79	787
Natural nests					
Mon Repos	Natural dune	55.00	4.27	42-79	676
Oaks Beach	Natural dune	52.06	2.27	48-60	47
Kellys & Archies Beaches	Natural dune	55.44	2.29	50-59	43
All other beaches	Natural dune	55.09	3.01	49-61	21
Artificial shade					
Mon Repos	Hatchery 1	60.84	3.23	53-78	70
	Hatchery 2	61.94	2.83	55-67	19
	Cage 1	61.34	3.58	52-70	23
	Cage 2	57.71	2.74	53-63	21
	Cage 3	57.26	2.37	54-62	19
	Cage 4	58.17	5.11	42-65	17
Kellys & Archies Beaches	Cage 5 & 7	54.00	2.27	51-61	37
Elliot Heads	Cage 8	59.76	2.86	56-65	13
Oaks Beach	Cage 9	57.81	2.75	52-64	33

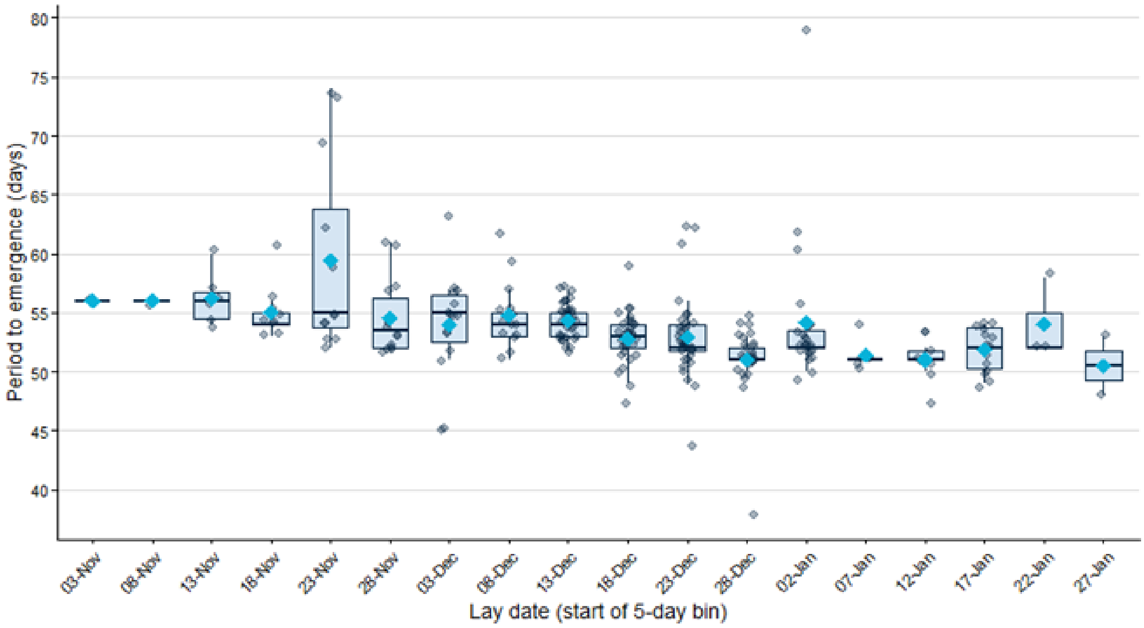


Figure 21. Loggerhead clutches naturally incubated in the dune habitat outside of shaded hatcheries and shaded predator-proof cages. PTE distribution plotted in 5-day lay-date bins. PTE not included for clutches in February (data deficient).

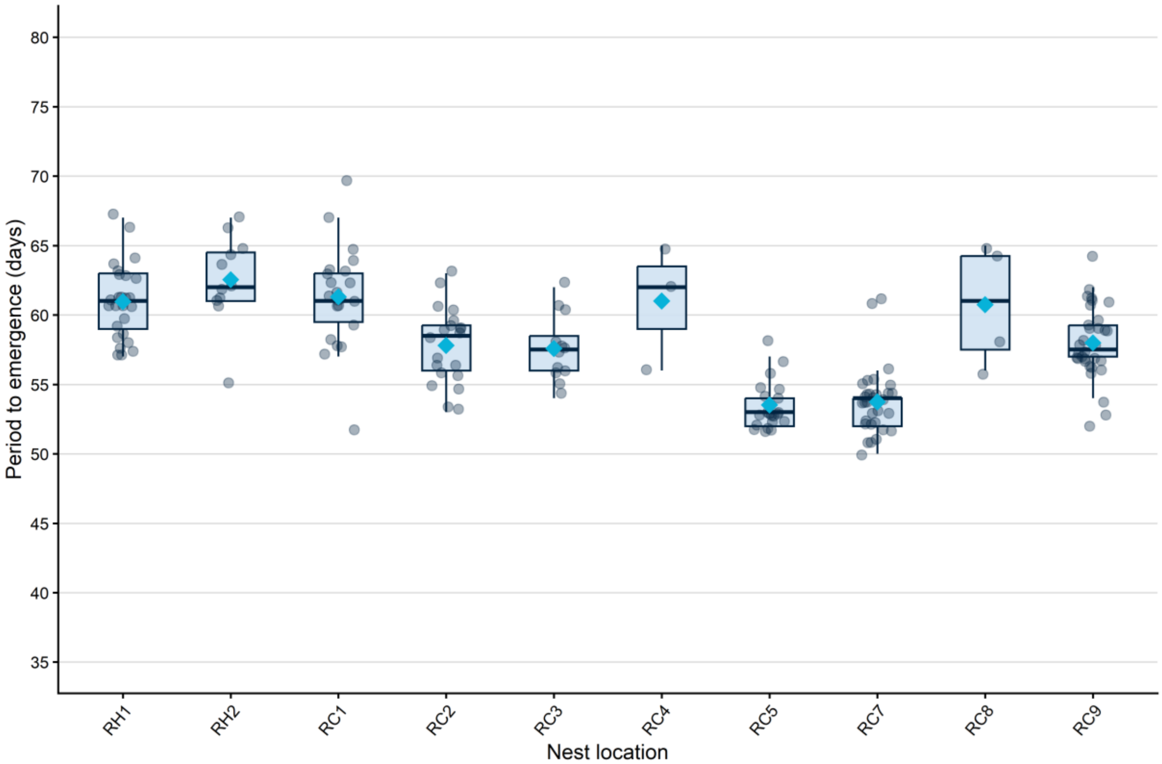


Figure 22. Loggerhead clutches relocated to incubate inside shaded hatcheries and shaded predator-proof cages.

Sand temperature records at nest depth from long-term open beach monitoring sites at Mon Repos (sectors 14C, 14A, 9C, 6, and 3; Figure 9) revealed a consistent pattern throughout the 2024–2025 nesting season. In the absence of heavy rain-induced cooling events, sand temperatures at nest depth consistently remained above the loggerhead pivotal temperature for the majority of the nesting season. However, heavy rain-induced cooling events in mid to late December briefly reduced sand temperatures below the pivotal temperature. These cooling events are likely to have resulted in the masculinisation of clutches laid approximately one month prior to the cooling period. The strong cooling spikes in sand temperature were associated with severe thunderstorms and isolated heavy rainfall across parts of central and south-east Queensland in mid to late December, as seen in Figure 11. Overall, the sand temperature data suggest that the loggerhead hatchling sex ratio from clutches incubating in natural dune habitat along the Woongarra Coast beaches were predominantly female-biased during the 2024–2025 nesting season.

Tables 13 and Table 14 summarises the hatching success of eggs and hatchling emergence success from nests on the Woongarra Coast, categorised by beach, clutch relocation history, and the presence of artificial shaded sites. The data indicates that emergence success between natural nests and relocated nest were similar across all beaches where there was enough replication to compare. Emergence success was unsatisfactory (<70%) at Oaks Beach and natural nest at Nielson Park (70.7%). Dune structure and high-density vegetation have been raised as underlining issues likely impacting hatchling emergence.

At Mon Repos, emergence success was slightly improved for clutches that were relocated to natural dune habitats in more suitable locations away from their original nesting site. This improvement is likely influenced by the relocation process, which biases emergence success by moving clutches to areas with more favourable incubation conditions within the vegetated dunes. Overall, the relocation of clutches to natural habitats at Mon Repos Beach and Oaks Beach resulted in improved emergence success. However, this trend was not observed at other beaches along the Woongarra Coast, indicating variability in outcomes. Further investigation is required to understand the factors influencing the differences in emergence success across these beaches.

Gastrula stage mortality (undeveloped eggs) represented the highest proportion of embryonic mortality in clutches across the Woongarra Coast, with a mean of 11.71 undeveloped eggs per clutch (Table 15). Booth et al. (2020) suggest that clutches laid in close proximity to maturing clutches on high-density nesting beaches may experience conditions of low oxygen, elevated carbon dioxide, and increased temperatures, which can contribute to early embryonic mortality. During the 2024–2025 nesting season, particularly at Mon Repos Beach, the elevated nesting population resulted in a significant number of clutches being laid in close proximity to one another. During incubation success assessments (nest digs), a significant proportion of clutches were observed to have been laid either directly on top of or adjacent to multiple other clutches. In some cases, 3–4 clutches were excavated from a single nest dig site. This high nesting density was also associated with a notable rate of clutch destructions, with over 66 clutches impacted during the season.

Hatchling emergence success from clutches laid on Mon Repos Beach has previously been identified as reduced and subject to greater year-to-year fluctuations since the swampland immediately inland of the dunes was drained by a local farming company, resulting in a lowered water table beneath the frontal dune. These decreases in hatchling emergence success have been particularly evident during hot or low-rainfall years (Figure 23). Efforts to restore the swampland are currently underway, following the QPWS acquisition of the land and the commencement of drainage reprofiling in 2025. The impacts of re-establishing this wetland system are expected to become evident in future nesting seasons.

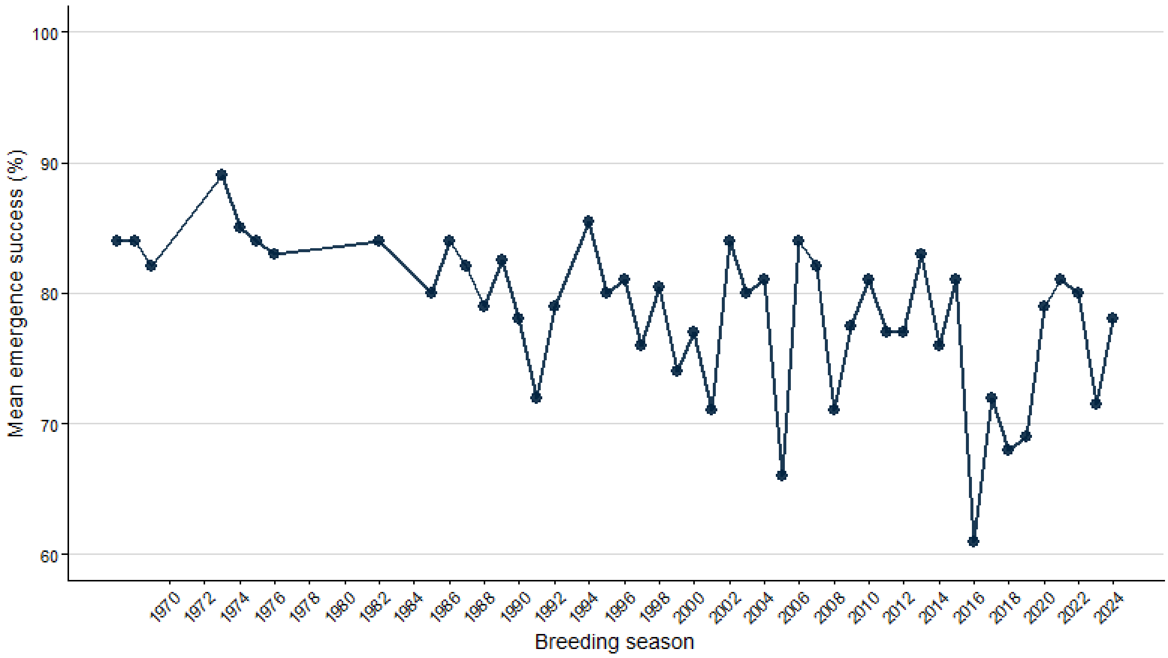


Figure 23: Annual variability of loggerhead turtle, *Caretta caretta*, hatchling emergence success from naturally incubated clutches laid on the upper slope of the frontal dunes on Mon Repos Beach since 1968. Years impacted by lowering of the water table under the dunes resulting from draining of the swamp land immediately inland of the dunes in the 1970s are identified. Data from the recent four heat wave years are circled in orange.

Table 13: Summary of hatching success of eggs and hatchling emergence for natural nests and clutches relocated to natural dune.

Beach	Subset	Hatching Success (%)				Emergence Success (%)			
		Mean	SD	Range	Sample	Mean	SD	Range	Sample
LOGGERHEAD									
Mon Repos	Natural nests	79.40	19.33	0.00-100.00	629	77.54	20.22	0.00-100.00	629
	Relocated to dune	81.44	16.22	2.36-100.00	485	79.52	16.87	2.36-100.00	485
Oaks	Natural nests	68.94	28.00	19.23-91.25	6	66.31	28.14	19.23-91.25	6
	Relocated to dune	73.31	20.44	10.47-96.64	45	69.95	20.37	8.14-96.64	45
Kellys & Archies	Natural nests	85.59	15.31	50.76-96.70	11	83.86	14.82	50.00-94.12	11
	Relocated to dune	82.76	15.65	38.16-99.16	39	77.21	23.69	3.64-99.16	39
Neilson Park	Natural nests	73.40	14.52	60.00-88.43	4	70.71	15.37	55.44-88.43	4
	Relocated to dune	84.65	18.81	51.81-99.12	5	83.54	20.26	48.19-99.12	5
Elliot Heads	Natural nests	92.58	1.95	90.00-94.69	4	91.94	2.78	88.18-94.69	4
	Relocated to dune	60.51	NaN**	60.51	1	50.32	NaN**	50.32	1
FLATBACK									
Mon Repos	Natural nests	62.74	24.53	16.07-91.80	10	56.05	27.68	16.07-90.16	10
	Relocated to dune	72.64	24.03	13.04-95.12	16	71.37	24.22	8.70-95.12	16
Kellys & Archies	Relocated to dune	89.47	NaN**	89.47	1	82.46	NaN**	82.46	1
GREEN									
Mon Repos	Natural nests	83.43	14.93	63.33-99.08	5	82.57	14.26	63.33-99.08	5
	Relocated to dune	83.24	18.13	62.67-96.94	3	81.41	17.35	62.67-96.94	3
Kellys & Archies	Natural nests	91.82	NaN**	91.82	1	91.82	NaN**	91.82	1

Table 14: Summary of hatching success of eggs and hatchling emergence for clutches relocated to cages and hatcheries

Beach	Subset	Hatching Success (%)				Emergence Success (%)			
		Mean	SD	Range	Sample	Mean	SD	Range	Sample
LOGGERHEAD									
Mon Repos	Hatchery 1	78.81	23.88	0.00-98.81	81	77.07	23.56	0.00-98.17	81
	Hatchery 2	79.00	18.85	24.32-96.58	23	77.02	18.36	24.32-96.58	23
	Cage 1	83.11	14.77	30.25-98.47	31	80.29	14.54	29.41-96.95	31
	Cage 2	76.32	25.07	0.00-99.22	30	75.67	24.96	0.00-99.22	30
	Cage 3	76.01	26.10	0.00-96.61	23	74.83	25.62	0.00-94.92	23
	Cage 4	84.99	16.04	36.04-98.84	25	84.73	15.94	36.17-98.84	25
Archies Bch	Cage 5 & 7	76.29	18.40	27.27-98.68	61	74.19	17.78	27.27-97.37	61
Elliot Heads	Cage 8	62.97	33.02	8.11-94.21	13	60.96	32.21	8.11-93.39	13
Oaks Bch	Cage 9	75.77	22.35	5.88-100.00	37	73.98	22.00	4.90-98.67	37
FLATBACK									
Mon Repos	Hatchery 1	35.94	NaN**	35.94	1	32.81	NaN**	32.81	1
	Hatchery 2	62.49	11.45	54.39-70.59	2	60.53	8.68	54.39–66.67	2
	Cage 3	26.09	NaN**	26.09	1	24.64	NaN**	24.64	1
Archies Bch	Cage 5 & 7	77.27	12.64	68.33-86.21	2	70.51	14.87	60.00-81.03	2
GREEN									
Mon Repos	Cage 4	96.19	NaN**	96.19	1	96.19	NaN**	96.19	1
Archies Bch	Cage 5 & 7	87.54	6.18	83.17-91.92	2	83.03	4.00	80.20-85.86	2

Table 15: Embryological staging from incubation success (nest digs) Woongarra Coast 2024-2025

Developmental Stages	Embryology (Loggerhead)				
	Subset	Mean	SD	Range	Sample Size
Undeveloped 0-6 days	Natural Nest	10.98	16.94	0-157	649
	Relocated	12.43	17.03	0-137	903
Unhatched 2 7-16 days	Natural Nest	2.60	4.26	0-34	649
	Relocated	2.47	4.61	0-61	903
Unhatched 3 17-28 days	Natural Nest	0.85	3.06	0-58	649
	Relocated	0.49	1.26	0-12	903
Unhatched 4 29-41 days	Natural Nest	1.96	3.54	0-38	649
	Relocated	1.38	2.75	0-37	903
Unhatched 5 42-49 days	Natural Nest	1.17	4.07	0-72	649
	Relocated	0.92	2.46	0-42	903
Unhatched 6 50-52 days	Natural Nest	1.31	4.30	0-57	649
	Relocated	1.23	3.90	0-45	903
Live in nest >52 days	Natural Nest	0.87	4.20	0-97	649
	Relocated	1.52	6.46	0-128	903
Dead in nest >52 days	Natural Nest	1.54	5.59	0-68	649
	Relocated	1.15	3.65	0-74	903
Predated 0-52 days	Natural Nest	5.66	7.77	0-78	649
	Relocated	5.07	6.77	0-77	903

3.2 Flatback turtles, *Natator depressus*

Thirteen flatback turtles were recorded ashore for breeding on the Woongarra Coast beaches over the 2024-2025 breeding season with one individual emerging but not returning to lay (Table 2; Figure 24).

Table 16 summarises the reproductive parameters of this small nesting population at the southern extremity of the breeding range for eAust genetic stock of flatback turtles for the 2024-2025 breeding season. The reproductive parameters recorded for this season continue to fall within the normal range for these parameters for this stock (Limpus, 2007).

The Woongarra Coast has not supported a nesting presence of this scale for flatback turtles since the 1978–1979 breeding season, when thirteen flatback turtles were documented nesting along the coast. Three flatback turtles were recorded as primary nesting individuals, indicating increased recruitment into the small annual flatback turtle nesting population for the Woongarra Coast. Twelve individuals exhibited strong nesting fidelity to Mon Repos Beach, while a single turtle nested on both Archies Beach and Kellys Beach (Table 17).

Flatback clutches on the Woongarra Coast during the 2024-2025 breeding season had a mean PTE = 55.69 d (Table 16). The limited number of PTE values recorded (n = 13) during the 2024–2025 season made it challenging to confidently evaluate the estimated pivotal PTE for flatback turtles (54 days). However, Figure 25 suggests that the flatback hatchling sex ratio was likely not skewed towards either gender.

Hatchling success for flatback turtle clutches remained low, with mean hatchling success of 62.74% for naturally incubated clutches and 72.64% for relocated clutches, and the mean emergence success of 56.05% and 71.37% respectively (Table 13). The causes of the continuing low emergence success from flatback clutches on the Woongarra Coast warrant further investigation.

Table 16: Summary of reproductive parameters of flatback turtle, *Natator depressus,* nesting on the Woongarra Coast, 2024-2025 breeding season, with data pooled across the age classes.

	MEASUREMENT				Sample size
	Mean	SD	Minimum	Maximum	
All Turtles					
Curved carapace length (cm)	94.19	3.17	87.80	98.90	12
Remigration interval (yr)	2.56	2.13	1	8	9
Eggs & clutches					
Number of clutches laid per season per female	2.92	0.67	2	4	12
Number of eggs per clutch	55.79	9.21	35	78	29
Yolkless eggs per clutch	Nil*	-	-	-	-
Multiyolked eggs per clutch	1*	***NaN	1	1	1
Mean egg diameter per clutch (cm)	5.12	0.08	5.00	5.22	110 eggs 11 clutches
Mean egg weight per clutch (g)	73.31	5.12	67.12	83.51	100 eggs 10 clutches
Nest depth to top egg	33.81	7.87	20.00	48.00	26
Nest depth to bottom	53.46	8.10	43.00	83.00	26
Hatchlings					
Mean hatchling length per clutch (cm)	6.03	0.26	5.45	6.34	138 hatchlings 18 clutches
Mean hatchling weight per clutch (g)	40.26	2.70	34.55	44.30	138 hatchlings 18 clutches
Incubation period to hatchling emergence (d)	53.39	4.57	48	64	18 clutches

*Calculated only from nests containing yolkless or multiyolk eggs

Table 17. Flatback turtle, *Natator depressus* nesting distribution on the Woongarra Coast, 2024-2025 breeding season.

Beach	NESTING CRAWLS (tracks)				
	Nesting Success (%) (± 95% CI)	Laid	Did Not Lay	Uncertain Nesting Success	Total Tracks (% by beach ± 95% CI)
Oaks	-	-	-	-	0
Mon Repos	74.4% ± 13.1%	32	11	-	43 (91.5% ± 8.0%)
Nielson Park	-	-	-	-	0
Bargara	-	-	-	-	0
Kellys	100% ± 0%	2	-	-	2 (4.3% ± 5.8%)
Archies	100% ± 0%	2	-	-	2 (4.3% ± 5.8%)
Rifle Range	-	-	-	-	0
Innes Park	-	-	-	-	0
Elliott Heads	-	-	-	-	0
TOTAL	**76.6% ± 12.1%**	**36**	**11**	**-**	**47**

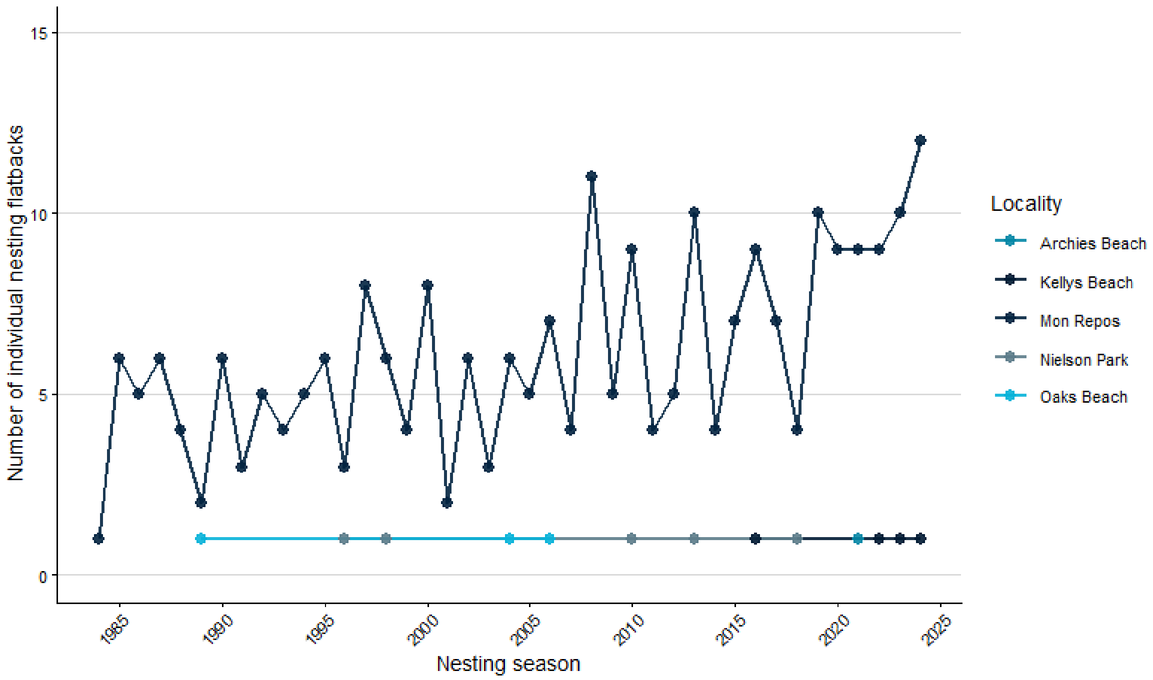


Figure 24: Summary of changing breeding numbers of flatback turtles, *Natator depressus*, on the Woongarra Coast, 1985-2024.

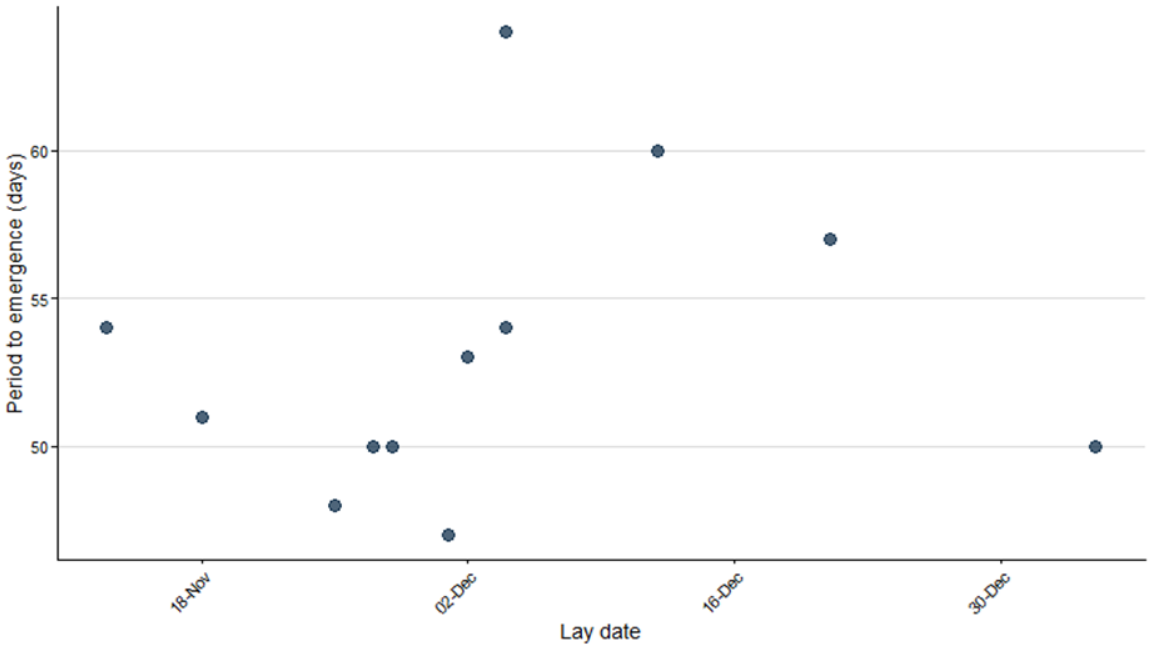


Figure 25: Incubation period from laying until hatchlings emerged onto the beach surface for flatback, *Natator depressus*, clutches laid on all beaches of the Woongarra Coast during 2023-2024 breeding season.

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