Gnaraloo Turtle Conservation Program

Day and Night Monitoring Program 2009/10
Final Report

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Gnaraloo would like to thank everyone involved with the GTCP during 2009/10 for their dedication, commitment and work during seven months of research and data analysis, including the turtle tracker teams and Gnaraloo staff who provided ongoing support in too many ways to mention throughout the season. Without you, we would not have had this program.

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					Colleen Mason, Marnie Bartley & Paul Richardson Gnaraloo Homestead area and 3Mile Camp
					Posted on **www.gnaraloo.com**

1 Copies also provided of Animal Pest Management Services (**APMS**), *Fox Management Project Technical Report for Gnaraloo*, November 2009 and APMS, *Fox Control Program for Gnaraloo Station, Turtle Predation Minimisation Project*, February 2010 (in relation to *Fox Control Project CC083432, Caring for our Country Community Coastcare 2008*).

2 Ibid.

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ABSTRACT

This report contains information on sea turtle nesting and hatching activities at monitored rookeries at Gnaraloo for the 2009/10 breeding season.

The *Gnaraloo Turtle Conservation Program* was modified during 2009/10 following the recommendations of the inaugural year's research during 2008/09 as well as due to logistical constraints on the night survey work. A Night monitoring component was added to the program during 2009/10, with four more team members.

This is the first study of both day and night research at Gnaraloo into sea turtle biology and behaviour. Further research over several seasons is required to establish conclusive baselines for the data obtained during the 2009/10 season. It is recommended that data in future years be cross-correlated with abiotic data sourced from an onsite weather station.

Day

Day monitoring at Gnaraloo occurred from 1 November 2009 - 28 February 2010.

The Total Study Area 2008/09 consisted of the area between the Gnaraloo Bay North marker and the Beach Point 10 marker (**GBN - BP10**). The Revised Day Study Area 2009/10 was limited to the area between the Gnaraloo Bay North marker and the Beach Point 9 marker (**GBN - BP9**).

Data gathered during Day research 2009/10 relating to the species composition of the monitored rookeries at Gnaraloo yielded results clearly identifying endangered Loggerhead turtles (*Caretta caretta*) as the predominant nesting species.

The density, frequency and distribution of sea turtle nests throughout the Revised Day Study Area 2009/10 resulted in 522 successful nests being recorded, with nesting activity peaking during late January 2010. Loggerhead turtles (*Caretta caretta*) were responsible for 402 of these nests, with Hawksbill turtles (*Eretmochelys imbricata*) and Green turtles (*Chelonia mydas*) laying 78 and 30 nests respectively.

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The number of nesting females at Gnaraloo (overall and per species) could not be determined during 2009/10.

Night

Night monitoring at Gnaraloo occurred from 1 January 2010 - 24 April 2010. Night research efforts were confined to the area between Beach Point 8 marker and Beach Point 9 marker (**BP8 - BP9**). This area was chosen for its high density of nests within a relatively small area.

Results presented and discussed in the night section pertain to Loggerhead (*Caretta caretta*) turtles only as the species most prevalent in the Night Study Area 2009/10.

Of the total 285 recorded nests in BP8 – BP9, a total of 49 (17.1%) hatched during the Night monitoring period. Night teams observed 44 of the 49 hatchings. The remaining 5 hatched nests displayed signs of emergence such as hatchling tracks emerging from 'cone' shaped depressions in front of nest marker stakes.

During the 2009/10 season, nest emergences were recorded from late January 2010 – mid April 2010, with the greatest proportion of emergences occurring during March 2010.

Incubation periods for hatched Loggerhead (*Caretta caretta*) nests within BP8 - BP9 ranged from 55 – 82 days, with the highest frequency of hatching at 60 - 70 days. Mean incubation time was 67.3 days. Nests dug earlier in the season (during November – December 2009) had longer incubation times (70.5 – 77.2 days) compared to those laid later in the season (during January – February 2010) (63.2 – 64.7 days).

The relatively low proportion of successful hatching nests may in part be attributed to **disturbances** by crab, fox and environmental conditions (the latter predominantly in the form of inundation of nests by tidal surges). Observed disturbances totalled 89.5% of the 285 nests within the Night Study Area 2009/10, inclusive of Golden ghost crab (*Ocypode convexa*) (132 egg chambers) (46.7%), Fox (*Vulpes vulpes*) (27 egg chambers) (9.5%) and environmental disturbances (92 egg chambers) (33.3%). A number of nests had a combination of disturbances.

Environmental disturbances in the form of tidal inundation of nests seemed to be largely concentrated to an area of the subsection called Turtle Bay, suggesting that there may be a relationship between location and inundation. Fox baiting was carried out throughout the

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2009/10 monitoring season and whilst this reduced the number of nests disturbed shortly following baiting, after time it did not appear to decrease the number and rate of nest disturbance by foxes. This indicates that the fox population was quickly replenished at Gnaraloo over the 2009/10 season.

A total of 1547 hatchlings were observed emerging from 44 nests. A total of 1126 (72.7%) hatchlings reached the water successfully, 190 (12.3%) were **predated** [inclusive of both Golden ghost crab (*Ocypode convexa*) and Fox (*Vulpes vulpes*)] and the fate of 231 (14.9%) hatchlings was not known. Ghost crabs were the biggest observed onshore predator of hatchlings, taking 185/190 (12%) predated hatchlings, with foxes only observed taking 5/190 (0.3%).

From the 44 nests observed to hatch, there were 109 recoded temporally discrete emergence events, with emergences for individual nests ranging from 1 – 6 days during the 2009/10 season. Emergence events were recorded between 19h00 - 06h00 within the Night Study Area 2009/10. Peak activity was found between 19h00 - 02h00, with emergence numbers staying roughly consistent through that period with a peak at around 24h00. Emergence activity in the night research area dropped dramatically after 02h00 hours.

Of the 44 nests observed to hatch by Night researchers, all were Loggerhead (*Caretta caretta*): 35/44 nests (79.5%) had previously correctly been identified by the Day team (based on track analysis) and 9/44 nests (20.5%) had been incorrectly identified by the Day team [6 nests were misidentified as Hawksbills (*Eretmochelys imbricate*) and 3 as Green turtles (*Chelonia mydas*)].

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BACKGROUND

Gnaraloo Station is situated adjacent to the *Ningaloo Marine Park* (**NMP**), on the Ningaloo coast within north western Australia. NMP is home to a number of significant sea turtle rookeries, with Loggerhead (*Caretta caretta*), Green (*Chelonia mydas*), and Hawksbill (*Eretmochelys imbricate*) turtles nesting in large numbers on the Gnaraloo coastline. The IUCN Red List currently classifies the Loggerhead and Green turtles as endangered species, with the Hawksbill turtle being listed as critically endangered species.

Gnaraloo developed and since 2008/09 has managed the *Gnaraloo Turtle Conservation Program* (**GTCP**) to monitor and protect sea turtle rookeries on its coastline, through the engagement of volunteers and guidance by the Department of Environment and Conservation (**DEC**), Exmouth District, Western Australia. The Day component of the GTCP is based on the *Ningaloo Turtle Program* (**NTP**) in Exmouth, a community partnership between DEC, the Cape Conservation Group and WWF. The GTCP contributes to the protection of endangered marine species and critical coastal habitat, biodiversity conservation, informed management activity and increased awareness and community engagement in conservation issues. The Gnaraloo program concerns Loggerheads as distinguished from the conservation work at Exmouth which focuses predominantly on Green turtles.

The GTCP has developed further over the 2009/10 monitoring season. Under arrangements with Gnaraloo, DEC provides ongoing scientific and technical advice, training and support to the program while Gnaraloo executes onsite monitoring activities. This includes attracting and managing the required scientific and community volunteers, daily data collection and entry into required databases, end-of-season data analyses and production of reports. DEC undertakes onsite inspections of the GTCP, which occurred during both 2008/09 and 2009/10. During the 2009/10 season, the program also hosted visits by representatives from Government, Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) (Tasmania), Curtin University (West Australia) and Edith Cowan University (West Australia).

The GTCP is supported by a complimentary predation control program managed by Gnaraloo, with support from DEC. The *Gnaraloo Fox Control Program* commenced during 2008/09, with contributory funding from the Australian Government (*Caring for our Country, Community*

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Coastcare). Gnaraloo developed this feral predation minimisation program as an essential accompaniment to the GTCP. The sole objective of the fox program is to protect turtle rookeries at Gnaraloo and reduce critical threats to egg chambers and hatchlings during the annual breeding season. It is not linked or directed at enhancing economic or pastoral production. Gnaraloo identifies and addresses linkages between the annual turtle and fox control programs, including essential liaison with third party contractors and State agencies, to provide recommendations for informed and adaptive management for most effective and efficient on-ground protection of the Gnaraloo rookeries.

ABOUT G TURTLE TRACKER TEAMS AND WORK DURING 2009/10

The GTCP is undertaken under the ongoing guidance and direction of Gnaraloo's Environmental Advisor, Karen Hattingh. Ms. Hattingh is an experienced environmental scientist who ensures overall planning, development, coordination and adaptive management of the GTCP for responsible protection of Gnaraloo rookeries. Ms. Hattingh oversees on-ground monitoring activities by volunteers as well as seasonal data analysis and reporting. Ms. Hattingh has assisted Gnaraloo with advice and management of operational activities since 2005 when the current leaseholder commenced onsite.

Following the successful development and utilization of the *Gnaraloo Scientific Volunteer Recruitment Program* during 2008, Gnaraloo again employed the program in 2009 to recruit required volunteers (6) for the 2009/10 research season. This effort focused on attracting capable candidates from local, national, and international fields.

Jessica Leonard and Amy James were appointed to form the Day team 2009/10, comprising of a Team Leader and a Second-in-Command. Ms. Leonard received accreditation as a Marine Biologist from the University of Alberta, Canada, while Ms. James is a Zoologist from Michigan State University, United States of America. Ms. Leonard was appointed as the Team Leader due to her previous experience working with sea turtles in Alberta, Canada.

Michael Williamson, John-Michael Stuart, Purusha Boelling and Sergio Jacomy were appointed as the Night teams 2009/10. Mr. Williamson received accreditation as a Zoologist from the Institute of Zoology, United Kingdom and Mr. Stuart qualified as an Environmental Biologist from Curtin University, Western Australia. Mr. Boelling received an Environmental Scientist

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designation from Murdoch University, Western Australia, and Mr. Jacomy had prior extensive experience with sea bird and mammal rescue. Based on their prior work with sea turtle conservation programs in South America, Mr. Williamson and Mr. Stuart were appointed as Team Leaders. Mr. Jacomy left the Night program on 16 March 2010 and was replaced by Ms. James (Day team member 2009/10) who continued as part of the Night monitoring teams, to completion of on-ground research effort, final data analysis and reporting.

Under the guidance of Gnaraloo's Environmental Advisor, the Day and Night turtle teams furthered the development of the research program during 2009/10. This included review of numerous reference documents related to turtle research and conservation programs, both prior to the commencement of formal monitoring activities as well as continuously throughout the research season. These efforts resulted in the *Turtle Monitoring Procedure 2009/10* (Hattingh *et al*., 2010).

Prior to commencement of formal monitoring activities, over a 4 day period during October 2009, Keely Markovina, then a certified *Turtle Scout* and *Trainer of Volunteer Turtle Trackers* under the *Ningaloo Turtle Program* (**NTP**) in Exmouth, provided onsite training and assessment to the Day team as *NTP Turtle Trackers*. This included turtle track identification and monitoring protocols as well as correct entry and management of the daily monitoring data. Ms. Markovina also provided refresher demonstrations and training to Gnaraloo's Environmental Advisor in beach track monitoring protocols and procedures.

The Day team commenced onsite beach monitoring, data collection and database entry work on 1 November 2009. The program undertook 4 months of daily monitoring activities along the coastline to correspond with the average turtle nesting season at Gnaraloo, extending until 28 February 2010. All data collected during beach monitoring activities was entered daily into both the *Gnaraloo Turtle Monitoring Workbook* (Excel) as well as a site copy of the *Ningaloo Turtle Program Database* (Access) developed by DEC (Exmouth District).

In order to assist with the design and development of the night research program 2009/10, Sergio Jacomy arrived at Gnaraloo during early December 2009. Mr. Jacomy accompanied the Day team during their daily beach monitoring activities as well as reviewed and considered numerous examples of night monitoring activities conducted by other sea turtle research programs. Mr. Stuart and Mr. Boelling arrived onsite later during December 2009, and together with Mr. Jacomy, they completed the development of the night monitoring program 2009/10.

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In order to allow adequate time for nest incubation, the night monitoring season commenced on 1 January 2010, 60 days after the nesting season commenced at Gnaraloo. Mr. Williamson, the final member of the night monitoring teams, arrived at Gnaraloo during early January 2010. All data collected during night monitoring activities was entered daily into the *Turtle Night Workbook* (Excel) and *Turtle Night Data Spreadsheet* (Excel).

Gnaraloo's Environmental Advisor undertook two site inspections during the 2009/10 monitoring season: firstly during October 2009 (immediately prior to and during commencement of the Day monitoring activities) and again during March 2009 (to review and guide on-ground activities as well as host the annual program inspection by DEC).

Senior officers of DEC (Exmouth District) carried out a program inspection during March 2010. During such time, Gnaraloo's Environmental Advisor and the Night teams 2009/10 provided a power point presentation detailing the activities, procedures and preliminary results of the Night monitoring program. Following the presentation, the DEC officers accompanied the Night teams on a night monitoring event. While no hatching events were witnessed at the time, the step-by-step monitoring procedures were outlined and the DEC officers were able to experience the unique Gnaraloo field conditions. The presentation and night tour were repeated during March 2010 for representatives of CSIRO (Tasmania), Curtin University (West Australia) and Edith Cowan University (West Australia).

The turtle teams produced summaries with preliminary results throughout the monitoring season for review by Gnaraloo's Environmental Advisor. One of the Day team members, Ms. James, travelled to Geraldton during February 2010 for a 5-day period to work directly under the guidance of Gnaraloo's Environmental Advisor to develop and enhance required templates for the Gnaraloo turtle monitoring procedure 2009/10 and the final season-end report (Day and Night) 2009/10. This work was completed during March 2010, when the other Day team member, Ms. Leonard, attended Geraldton for a 8-day period to complete data analysis and season-end reporting of the Day results 2009/10. The night teams, comprising of Mr. Williamson, Mr. Stuart, Mr Boelling and Ms. James, undertook data analysis and season-end reporting of the Night results 2009/10 over a 8-day period in Geraldton during April – May 2010.

The season-end report 2009/10 will be provided to DEC (Exmouth District) upon completion to contribute to the information base and knowledge of Ningaloo sea turtles.

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All members of the *Gnaraloo Turtle Tracker Teams 2009/10* are enthusiastic scientists who are passionate about the research and preservation of threatened marine species. Considerable time and effort was contributed to the furthered development and implementation of the GTCP by these individuals, with the goal of collecting reliable data to assist in the management of sea turtles in both local populations and worldwide.

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1 INTRODUCTION

Six sea turtle species are known to breed in Australian waters[3]. Three of those species are known to nest at Gnaraloo, a pastoral station located approximately 150 kilometres north of Carnarvon, in Western Australia. Of these species, Loggerhead (*Caretta caretta*) and Green (*Chelonia mydas*) turtles are listed as endangered while Hawksbill (*Eretmochelys imbricata*) turtles are listed as critically endangered (IUCN's Red List 2010). These species have become more endangered since formal turtle research commenced at Gnaraloo during the 2008/09 breeding season, when Green and Hawksbill turtles were both listed as vulnerable. The status of Loggerhead turtle populations has remained endangered.

As turtle populations have been on the decline worldwide, studying these species' primary nesting sites within Australia is of utmost importance. The *Gnaraloo Turtle Conservation Program* is in its second year of operation under the initiative of the Gnaraloo leaseholder, Paul Richardson, and guidance and direction of Gnaraloo's Environmental Advisor, Karen Hattingh.

Gnaraloo comprises of a 90,000 hectare area, with approximately 65 kilometres of coastline. Of those 65 kilometres, 7 kilometres were monitored daily by GTCP researchers during 2009/10. The research included day and night monitoring programs, running a total of 6 months over the nesting and hatching season. The Day monitoring operated from 1 November 2009 - 28 February 2010, whilst the night monitoring operated from 1 January 2010 - 24 April 2010, having a 2 month overlap period from 1 January 2010 to 28 February 2010.

Long term goals of the GTCP include determination of the significance of Gnaraloo rookeries to turtle populations globally as well as development of useful and effective management structures for the conservation and protection of Gnaraloo turtle populations. It also aims to create community awareness and support for the conservation of all sea turtles and their environments. Specifically, the objectives of the GTCP are as follows:

3 According to the Great Barrier Reef Marine Park Authority of the Australian Government.

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Overall

- Identify significant rookeries, relative significance, trends and management issues for sea turtles along the Gnaraloo coastline to assist conservation of endangered species and biodiversity protection.
- Contribute to establishment of baseline for sea turtle populations along the Gnaraloo coastline, an area for which there is very little such existing scientifically verified information or data.
- Provide reliable and beneficial data for conservation of Gnaraloo sea turtles, including informed management activity.
- Engage the community through volunteer activity and increase public awareness of conservation issues.
- Educate scientific volunteers and visitors about sea turtles and their conservation.

Day

- Identify the number of nests, distribution trends and number of breeding females at monitored nesting sites along the Gnaraloo coastline.
- Identify incubation periods at monitored nesting sites along the Gnaraloo coastline.
- Identify the level of predation of turtle nests by native and feral predators.
- Determine the significance of key monitored rookeries along the Gnaraloo coastline.
- Through aerial survey, identify and confirm any additional potential significant rookeries along the Gnaraloo coastline.
- Monitor the conservation status of sea turtle populations at key monitored rookeries along the Gnaraloo coastline.

Night

- Determine nest emergence success rates within night study area, including location impacts on nests.
- Determine predation rates of egg chambers and neonates by native and feral predators within night study area.
- Confirm species identification by day team [Comparison Day findings (tracks only) vs. Night results (hatchlings) in night study area].

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- Determine frequency of hatched nests in night study area with previous history of disturbances by predators [Comparison Day findings (based on observed disturbances) vs. Night results (based on observed emergences from nests previously recorded as disturbed)].
- Determine breeding success rate[4] in night study area.

2 FUNDING AND RESOURCING

During the inaugural 2008/09 season, the GTCP was funded by the Gnaraloo leaseholder with contributory funding support by the Australian Government (*Envirofund Round 10*). During the 2009/10 season, all financial and in-kind contributions to the GTCP (including the on-ground Day and Night research programs described in this report as well as subsequent technical data analysis and report production in Geraldton) were provided solely by the Gnaraloo leaseholder.

3 GNARALOO FOX CONTROL PROGRAM

The *Gnaraloo Fox Control Program* was developed as a partnership between Gnaraloo leaseholder and DEC during 2008. It is a separate, complementary program to the *Gnaraloo Turtle Conservation Program* and is conducted with support by a licensed third party pest controller, namely Animal Pest Management Services (**APMS**). The objectives of the program are to minimise towards zero all fox disturbance and predation of turtle rookeries (egg chambers and hatchlings) on beaches along the coast of Gnaraloo Station. For an overview of the program, refer to reports by APMS (December 2008, January 2009, November 2009 and February 2010).

4 G TURTLE MONITORING PROCEDURE

The methodologies and protocols employed during the 2009/10 research season are described in Gnaraloo's *Turtle Monitoring Procedure 2009/10* (Hattingh *et al*., 2010). Day research procedures are based on the beach monitoring and data management practices developed and

4 'Successful breeding' defined as hatchling entry into the water (refer Glossary).

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maintained by DEC for the *Ningaloo Turtle Program*, including the *Guide to Turtle Track Beach Monitoring in Australia* (DEC, Lewis *et al*. 2008). Night research procedures are based on research carried out in Australia and overseas and were developed under the guidance of Gnaraloo's Environmental Advisor.

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5 DAY MONITORING

5.1 Results

5.1.1 Track monitoring

5.1.1.1 Summary of Revised Day Study Area 2009/10

During the Day monitoring season, a total of 522 nests were recorded within the Revised Day Study Area 2009/10 (refer Figure 1 below).

Loggerhead (*Caretta caretta*) turtle nests were predominantly recorded in the Revised Day Study Area 2009/10. In total (refer Figure 1),

- Loggerheads accounted for 402 nests of the 522 laid during the monitored period;
- Hawksbills (*Eretmochlys imbricata*) for 78 nests;
- Greens (*Chelonia mydas*) for 30 nests;
- 12 nests were unable to be identified due to track erosion.

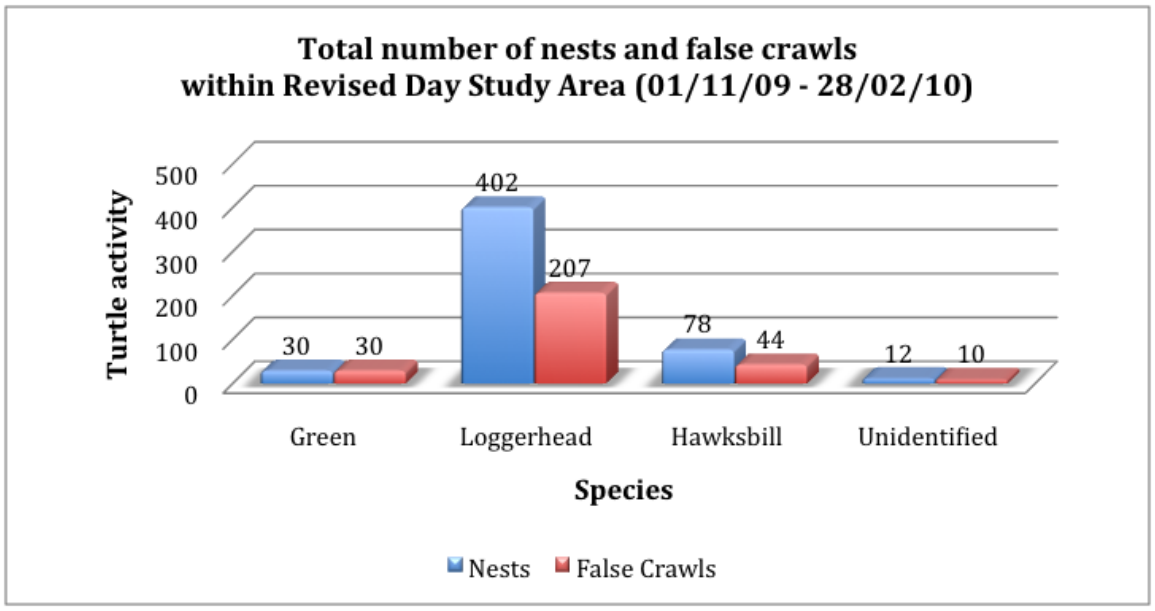

Figure 1: Total number of nests and false crawls within Revised Day Study Area (01/11/09 - 28/02/10)

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There was a total of 813 tracks in the Revised Day Study Area 2009/10. This included 291 false crawls, 207 of those were Loggerhead (refer to Figure 1 above).

As can be seen in Figure 2, the Total Study Area was predominately nesting Loggerhead (*Caretta caretta*) turtles. In total, Loggerheads accounted for 402 nests of the 522 laid, followed by the next largest percentage of Hawksbill (*Eretmochlys imbricata*) turtles with 78 nests. Green (*Chelonia mydas*) turtles accounted for 30 nests and only 12 nests were unable to be identified due to track erosion. The nests recorded in the Revised Day Study Area 2009/10 per day per species can be seen in Figure 3.

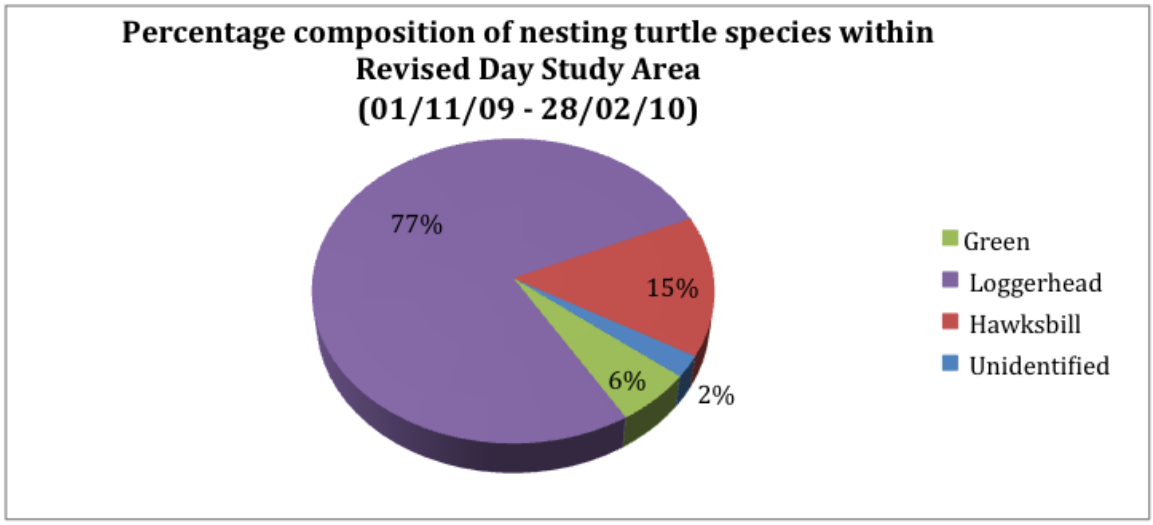

Figure 2: Percentage composition of nesting turtle species within Revised Day Study Area (01/11/09 - 28/02/10)

As Figure 3 demonstrates, there were peaks in nesting activity witnessed in both late December 2009 and mid-January 2010. It can also be noted that nesting activity remained relatively similar between all species of sea turtles in the Revised Day Study Area 2009/10.

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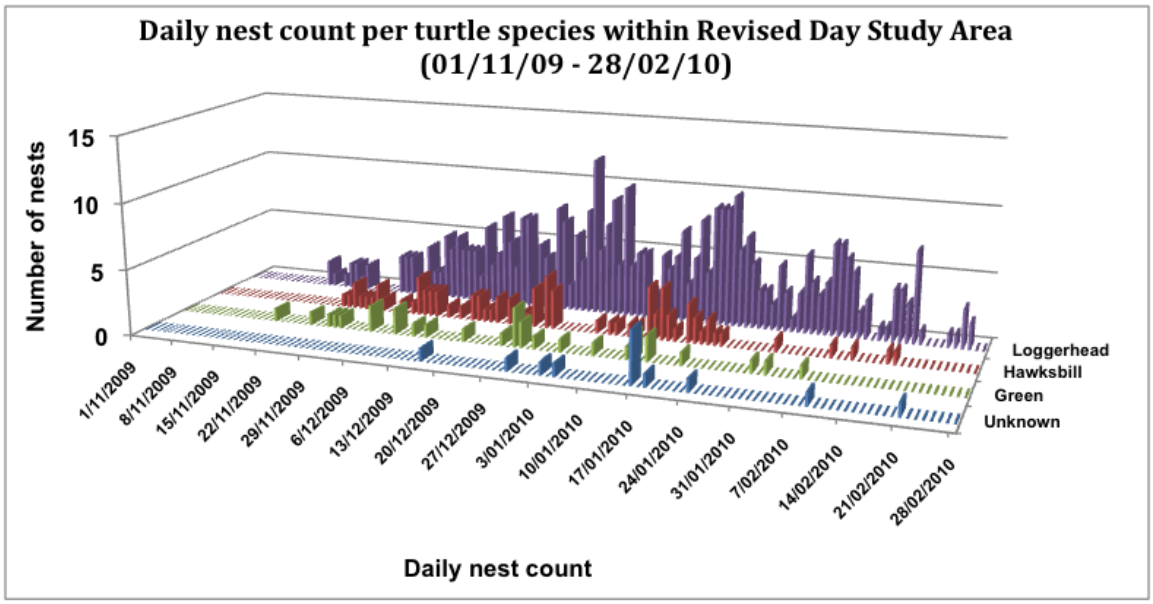

Figure 3: Daily nest count per turtle species within Revised Day Study Area (01/11/09 - 28/02/10)

For a breakdown of coastal nest distribution trends, please refer to the Maps document.

In an attempt to determine the number of nesting females in the Revised Day Study Area 2009/10 formulaically, Mr. Bob Thomson of the Mon Repos research facility in Bundaberg, Queensland, was contacted. Mr. Thomson provided two research papers by Dr Col Limpus[5].

Upon review of these documents, no nesting female formula was observed. It became apparent that nesting females are identified physically in the population, by performing laparoscopic examinations (Limpus & Limpus, 2003) as well as by measuring curved carapace length (CCL) using a flexible fibreglass tape (Limpus *et al*., 2006). Additionally, observing tagged turtles returning to nesting beaches is also used to count numbers of breeding females. As data was collected most conservatively in the 2009/10 study season, the Day team had no physical contact with nesting females whatsoever and only monitored their tracks.

As can be seen in Figure 4 below (green line), nesting began on 15 November during the 2009/10 Day Monitoring season and climbed to approximately 45 nests per week, where it stayed relatively constant until mid-January 2010. Peaking at 67 nests during the week ending

[5] (1) *Queensland Turtle Conservation Project: Monitoring marine turtle population dynamics in Moreton Bay Marine Park, 2005-2006 and* (2) *Biology of the Loggerhead Turtle in Western South Pacific Ocean Foraging Areas*.

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23 January, nesting frequency gradually abated throughout the remainder of the monitoring season where in the final week 8 new nests were recorded (Figure 4). Looking at the cumulative nest total line (red line in Figure 4), a very minimal slope from 1 November 2009 until 5 December 2009 may be observed, indicating a lower amount of nesting activity per week. Following this, the slope rose sharply and continued to rise at a similar gradient until 30 January 2009, indicating a high amount of nesting activity per week. Nesting activity then lessened considerably throughout February 2010.

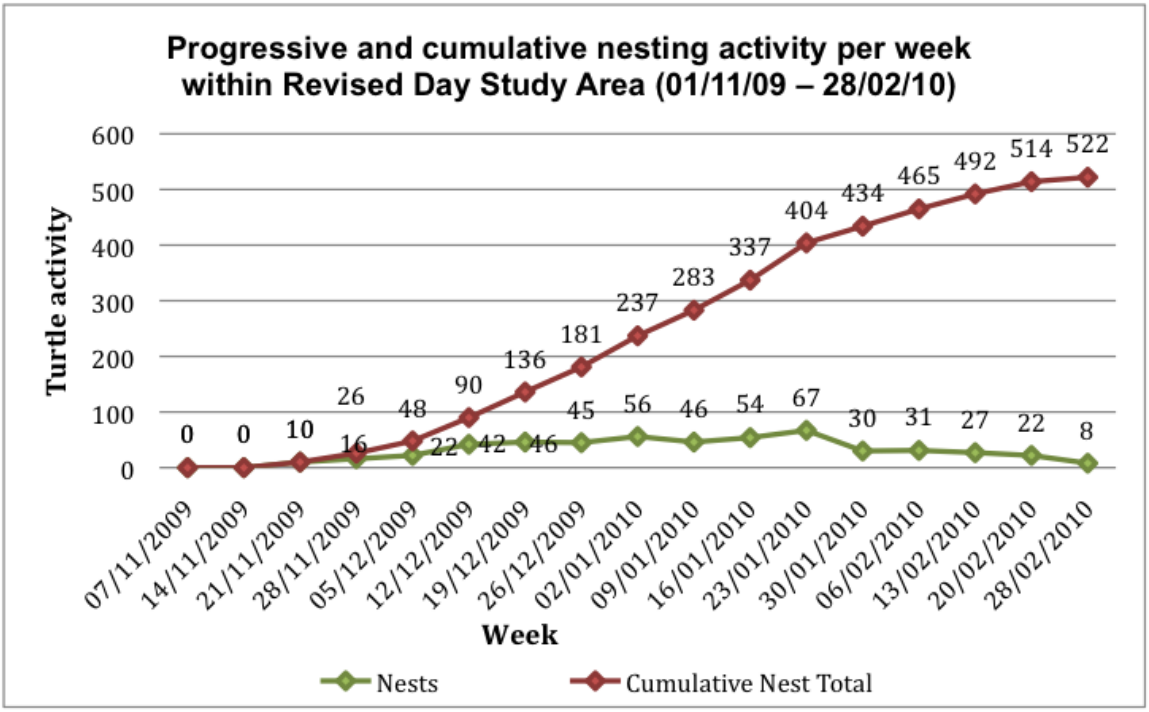

Figure 4: Progressive and cumulative nesting activity per week within Revised Day Study Area (01/11/09 – 28/02/10)

As can be seen in Figure 5 below, sea turtle nesting activity in the Revised Day Study Area 2009/10 was present throughout the majority of the monitoring season. After the first recorded nest on 15 November 2009, the nesting frequency (green line) steadily increased until 19 December 2009 and remained relatively constant until the season's peak during the week of 23 January 2010. From the week ending 6 February until the end of season, nesting frequency steadily decreased to 8 new nests recorded in the final week of monitoring. Total turtle activity per week within the Total Study Area shows the combined nesting and false crawl activities (red line) peaked the week of 19 December 2009 and again during 23 January 2010.

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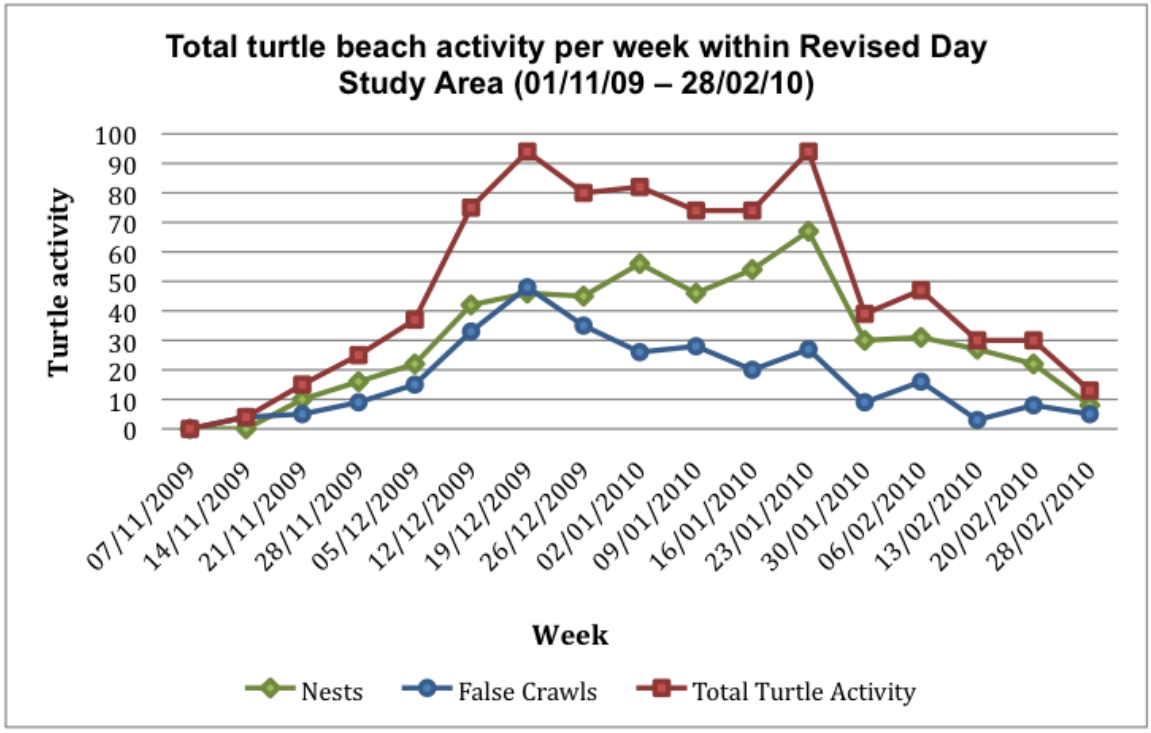

Figure 5: Total turtle beach activity per week within Revised Day Study Area (01/11/09 – 28/02/10)

The incubation period for the nests ranged from 52 to 82 days with the highest frequency hatching at between 61 and 64 days. In Figure 6, orange bars represent the nests dug in the first 30 days of monitoring, and purple bars represent those laid later in the season. It can be said that nests that were laid earlier in the season required longer incubation periods than those nests that were laid later in the season.

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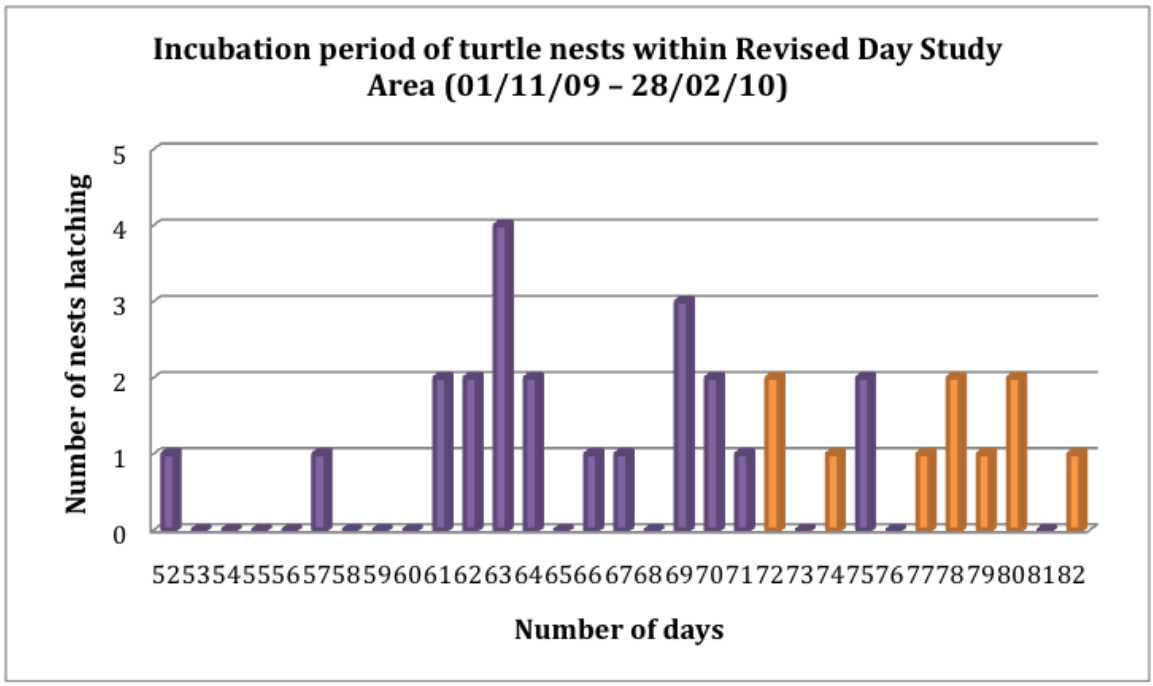

Figure 6: Incubation period of turtle nests within Revised Day Study Area (01/11/09 – 28/02/10)

Data recorded during daily Day monitoring activities indicated nest disturbances within the Revised Day Study Area 2009/10 during the Day monitoring period as follows (refer to Table 1 below) (**Note:** 'disturbance' does not necessarily equate to 'predation', refer to Glossary for definitions used):

- observed Golden ghost crab (*Ocypode convexa*) disturbances recorded the highest percentage of nest disturbances within the Revised Day Study Area 2009/10 (37.93%);
- observed nest disturbances by Foxes (*Vulpes vulpes*) totalled 6.51%;
- observed nest disturbances by environmental factors totalled 4.02%.

Table 1: Observed nest disturbances within Revised Day Study Area (01/11/09 - 28/02/10)

Type of disturbance	Golden ghost crab (*Ocypode convexa*)	Fox (*Vulpes vulpes*)	Environmental conditions
Revised Day Study Area	37.93%	6.51%	4.02%

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Disturbance did not necessarily preclude a nest from hatching (refer Table 2 below):

- 6.13% nests (32) were observed to hatch within the Revised Day Study Area 2009/10 during the Day monitoring period (using hatchling and track observation as indicators of emergence), 10 of those nests had recorded disturbance as some point in the incubation period [disturbances included one or more of the following: Golden ghost crab, Fox, and/or Environmental (refer Glossary for definitions)];
- the majority of nests (93.87%) within the Revised Day Study Area 2009/10 were unknown to have hatched (as incubation periods extended to outside the Day monitoring period 2009/10).

Table 2: Observed nest status in Revised Day Study Area (01/11/09 - 28/02/10)

Nest activity	Nests hatched with no recorded disturbance	Nests hatched with recorded disturbance	Undetermined
Revised Day Study Area	4.21%	1.92%	93.87%

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5.1.2 Fox tracks and nest disturbances in Revised Day Study Area

The Day monitoring season during 2009/10 consisted of 120 sample days. Fox tracks were recorded within the Revised Day Study Area 2009/10 for 104 out of 120 sample days (85% of the time) (refer Figure 7).

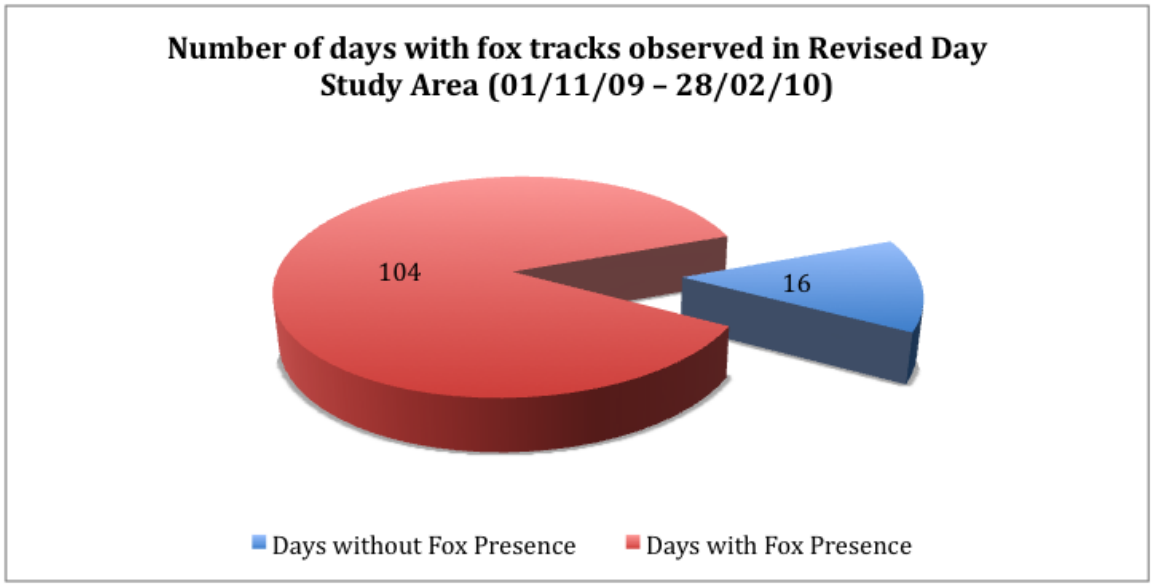

Figure 7: Number of days with Fox (*Vulpes vulpes*) tracks observed in Revised Day Study Area (01/11/09 – 28/02/10)

Fox tracks were observed on all beaches within the Revised Day Study Area 2009/10 and were frequent throughout all subsections. Throughout the Day monitoring season (refer Figure 8):

- fox tracks were most persistent in Beach Point 6 – Beach Point 7 (**BP6 – BP7**), with 93 out of 120 sample days recording fox tracks;
- **GBN - BP6** had fox tracks 71 out of 120 sample days;
- **BP7 - BP9** had fox tracks 61 out of 120 sample days.

Note: the values indicated in Figure 8 for 'Number of days with fox tracks' overlap (with particular fox tracks recorded in more than one sub-section on a particular day), resulting in the values shown in Figure 8 not adding up to the 104 days with fox tracks shown in Figure 7.

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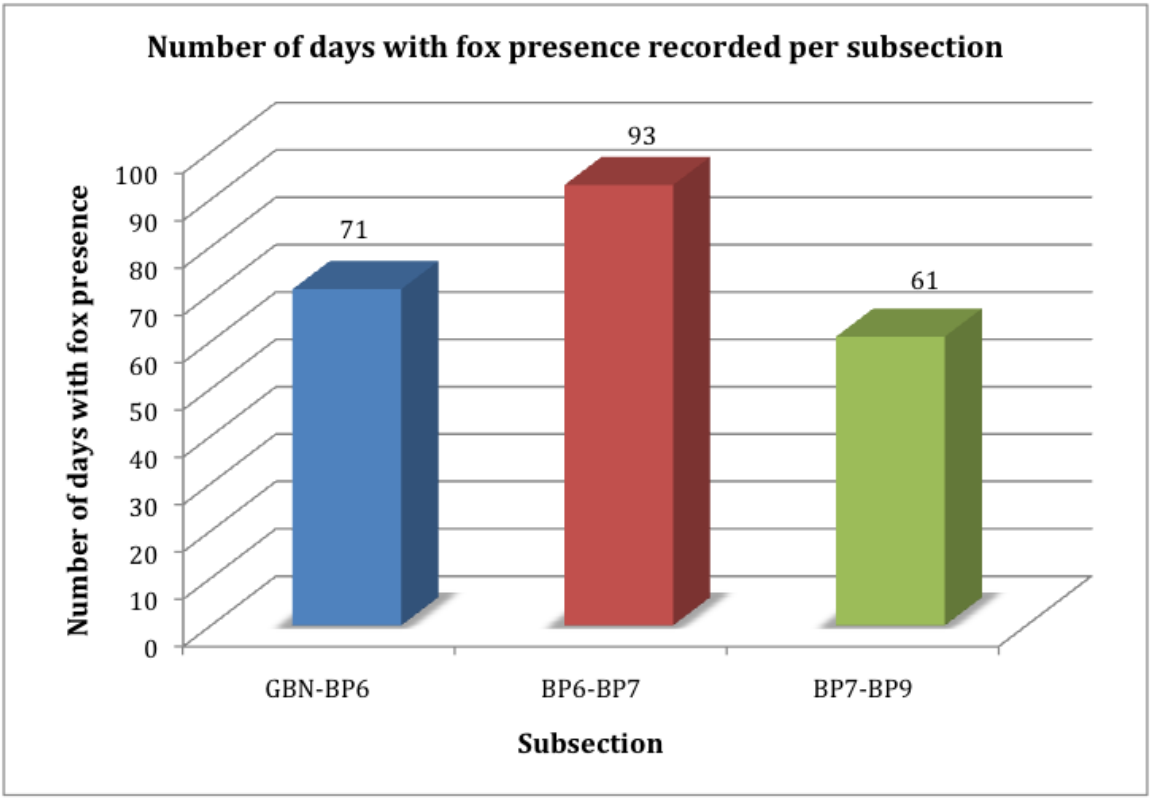

Figure 8: Number of days with Fox (*Vulpes vulpes*) tracks observed per sub-section within Revised Day Study Area (01/11/09 – 28/02/10)

For the purposes of the 2009/10 Day monitoring program, nests were recorded as **disturbed** by foxes when digging into the nest was evident, with or without turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.

Fox tracks were observed throughout the Revised Day Study Area 2009/10 for the majority of the Day monitoring period (104/120 sample days), but nest disturbances by foxes did not begin to take place until the first week of December 2009 and continued to the end of the Day monitoring season on 28 February 2010 (refer Figure 9 below). All sub-sections were subject to nest disturbances by foxes during 2 December 2009 - 28 February 2010, with BP7 - BP9 experiencing the highest frequency of nest disturbances by foxes.

A total of 6.51% of nests (34/522 nests) were disturbed by foxes within the Revised Day Study Area 2009/10 during the Day monitoring period (**Note:** 'disturbance' does not necessarily equate to 'predation', refer to earlier discussion and to Glossary for definitions used).

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Three nests were disturbed repeatedly for a total of 38 disturbance occurrences during the 2009/10 Day monitoring period (36 of those occurrences took place after 1 January 2010).

Although fox control efforts were consistent throughout the Day monitoring season, they failed to completely eradicate fox tracks and nest disturbances by foxes within the Revised Day Study Area 2009/10 (refer Figure 9).

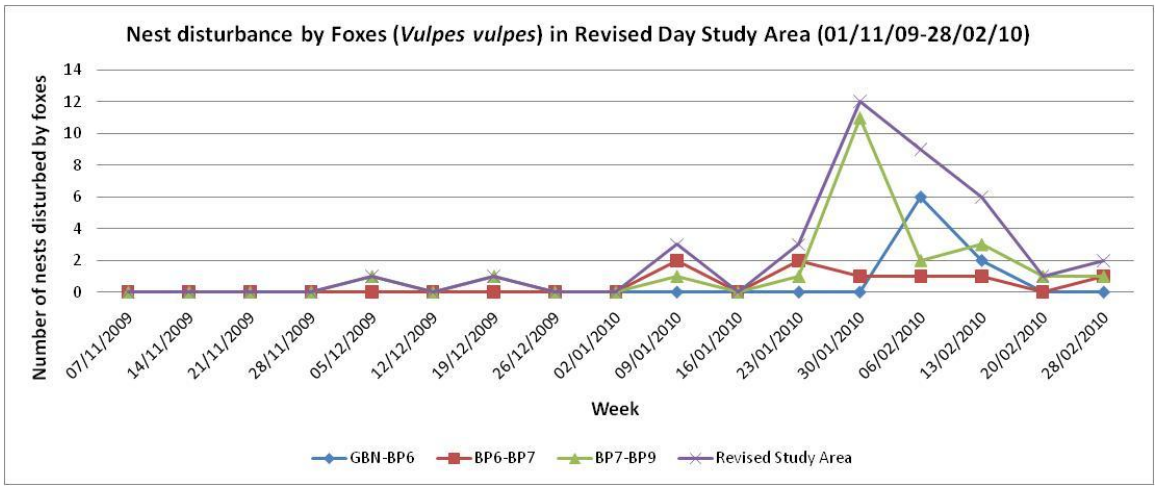

Figure 9: Nest disturbance by Foxes (*Vulpes vulpes*) in Revised Day Study Area (01/11/09 – 28/02/10)

Note: An 'occurrence' of fox disturbance was a temporally discrete event separated by at least a 24-hour period in monitoring. A new occurrence was recorded when signs of fresh diggings were witnessed.

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5.1.3 Nest disturbances by crabs

The Golden ghost crab (*Ocypode convexa*) is common along the Gnaraloo coastline. Besides the Golden ghost crab, there are other species of Ghost (or Sand) crabs that were observed within the Revised Day Study Area 2009/10. Running ghost crab (*Ocypode ceratophthalma*) was the only other species positively identified, but there is thought to be a minimum of 2 additional morphologically distinct but unidentified species. None of these species were observed to predate the sea turtle nests, but it is recommended that further investigation be done in future to see whether or not this holds true.

The Golden ghost crab is a native species that is abundant in the Revised Day Study Area 2009/10. For the purpose of the Day research, disturbance by Golden ghost crabs was recorded when there was any evidence of burrowing activity into the nest (refer to Glossary). As egg chamber exhumations are not currently being performed as part of the GTCP, without egg shells present at the surface, it cannot be determined whether or not the crabs successfully reached an egg chamber or whether the burrowing was simply coincidental. Nests with repeated Golden ghost crab disturbances were still observed to hatch during the 2009/10 Day monitoring season (refer Table 2), which indicates that the extent of the damage done cannot be assessed from the surface.

A total of 198/522 nests (38%) within the Revised Day Study Area 2009/10 were recorded to be disturbed by Golden ghost crabs during the Day monitoring season (refer Figure 10).

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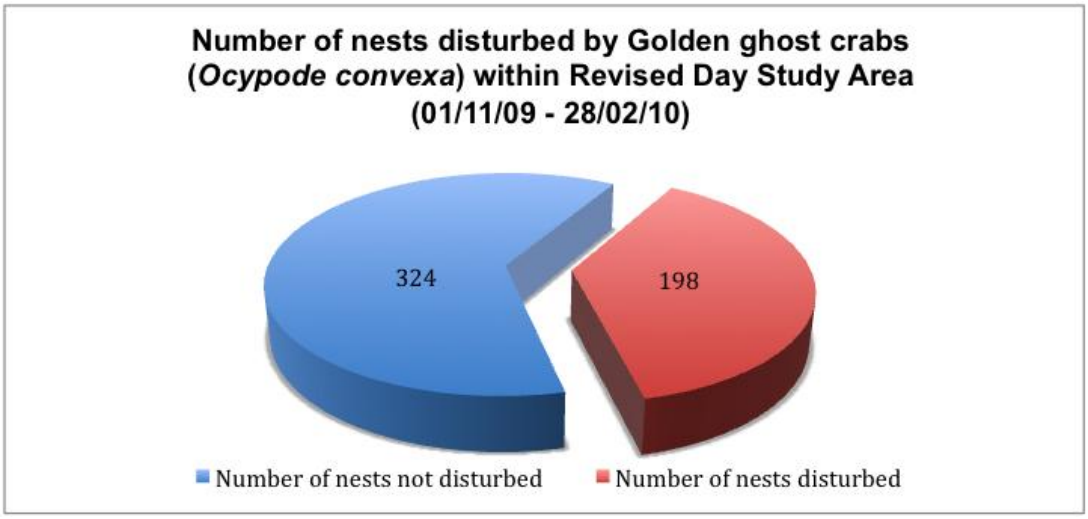

Figure 10: Number of nests disturbed by Golden ghost crabs (*Ocypode convexa*) in the Revised Day Study Area (01/11/09 - 28/02/10)

As can be seen in Figure 11, BP7 - BP9 had the highest frequency of nests disturbed by Golden ghost crabs.

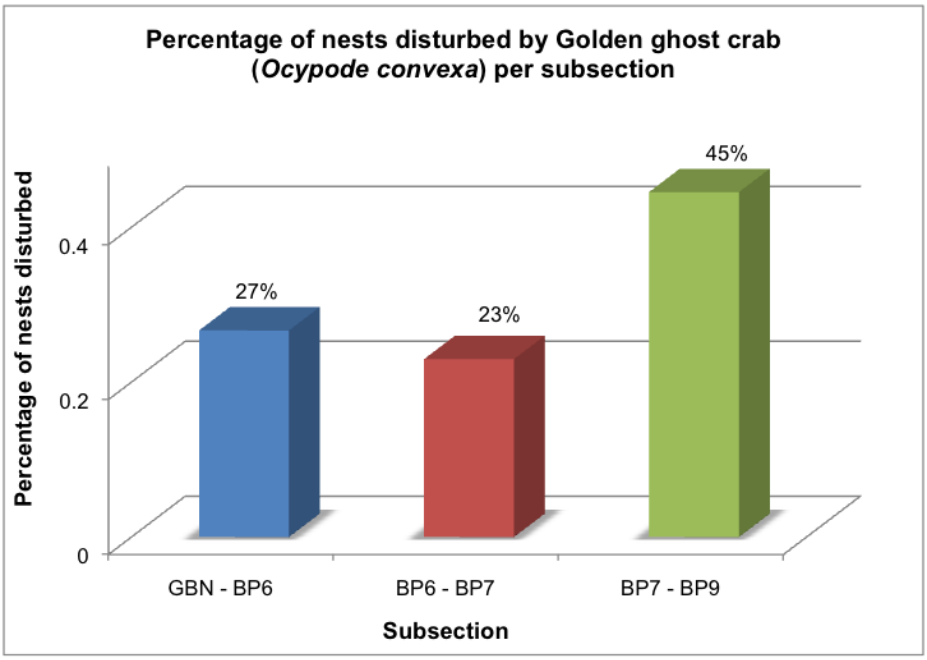

Figure 11: Percentage of nests disturbed by Golden ghost crab (Ocypode convexa) per subsection

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Subsection GBN – BP6 consisted of 30 nests, approximately 27% with observed disturbances by Golden Ghost Crabs (*Ocypode convexa*) (refer Figure 12 below). This flat, stable beach is sheltered by the offshore fringing reef and has little environmental debris (seaweed, etc) deposited on its shores.

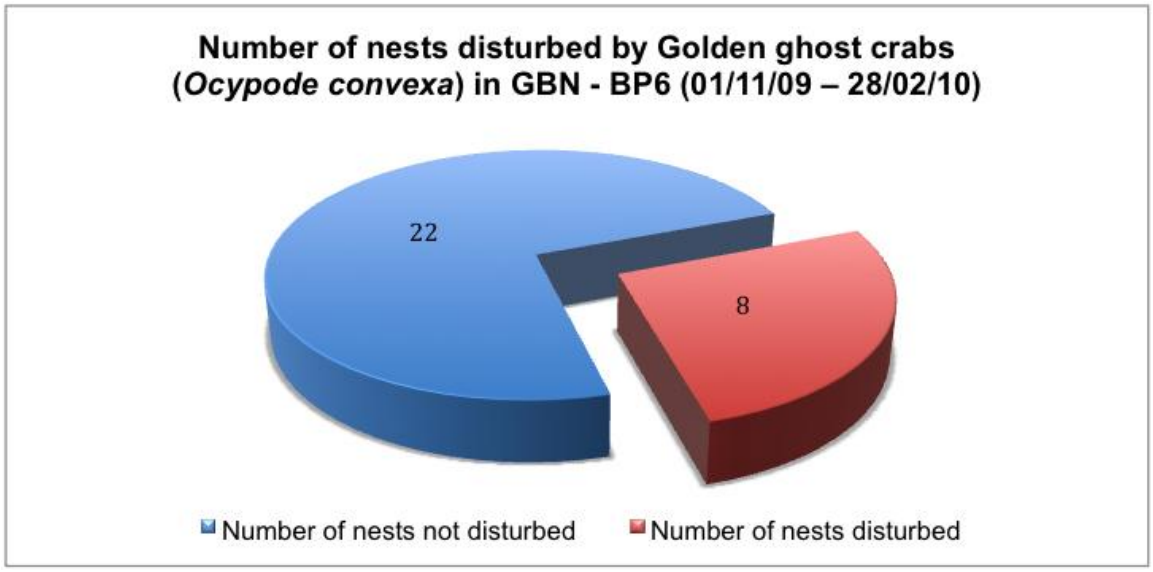

Figure 12: Number of nests disturbed by Golden Ghost Crabs (*Ocypode convexa*) in GBN - BP6 (01/11/09 – 28/02/10)

Similar to GBN - BP6, BP6 – BP7 had a relatively low percentage of predation (refer Figure 13 below). With 135 nests recorded in this subsection, only 22% of nests were disturbed by Golden Ghost Crabs (*Ocypode convexa*). This subsection contains more dynamic beaches with still very little environmental debris on shore (seaweed, etc) which may have an impact on the presence of Ghost Crabs in this area.

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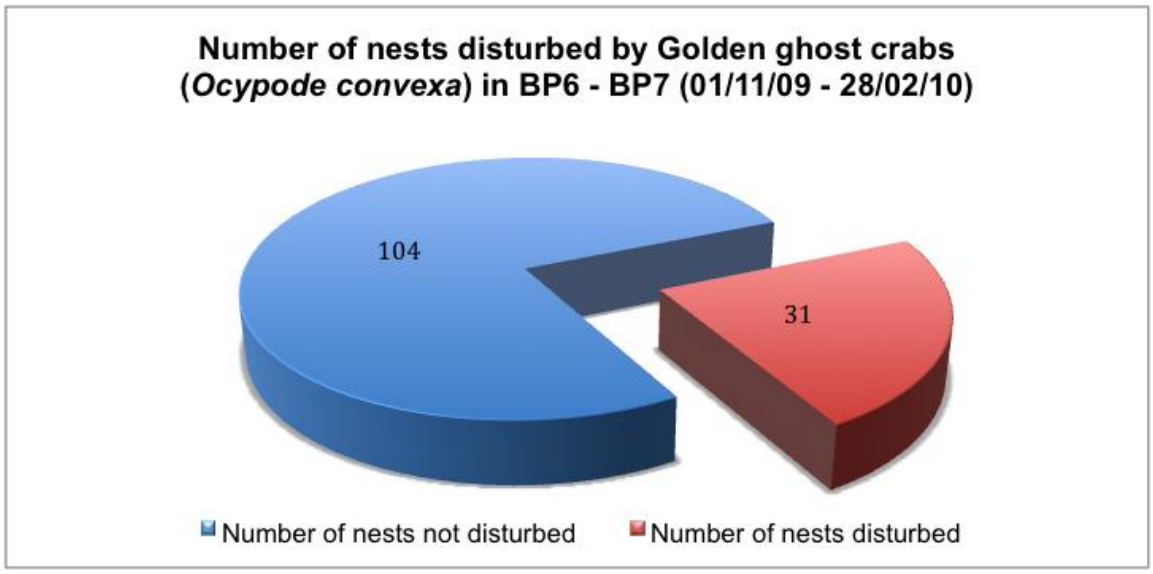

Figure 13: Number of nests disturbed by Golden Ghost Crabs (*Ocypode convexa*) in BP6 - BP7 (01/11/09 - 28/02/10)

The northernmost subsection in the Revised Day Study Area 2009/10, BP7 – BP9, contained the majority of nests during the Day monitoring period, with 357 nests in total. Interestingly, 159 nests (approximately 45%) were disturbed by Golden ghost crabs (*Ocypode convexa*) over the 120-day Day monitoring period (refer Figure 14 below). This subsection contains very dynamic beaches and locations with high wave energy, which deposits a substantial amount of environmental debris on shore, providing food for crabs and sustaining their high population numbers here.

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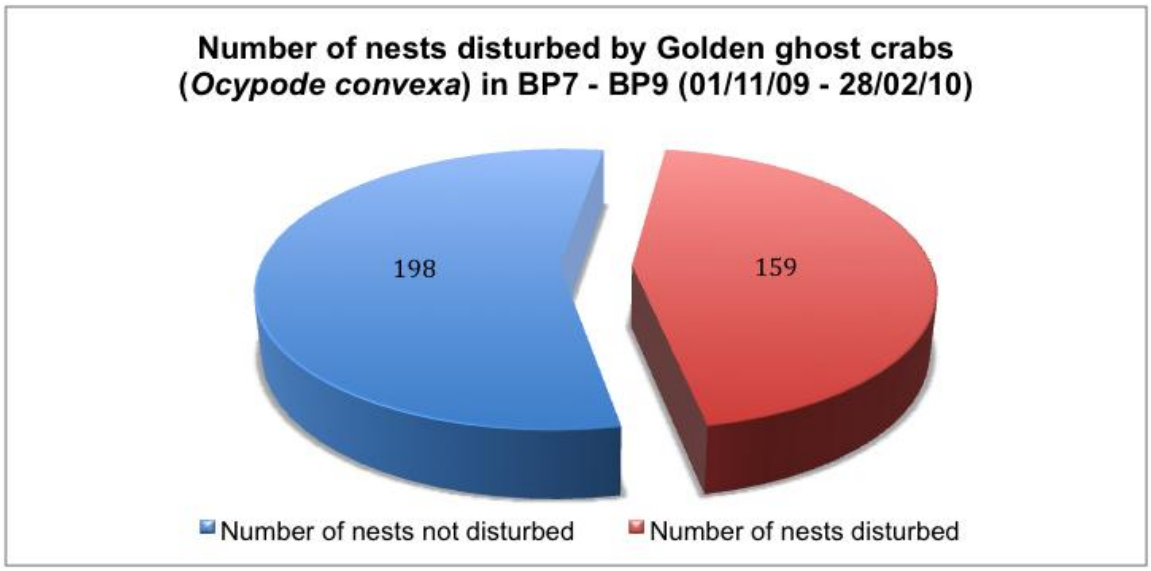

Figure 14: Number of nests disturbed by Golden Ghost Crabs (*Ocypode convexa*) in BP7 - BP9 (01/11/09 - 28/02/10)

5.1.4 Nest disturbances by environmental conditions

Other disturbances to nests noted during the Day monitoring period 2009/10 were those caused by environmental conditions. Tidal inundation, erosion and shifting dune systems were all noted when observing nest status. As Table 1 shows, 4.02% of nests were disturbed by environmental factors up until the end of Day monitoring.

For more fulsome information, the results of recorded environmental disturbances during the Night program 2009/10 should be considered as this research extended until 24/04/10 and monitored the incubation period of nests (within the Night Study Area 2009/10) past the conclusion of the Day program on 28/02/10.

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5.2 Discussion

Revised Day Study Area 2009/10

The area chosen along the Gnaraloo coastline for the Day monitoring season 2009/10 contained the area from Gnaraloo Bay North (**GBN**) to Beach Point 9 (**BP9**). Although the season originally began with the monitoring a total of 10.64 kilometres extending from GBN to Beach Point 10 (**BP10**) (**Total Study Area 2008/09**), the monitored area was reduced early in November 2009 due to logistical constraints. Total Study Area 2008/09 was originally selected as a significant sea turtle rookery based on advice from DEC (Exmouth District) during November 2008 and informal Gnaraloo monitoring records since 2001.

The Revised Day Study Area 2009/10 (6.69 km) was divided into sub-sections as follows:

- Gnaraloo Bay North to Beach Point 6 (**GBN - BP6**);
- Beach Point 6 to Beach Point 7 (**BP6 – BP7**); and
- Beach Point 7 to Beach Point 9 (**BP7 – BP9**).

Whilst GBN – BP6 is frequented by visitors and shore fishermen, the area BP7 – BP9 has remained remote with no human presence. Vehicle driving on beaches is not allowed at Gnaraloo.

Number of nests and distribution trends at monitored rookeries along the Gnaraloo coastline

The total number of sea turtle nests recorded over the course of the 2009/10 season resulted in 522 nests, inclusive of all species. Within the Revised Day Study Area 2009/10, 813 turtle beach crawls were evident over the 4 month beach monitoring period, from 1 November 2009 to 28 February 2010.

The Revised Day Study Area 2009/10 was principally visited by endangered Loggerhead Turtles (*Caretta caretta*), comprising 77% of the turtle nesting activity in the area. Other sea turtles that also frequented the area included critically endangered Hawksbill (*Eretmochelys imbricata*) (15%) and endangered Green (*Chelonia mydas*) (6%).

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A total of 2% of turtle nests were unable to be species-identified during the course of the Day monitoring season chiefly due to environmental effects of strong early morning winds and extreme high tides eradicating the characteristics of the tracks.

The distribution of turtle nests was non-uniform over the Revised Day Study Area 2009/10 and higher densities were apparent in specific sub-sections. This may be due to intrinsic characteristics of the coastline and beaches such as the topography and bathymetry. The highest density of turtle nests corresponded with exposed beaches that had open access to the ocean (being sub-sections BP6 – BP7 and BP7 – BP9), as opposed to sheltered beaches with adjacent fringing coral reefs (being the sub-section GBN - BP6). The beaches with open access to the ocean were dynamic beaches and often had deeper water with high wave energy and coarser sand; this being the case with the relatively open stretch of Gnaraloo coastline between BP6 - BP9, which had the highest nesting density and overall turtle activity of the Revised Day Study Area 2009/10.

Species percentage composition varied considerably between the 2008/09 and 2009/10 monitoring seasons. While Loggerhead (*Caretta caretta*) turtles comprised 90% of nesting turtles within the Total Study Area 2008/09, they made up 77% of the nesting turtles within the Revised Day Study Area 2009/10. Green (*Chelonia mydas*) turtles increased in frequency, from 2% in the Total Study Area 2008/09 to 6% in the Revised Day Study Area 2009/10. Additionally, critically endangered Hawksbill (*Eretmochelys imbricata*) turtles also increased, from 5% in the Total Study Area 2008/09 to 15% of overall species composition in the Revised Day Study Area 2009/10.

Sub-section GBN - BP6 is an area of relatively low wave energy within the fringing coastal reefs. GBN - BP6 recorded the lowest numbers of turtles nesting in the Revised Day Study Area 2009/10, with 30 nests and 14 false crawls during the Day monitoring season. Public access to these beaches and near shore waters may contribute to this result.

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As shown by Figure 15, there was variation in daily nest counts between the 2008/09 season and the 2009/10 season. Despite the obvious difference of dates that were monitored (01/12/08 – 31/03/09 versus 01/11/09 – 28/02/10), the nesting peak times also varied between the 2 years. The 2008/09 breeding season experienced a peak in nesting activity in mid-January 2009, then declined until early March 2009 where there was no more nesting activity recorded. The 2009/10 breeding season experienced two peaks in nesting activity, both in late December 2009 and mid-January 2010. While all species appeared to follow a similar nesting trend in the 2009/10 monitoring season, activity was more species-independent in the 2008/09 season.

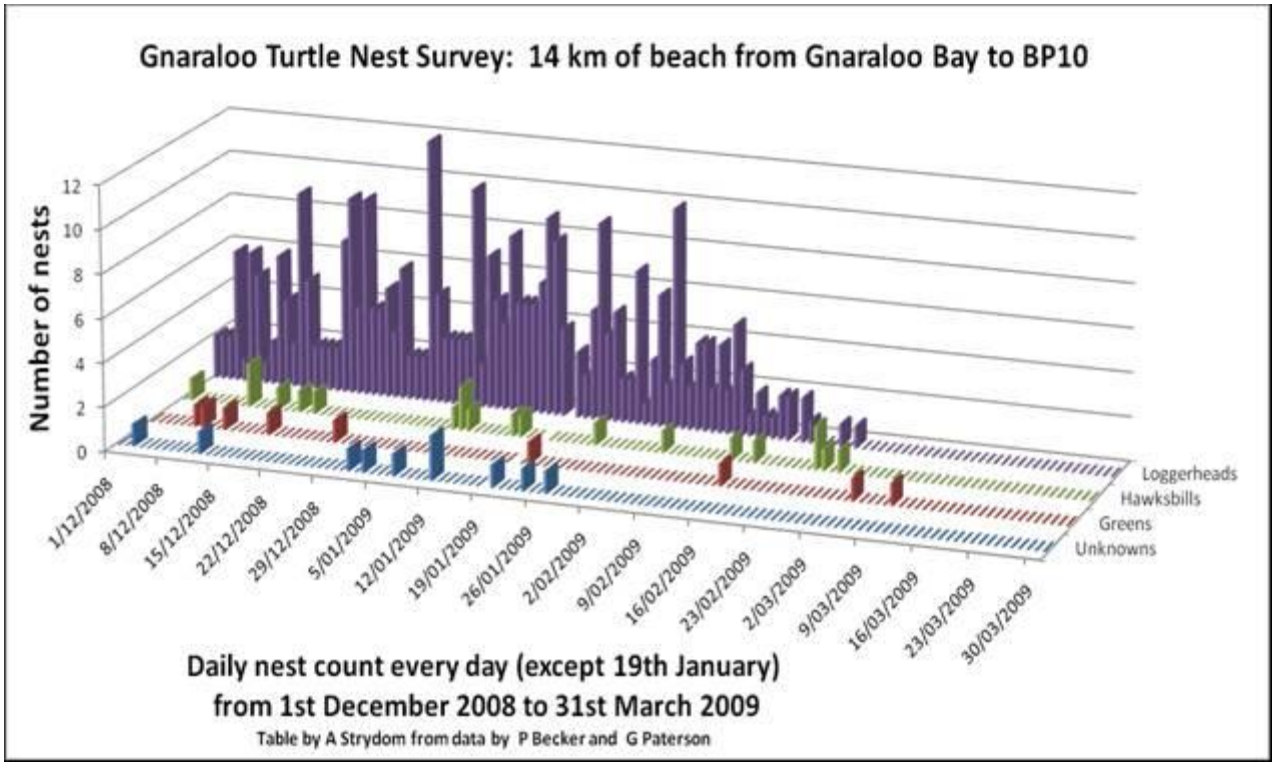

Figure 15: Turtle nest count per day in Total Study Area 2008/09 (01/12/08 - 31/03/09)

Number of nesting females in Revised Day Study Area 2009/10

In an attempt to determine the number of nesting females in the Revised Day Study Area 2009/10 formulaically, Mr. Bob Thomson of the Mon Repos research facility in Bundaberg,

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Queensland, was contacted and provided two research papers by Dr Col Limpus[6]. Upon review of these documents, no nesting female formula was observed. It became apparent that nesting females are identified physically in the population, by performing laparoscopic examinations (Limpus & Limpus, 2003) as well as by measuring curved carapace length (CCL) using a flexible fibreglass tape (Limpus *et al*., 2006). Additionally, observing tagged turtles returning to nesting beaches is also used to count numbers of breeding females.

As data was collected most conservatively during the 2009/10 study season, the Day team had no physical contact with nesting females whatsoever and only monitored their tracks.

Review of this report by Dr Mark Hamann during July 2010 provided the following comment:

- Female Loggerhead (*Caretta caretta*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10 (**LTPG**) = number of nests (402) / number of clutches per season per female (4 +/- 1) (Limpus, 2008).

  LTPG = 100.2 (range 80 to 134)

- Female Hawksbill (*Eretmochelys imbricata*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10 (**HTPG**) = number of nests (78) / number of clutches per season per female (2.5).

  HTPG = 31

- Female Green (*Chelonia mydas*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10 (**GTPG**) = number of nests (30) / number of clutches per season per female (6).

  GTPG = 5

Incubation periods at monitored rookeries along Gnaraloo coastline

Data collected during the 2008/09 study season indicated that the highest frequency of incubation required 59 – 61 days before the first run of hatchlings was seen. The 2009/10

[6] (1) *Queensland Turtle Conservation Project: Monitoring marine turtle population dynamics in Moreton Bay Marine Park, 2005-2006* and (2) *Biology of the Loggerhead Turtle in Western South Pacific Ocean Foraging Areas*.

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monitoring season witnessed a much higher incubation period, with the highest frequency of incubation requiring 61 – 80 days before the first run of hatchlings was observed.

This may be attributed to when the data was recorded, as the 2008/09 study season monitored until 31 March 2009, when nests dug later in the season (in warmer conditions) would have been hatching, and it is known that warmer conditions contribute to lower incubation times. Conversely, the 2009/10 monitoring season recorded data only until 28 February 2009, and thus only collected hatching data on nests dug earlier in the season (cooler conditions) and would have had higher incubation times.

Observed nest disturbances by feral and native species

Foxes (*Vulpes vulpes*) tracks

The 2009/10 monitoring season consisted of 120 sample days, approximately 85% of which experienced fox presence (tracks). Fox presence was observed on all beaches monitored and was frequent throughout all subsections. The highest frequency of fox presence occurred in BP6 – BP7, with 93 of 120 days recording fox prints. This may be because this area could be well-suited for dens, and there are not high secondary dunes in this sub-section, giving easy access to the beach (P. Richardson, Gnaraloo Station, Personal communication, January 2010). Interestingly, BP7 – BP9 recorded the lowest number of days with fox prints (61/120) but experienced the highest amount of nest disturbances by foxes (22 of 38 occurrences).

Nest disturbance by foxes was minimal at the commencement of the turtle monitoring season in November 2009, but increased significantly in January 2010. A total of 34 nests (6.51% of total nests within Revised Day Study Area 2009/10) were disturbed by foxes during the Day monitoring period. Three nests were disturbed repeatedly for a total of 38 occurrences during the Day monitoring period, 36 of those occurrences taking place after 1 January 2010.

While this is the total amount of fox disturbance recorded in the Revised Day Study Area 2009/10 during the Day monitoring period (ending 28/02/10), for more fulsome information on fox disturbance rates, refer to the Night program's fox disturbance results (Table 5) [running total for a small section of the Total Study Area 2009/10 (being BP8 - BP9, the Night Study Area 2009/10), from 01/11/09 - 24/04/10].

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Golden ghost crabs (*Ocypode convexa*)

A minimum of 2 species of Ghost (or Sand) crabs were observed throughout the Total Study Area 2009/10, namely: Golden Ghost Crab *(Ocypode convexa*) and Running ghost crab *(Ocypode ceratophthalma*) (refer to the Photo plate document).

The Golden Ghost Crab (*Ocypode convexa*) was predominant throughout the Revised Day Study Area 2009/10 and is known to be a native predator of both sea turtle eggs and hatchlings. Running ghost crabs *(Ocypode ceratophthalma*) were not witnessed to have any effect on sea turtle nests or hatchlings, but more observation is required to draw definite conclusions.

For the purpose of the Day research, disturbance by Golden ghost crabs was recorded when there was any evidence of burrowing activity into the nest (refer to Glossary). The disturbance of turtle nests by Golden ghost crabs was high within the Revised Day Study Area 2009/10. A total of 198/522 nests (38%) were disturbed by Golden ghost crabs during the 2009/10 study season.

Investigation into crab disturbance and predation was not included in the Scope of Work for this study. Refer to the 'Recommendations' section for study proposals.

Gnaraloo Fox Control Program

Following the successful fox baiting program implemented during the 2008/09 season, Gnaraloo and Animal Pest Management Services (**APMS**) designed and developed the 2009/10 baiting program, based on the principles of adaptive and integrated management.

Structured 3-day fox baiting events by APMS occurred at the beginning of the study season in November 2009 and proved to be effective, with little or no nest predation evident throughout the first half of the season. APMS returned in December 2009 and February 2010. Gnaraloo staff provided support baiting.

Although fox control efforts were consistent throughout the Day monitoring period, they failed to completely eradicate fox tracks and nest disturbances by foxes within the Revised Day Study Area 2009/10. It is hypothesized that the fox population on the Gnaraloo coastline is quickly replenished from unbaited adjacent areas / zones by young foxes seeking and finding new territory. Whilst the young foxes were present within the Revised Day Study Area 2009/10, they had not yet developed the ability and knowledge to locate and unearth turtle nests. However,

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they are expected to exert predatory pressure on emerging hatchlings later during the breeding season.

Significance of key monitored rookeries along the Gnaraloo coastline

It is understood that a rookery with 300 nests per season is considered to be a significant turtle rookery (B. Thomson, Mon Repos research facility, Bundaberg, Queensland, Personal communication, 2009). The Revised Day Study Area 2009/10 contained 522 recorded nests and as such is considered to be a significant sea turtle rookery [402 Loggerhead (*Caretta caretta*), 78 Hawksbill (*Eretmochelys imbricata*) and 30 Green (*Chelonia mydas*) turtle nests were recorded during the Day monitoring period].

Numbers of Loggerhead, Hawksbill and Green turtles have increased since the 2008/09 monitoring season.

Potential additional significant rookeries along the Gnaraloo coastline

An aerial survey was undertaken during January 2010 in order to identify any potential additional significant sea turtle rookeries outside the breeding areas currently being monitored at Gnaraloo. Results showed a significant amount of turtle activity along the Gnaraloo coastline north of the Revised Day Study Area 2009/10, as far as Gnaraloo's most northern border. Additionally, turtle tracks and nests were witnessed just north of the 3Mile Marine Sanctuary Zone during the 2009/10 season, indicating another possible rookery south of the currently monitored area.

The information gathered through the survey could potentially translate into an extension of the Total Study Area which currently extends from Gnaraloo Bay (**GBN**) to Beach Point 9 (**BP9**). A future out-camp allowing team members easy access to rookeries that are a greater distance from the Gnaraloo Homestead area may facilitate an extension of the currently monitored rookeries.

Conservation status of turtle populations at key monitored rookeries along the Gnaraloo coastline

The IUCN Red List (IUCN, 2010) status of 2 of the 3 sea turtle populations nesting along the Gnaraloo coastline have been revised following the 2008/09 monitoring season. The classification of Loggerhead turtles (*Caretta caretta*) was endangered, while Hawksbill

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(*Eretmochelys imbricata*) and Green (*Chelonia mydas*) turtles were listed as vulnerable species during the 2008/09 season. As of the 2009/10 monitoring season, Loggerhead turtle populations remained endangered, while Hawksbill turtle populations have been newly listed as critically endangered and Green turtle populations listed as endangered.

According to the IUCN Red List, a taxon is endangered when it is facing a **very high risk of extinction** in the wild in the near future. Akin to this, a taxon is critically endangered when it is facing an **extremely high risk of extinction** in the wild in the near future. This is based on criteria related to observed population reduction caused by any number of factors.

As illustrated by Figure 16 below, the Revised Day Study Area 2009/10 on the Gnaraloo coastline is frequented by *Endangered* and *Critically Endangered* species of sea turtle. Although there were 12 unidentified nesting events during the Day monitoring period 2009/10 (due to track erosion), it is expected that those turtles were of the species that are known to be in the Gnaraloo area – namely, endangered Loggerhead (*Caretta caretta*) and Green (*Chelonia mydas*) turtles, or critically endangered Hawksbill (*Eretmochelys imbricata*) turtles.

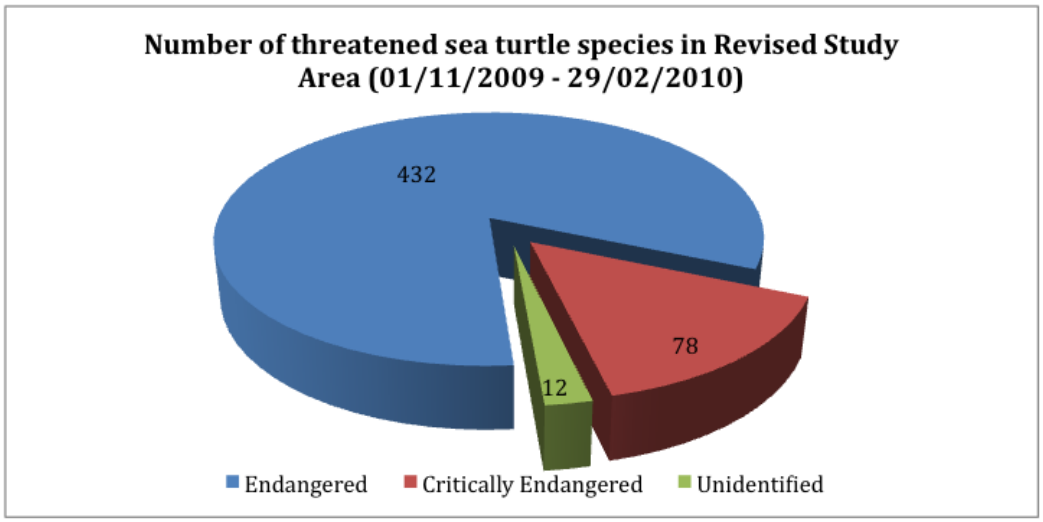

Figure 16: Number of threatened sea turtle species in Revised Day Study Area (01/11/2009 - 29/02/2010)

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Community volunteers and visitors

During the 2009/10 Day monitoring period, members of the community and visitors occasionally accompanied team members during their survey work. During early March 2010, the GTCP hosted Ms. Erin Wood, a university student from the USA, immediately following her 2-month turtle volunteer position with the *Ningaloo Turtle Program* in Exmouth. This volunteer attended Gnaraloo to shadow the GTCP monitoring teams over a 3-day period. The volunteer then produced a review document for consideration by Gnaraloo Station concerning possible future expanded community volunteer participation with the GTCP.

During February 2010, Gnaraloo hosted a home-schooling group. A 2-hour long tutorial in track identification and monitoring protocols[7] was provided by the Day team prior to their field experience. The group partook in 1 day monitoring event and 2 night monitoring events, hosted by the Day team.

These practices help to increase public awareness, participation and engagement in sea turtle conservation.

Refer to Gnaraloo's *Turtle Monitoring Procedure 2009/10* (Hattingh *et al*., 2010) for protocols concerning community volunteer and visitor management.

Data integrity, environmental and location impacts on nests

Although the data collection and management protocols set out in Gnaraloo's *Turtle Monitoring Procedure 2009/10* (Hattingh *et al*., 2010) were strictly adhered to, slight ambiguity in the results was unavoidable due to a wide variety of environmental conditions which impacted the nests as well as nest data collection. This included strong winds, sand drifts, beach erosion and sediment movement due to a variety of extreme environmental factors. For this reason, it is important to check correlation between day results and night research to confirm correct species identification and ultimate nest predation or mortality rates.

The unrelenting and often strong southerly winds characteristic of the Gnaraloo turtle nesting season 2009/10 contributed to a huge degree of sand movement which created large sand drifts

[7] This included the *Ningaloo Turtle Track Monitoring Tutorial* provided to the Day team during pre-season training at Gnaraloo as well as a Question-and-Answer session to assess knowledge.

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that buried nests and their associated nest identification markers. Besides influencing the recording of nest data, this led to the visual loss of the nest and may have impacted the hatching success of that nest later during the season.

Many of the beaches within the Revised Day Study Area 2009/10 are relatively narrow and steep, and this resulted in a high degree of erosion and sediment movement of the beach topography. The occurrence of spring tides and large swells during the Day monitoring season 2009/10 moved large amounts of sediment off the beach and frequently impacted associated turtle nests. Specific beaches within the Revised Day Study Area 2009/10 are more susceptible to this than others. Those beaches that are not protected by adjacent fringing reefs experienced the highest degree of erosion, and this unfortunately often coincided with the highest nesting densities. This impact was aggravated during February 2010 when a large degree of nest inundation and mortality was experienced in BP6 - BP7 and BP7 - BP9 due to extremely high tides.

Data regarding air temperature, wind speed and humidity was collected daily from the Gnaraloo Weather Station immediately after Day monitoring activities, and is available for analysis for correlations between sea turtle nesting frequency and weather conditions.

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5.3 Conclusions

Number of nests and distribution trends at monitored rookeries along the Gnaraloo coastline

Day monitoring activities during 2009/10 successfully collected further data on the nesting population and characteristics of the sea turtles along the Gnaraloo coastline to enhance the baseline data recorded during the inaugural 2008/09 breeding season.

A total of 522 sea turtle nests, inclusive of all species, were recorded within the Revised Day Study Area 2009/10 (1 November 2009 to 28 February 2010).

Overall the nesting density and frequency peaked in mid January 2010 before decreasing until the end of the study season on 28 February 2010. BP6 – BP7 and BP7 – BP9 had the greatest number of turtle nests, with 135 and 357 respectively.

Number of nesting females in Revised Day Study Area 2009/10

Review of this report by Dr Mark Hamann during July 2010 provided the following comment:

Female Loggerhead (*Caretta caretta*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10 = 100.2 (range 80 to 134).

Female Hawksbill (*Eretmochelys imbricata*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10 = 31.

Female Green (*Chelonia mydas*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10 = 5.

Incubation periods at monitored rookeries along the Gnaraloo coastline

Incubation period for nests in the Revised Day Study Area 2009/10 ranged from 52 - 82 days, with the highest frequency hatching at between 61 - 64 days.

Nests dug earlier in the season required longer incubation periods than nests dug later in the season. This may be due to the different sand temperatures, as cooler sand (those nests dug

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early in the season) may be related to longer incubation periods, while warmer sand (those nests dug later in the season) may relate to shorter incubation periods.

Nest disturbances

The nests within the Revised Day Study Area 2009/10 faced a variety of predatory (by feral and native species) and environmental disturbance impacts (such as loss of nests due to erosion from spring tides, large swells and sand dune drifts).

Nests faced Fox (*Vulpes vulpes*) disturbance in the form of deliberate unearthing of egg clusters within nests. Fox control efforts through 1080 baiting were consistent throughout the monitoring season, but failed to completely eradicate fox presence (tracks), even temporarily.

Structured 3-day fox baiting events were undertaken by Animal Pest Management Services (**APMS**) during the 2009/10 season, with a decrease in fox presence immediately after baiting. Gnaraloo Station provided support baiting activities.

It is recommended that the structured fox baiting events by APMS be repeated more frequently throughout future seasons, preferably at the beginning of each month during the turtle breeding season in order to maintain fox numbers to a minimum. This will not only protect the eggs whilst incubating, but also reduce predation on emerging hatchlings later in the season.

Golden ghost crabs (*Ocypode convexa*) also contributed to nest disturbance, with direct burrowing into nests. Although there are other species of Ghost crabs present on the Gnaraloo beaches, namely Running Ghost Crab *(Ocypode ceratophthalma*), the impact by all species of sand crabs on turtle rookeries needs to be further investigated in future monitoring seasons in order to draw any definite conclusions.

Significance of key monitored rookeries along the Gnaraloo coastline

The monitored sea turtle breeding area at Gnaraloo is considered to be a significant rookery, with 522 nests being recorded during the Day monitoring period 2009/10.

This included 402 Loggerhead (*Caretta caretta*), 78 Hawksbill (*Eretmochelys imbricata*) and 30 Green (*Chelonia mydas*) turtle nests.

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Numbers of Loggerhead, Hawksbill and Green turtles have increased since the 2008/09 monitoring season.

Potential additional significant rookeries along the Gnaraloo coastline

The aerial survey conducted during January 2010 indicated significant turtle activity north of the Revised Day Study Area 2009/10, as far as Gnaraloo's most northern border as well as an area just north of the 3Mile Marine Sanctuary Zone. The practicality of monitoring this area needs to be explored as well as the possibility of the establishment of a remote camp in this area in order to facilitate this.

Conservation status of turtle populations at key monitored rookeries along the Gnaraloo coastline

Loggerhead (*Caretta caretta*) turtles has remained endangered species (2008/09 – 2009/10), while the classification of Hawksbill (*Eretmochelys imbricata*) turtles has been revised from vulnerable species (2008/09) to critically endangered Species (2009/10). Green (*Chelonia mydas*) turtle status has been revised from vulnerable species (2008/09) to endangered species (2009/10) (IUCN Red List 2010).

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6 NIGHT MONITORING

6.1 Results

6.1.1 Beach monitoring

6.1.1.1 Summary of Night Study Area: NEW BP8 – BP9

Gnaraloo sub-section from the Beach Point 8 Marker to the Beach Point 9 Marker (**BP8 - BP9**) was used for the Night Study Area 2009/10. This area was chosen for its high density of nests within a relatively small area.

During the 2009/10 season, a total of 285 nests were recorded within the Night Study Area. Loggerhead (*Caretta caretta*) turtle nests were predominantly recorded in the Night Study Area 2009/10. In total (refer Figure 17):

- Loggerheads accounted for 230 out of 285 (80.7%) within the Night Study Area 2009/10;
- Hawksbills (*Eretmochelys imbricata*) for 29 nests (10.2%);
- Greens (*Chelonia mydas*) for 11 nests (6.3%); and
- 11 nests (2.8%) were laid where the species was not known.

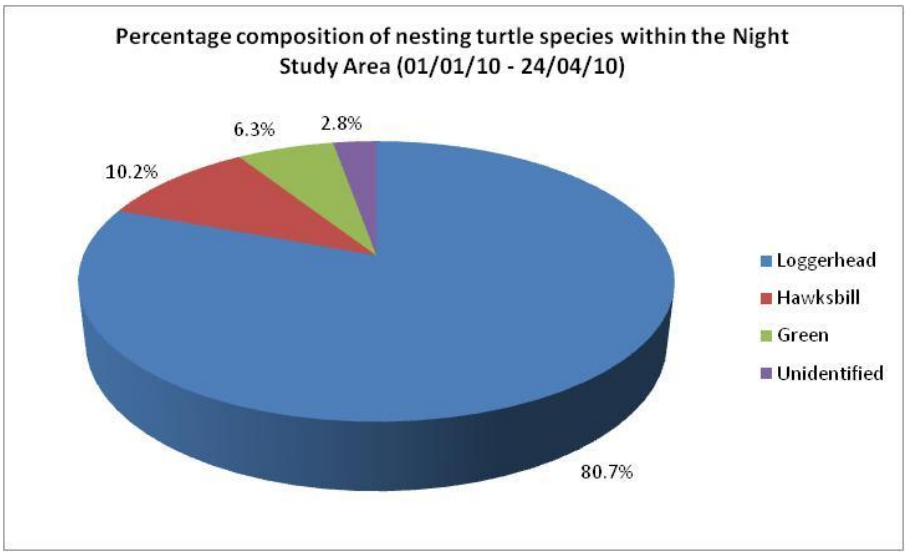

Figure 17: Percentage composition of nesting turtle species within Night Study Area (01/01/10 - 24/04/10)

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As Loggerhead (Caretta caretta) turtles were the most prevalent turtle species in the Night Study Area 2009/10, results presented below pertain to Loggerheads only.

Of the 285 nests within the Night Study Area 2009/10, 44 nests were observed to hatch (refer Table 3). Of these 44 hatched nests, 1547 hatchlings were observed emerging. Of these hatchlings, 100% were Loggerheads.

Table 3: Observations of nest frequency, hatching, emergence events and hatchling numbers in Night Study Area (01/01/10 – 24/04/10)

No. of nests	No. of hatched nests[1]	No. of nests observed to hatch[1]	No. of observed Emergence Events[2]	No. of hatchlings observed[3]	No. of successful hatchlings[4]	No. of predated hatchlings[5]	No. of hatchlings with unknown fate[6]
285	49	44	102	1547	1126	190	231

Notes:

[1] A nest was recorded as hatched if either a researcher was present at the hatching (recorded as an observed hatching), or if recognisable signs of hatching were seen (e.g. numerous hatchling tracks emanating from a focal point in front of a nest stake).

[2] An Emergence Event was recorded as 1 or more hatchlings emerging from a nest more than 30 minutes after the last Emergence Event was recorded (hence, 102 Emergence Events stemmed from the 44 nests observed to hatch).

[3] Hence, 1547 hatchlings stemmed from the 44 nests observed to hatch. The number was not exhaustive (i.e. does not include all possible hatchlings from the nests observed to hatch).

[4] A hatchling was recorded as successful when observed as reaching the water.

[5] A hatchling was recorded as predated when observed by a researcher as being predated.

[6] A hatchling was recorded as having an unknown fate if it was observed emerging from a nest but was not observed being predated or successfully reaching the water.

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Figure 18 below shows the number of Emergence Events recorded per day for Loggerhead (*Caretta caretta*) hatchlings within the Night Study Area 2009/10.

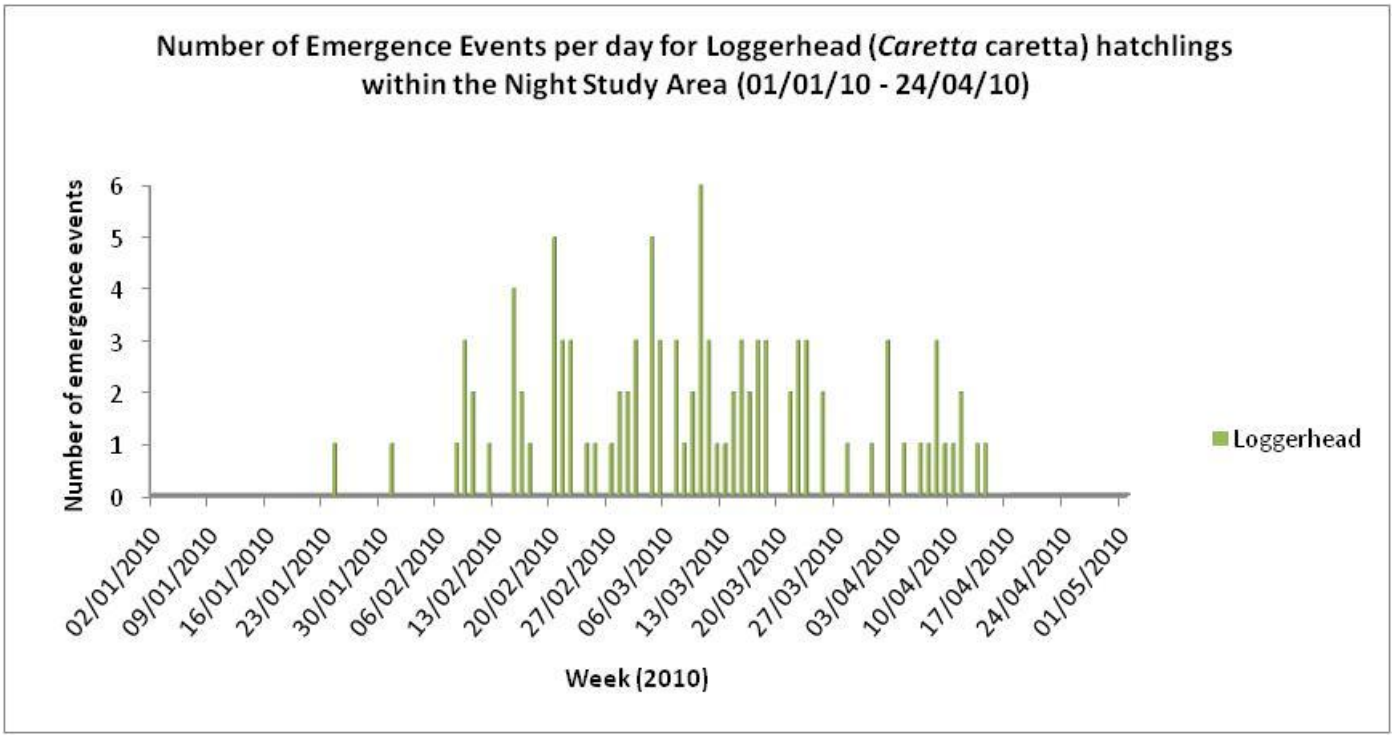

Figure 18: Number of Emergence Events per day for Loggerhead (*Caretta caretta*) hatchlings within the Night Study Area (01/01/10 - 24/04/10)

As Figure 19 demonstrates, emergence activity started late January 2010, was more prevalent during February 2010, peaked in March 2010 and stopped by mid April 2010. When broken down month by month, March 2010 was significantly more prevalent for nest hatchings compared to the other three research months, namely January, February and April 2010 (refer Figure 19).

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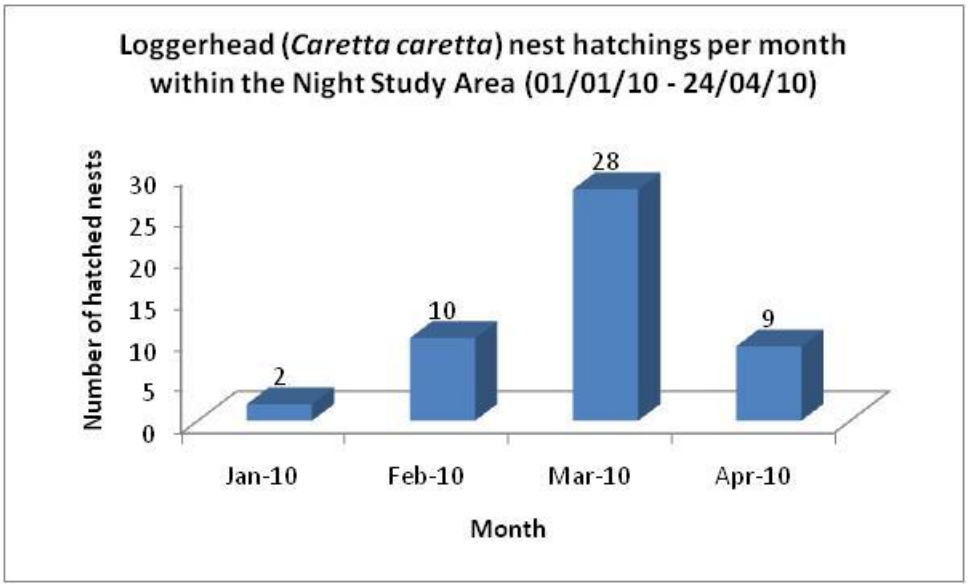

Figure 19: Loggerhead (*Caretta caretta*) nest hatchings per month within the Night Study Area (01/01/10 - 24/04/10)

After the first recorded emergences on 24 January 2010 and on 31 January 2010, from 7 February to 27 March 2010, emergence frequency (refer green line in Figure 20) increased and stayed relatively constant (peaking on week ending 13 March 2010). Emergence activity then dropped to lower levels towards the start of April 2010 and remained there until ceasing completely by 24 April 2010.

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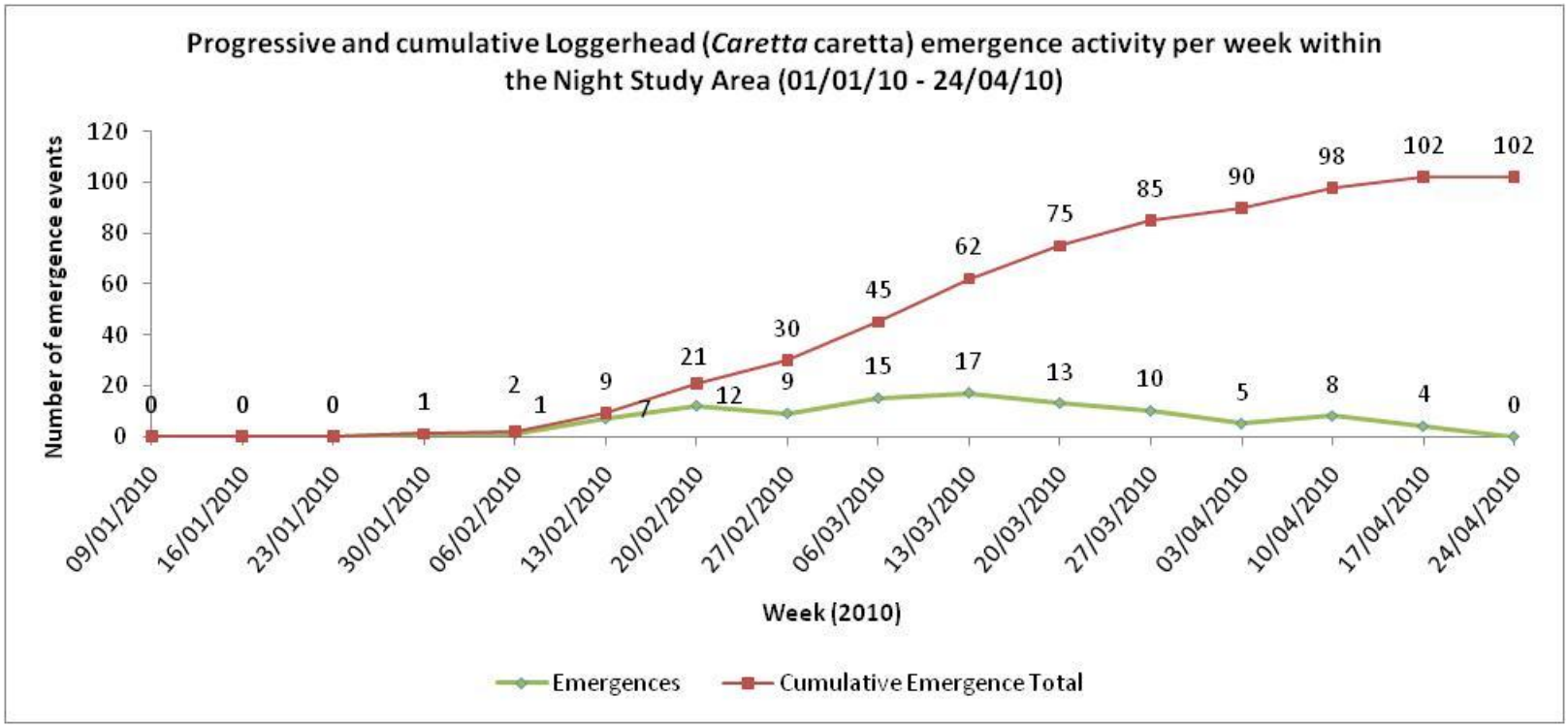

Figure 20: Progressive and cumulative Loggerhead (*Caretta caretta*) emergence activity per week within the Night Study Area (01/01/10 - 24/04/10)

For the coastal distribution trends of hatched nests within BP8 - BP9, refer to the Maps document. The distribution displays a clear trend of hatched nests in the southern section of the Night Study Area 2009/10. Only two hatched nests were recorded in the northern section of the study area, within Turtle Bay.

The incubation periods for hatched Loggerhead (*Caretta caretta*) nests within BP8 - BP9 ranged from 55 - 82 days, with the highest frequency of hatching at 60 - 70 days (31/49) (63.3%) (refer Figure 21).

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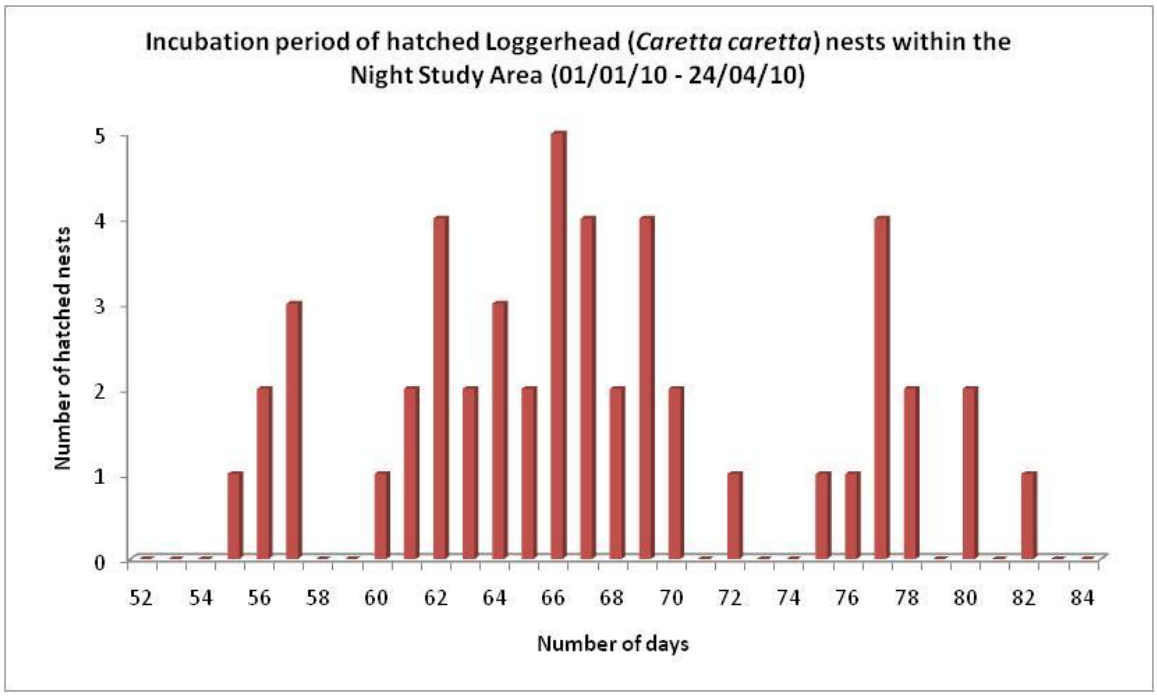

Figure 21: Incubation period of hatched Loggerhead (*Caretta caretta*) nests within the Night Study Area (01/01/10 - 24/04/10)

Nests dug earlier in the season (during November – December 2009) were found to have longer mean monthly incubation periods (70.5 – 77.2 days) than nests dug later in the season (during January – February 2010) (63.2 – 64.7 days) (refer Table 4).

Table 4: Mean monthly incubation periods for Loggerhead (*Caretta caretta*) nests dug within the Night Study Area (01/11/09 - 28/02/10)

Month nest was laid	November 2009	December 2009	January 2010	February 2010
Mean incubation time (days)	77.2	70.5	64.7	63.2

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6.1.2 Total disturbances (Egg chambers) and predation (Hatchlings) in Night Study Area

Disturbance data from the Day research 2009/10 was combined with disturbance data from Night survey work (i.e. a running total, builds on the Day disturbance numbers) to determine total numbers for disturbance of egg chambers within the Night Study Area 2009/10.

Data over the period **01/11/09 – 24/04/10**, indicated that **observed disturbances of egg chambers** was 89.5% of the 285 nests within the Night Study Area 2009/10, inclusive of Golden ghost crab (*Ocypode convexa*), Fox (*Vulpes vulpes*) and environmental disturbances (refer Table 5 below).

The night teams defined 'disturbance by crabs' as (refer Glossary):

> *'Sightings of a crab burrow(s) into a nest (the area 2 metres in front of the stake, in a 180° radius) with turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.* ***Alternatively****, sightings* ***of 5 or more*** *crab burrows into a nest with or without turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface'.*

The night teams defined 'disturbance by foxes' as:

> *'Sightings of fox digging(s) into a nest with or without turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface'.*

The night teams defined 'environmental disturbance' as:

> *'Inundation by tides, storm surge, erosion or wind-blown shifting dunes'*

Note: 'Disturbance' relates to egg chambers. 'Predation' relates to hatchlings only.

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Table 5: Disturbance of Loggerhead (*Caretta caretta*) egg chambers within the Night Study Area (01/11/09 – 24/04/10)

Observed disturbances	Egg chambers
Golden ghost crab (*Ocypode convexa*)	46.7%
Fox (*Vulpes vulpes*)	9.5%
Environmental	33.3%
Total	89.5%

Data over the period 01/01/10 – 24/04/10 showed that **observed hatchling predation** was 12.3% of the hatchlings observed to hatch within the Night Study Area 2009/10 (190/1547 hatchlings), inclusive of both Golden ghost crab (*Ocypode convexa*) and Fox (Vulpes vulpes) predation (refer Table 6). The night teams defined 'predation' as (refer Glossary):

Actual sighting of a predator consuming a hatchling.

Table 6: Predation of Loggerhead (*Caretta caretta*) hatchlings observed to hatch within the Night Study Area (01/01/10 – 24/04/10)

Observed predation	Emerged hatchlings
Golden ghost crab (*Ocypode convexa*)	12.0%
Fox (*Vulpes vulpes*)	0.3%
Environmental	N/A
Total	12.3%

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Findings indicated that hatchlings were less likely to be predated by terrestrial predators if they emerged in large groups compared with those that emerged individually or in smaller groups ≤ 20 (refer Table 7). .

Table 7: Loggerhead (*Caretta caretta*) hatchlings predation percentage within Night Study Area comparing Emergence Events of ≤ 20 and > 20 individuals (01/01/10 – 24/04/10)

Size of Emergence Event	Number of hatchlings observed in Emergence Events	Number of emerged hatchlings observed to be predated	% Observed predation
≤ 20	320	123	38.4%
> 20	1227	67	5.46%
	1547	190	

Egg chamber disturbances by Golden ghost crabs (*Ocypode convexa*) were relatively evenly distributed over the Night Study Area 2009/10 (refer to the Maps document). Egg chamber disturbance by Foxes (*Vulpes vulpes*) had a slightly higher concentration in the southern compared with the northern section of the Night Study Area 2009/10.

6.1.3 Location impacts on nests in Night Study Area

The majority of the environmentally disturbed nests (inundation by tides and/or storm surges) were located in the northern section of the Night Study Area 2009/10, in Turtle Bay (predominantly between the latitudes of 23.724°S and 23.728°S) (refer to the Maps document).

6.1.4 Confirmation of species identification by Day team

The night team identified species (based on emerged hatchlings) and compared these results with the track survey information from the Day team 2009/10 to determine the accuracy of the predictive track monitoring work earlier during the season. As can be seen in Figure 22, this was able to be undertaken for 15.4% of the nests within the Night Study Area 2009/10 (44/285) (84.6% of the nests were unable to be verified in terms of species identification as they were not observed to hatch).

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Figure 22 shows that of the 15.4% of nests for which the comparative analysis was undertaken:

- 12.3% (35) of the nests matched the species identification as predicted by the track analysis of the Day monitoring program;
- 3.1% (9) of the nests were misidentified by the Day team [6 nests were incorrectly identified as Hawksbills (*Eretmochelys imbricate*) and 3 were misidentified as Green turtles (*Chelonia mydas*). All 9 nests were in fact Loggerhead (*Caretta caretta*)].

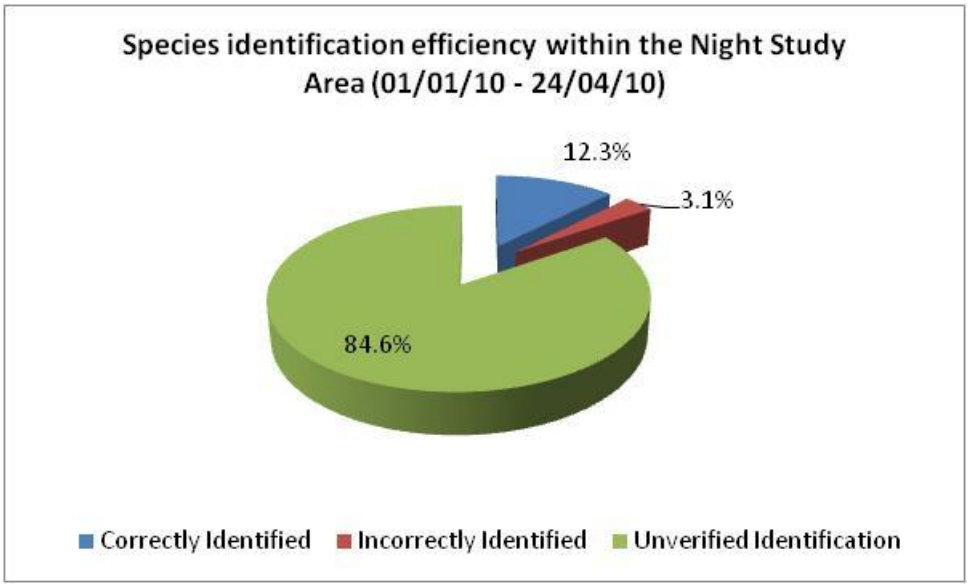

Figure 22: Species identification efficiency within the Night Study Area for nests observed to hatch (01/01/10 - 24/04/10)

6.1.5 Frequency of hatched nests with previous recorded disturbance in Night Study Area

As Table 8 below shows, 255/285 nests within the Night Study Area 2009/10 was observed by the Day and Night teams to be disturbed by predators (such as crabs and foxes) and by environmental factors (such as inundation and erosion). However, disturbed nests were observed to hatch by the Night team. The percentage of hatched nests with previous predatory or environmental disturbance was high at 36.7% (18/49).

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A significant number of hatchlings emerged from these nests (695), at an average of 38.6 hatchlings per nest. This is slightly above the average of 36.0 hatchlings per nest for all nests observed to hatch within the Night Study Area 2009/10.

Table 8: Frequency of hatched Loggerhead (*Caretta caretta*) nests with previous recorded disturbance within the Night Study Area (01/01/10 – 24/04/10)

Number of disturbed nests within Night Study Area (by predators & environmental factors)	Number of hatched nests within Night Study Area	Number of hatched nests with previous disturbance	Number of emerged hatchlings from hatched nests with previous disturbance
255	49	18	695

6.1.6 Temporally discrete emergences in Night Study Area

As Figure 23 below shows, temporally discrete Emergence Events were found within the Night Study Area 2009/10. Emergences were found to occur up to 6 days after an initial hatching event. Nests with emergences occurring over a single night were the most prevalent, with the frequency of nests that had emergences over multiple days decreasing with increasing number of days.

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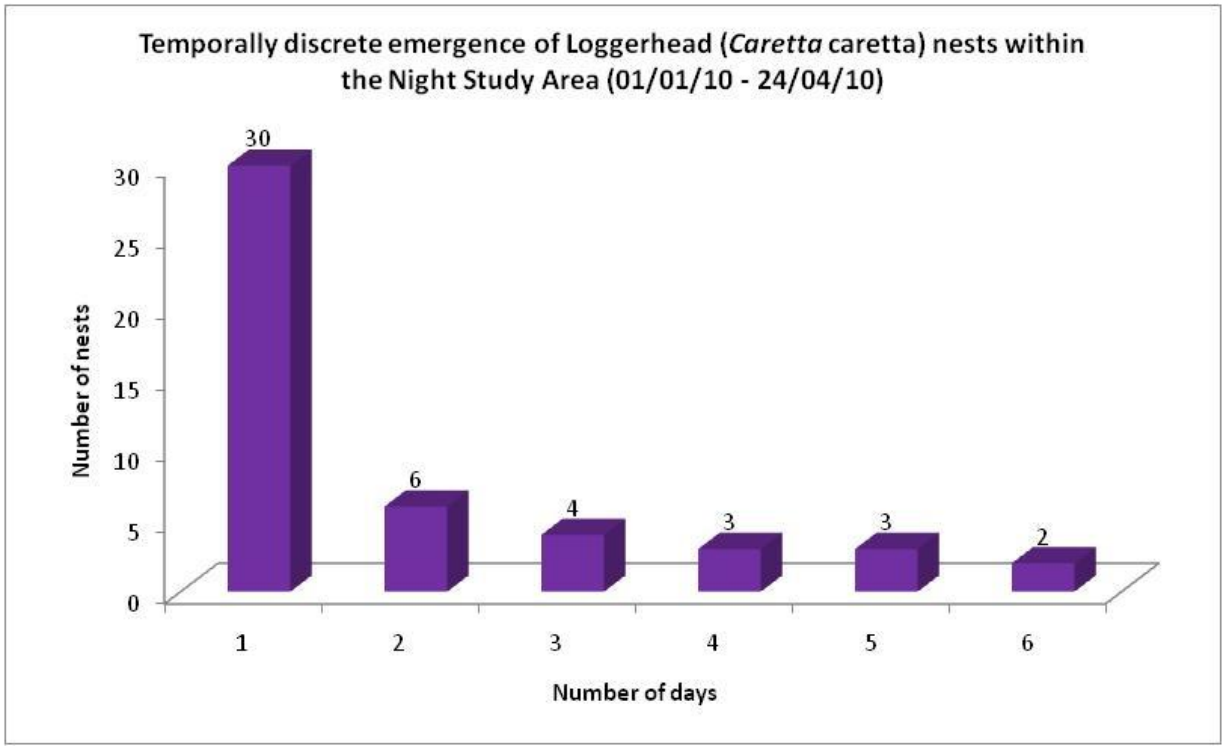

Figure 23: Temporally discrete emergence of Loggerhead (*Caretta caretta*) nests within the Night Study Area (01/01/10 - 24/04/10)

Note: Figure 23 is not inclusive of the final emerged nest which had its initial hatching on the final night of research (being 24/04/10) and is therefore not included in this graph as the number of days taken to emerge is unknown.

6.1.7 Temporal distribution of Emergence Events in Night Study Area

As Figure 24 below shows, the total number of Emergence Events observed during the night monitoring period (102) was recorded between the hours of 19h00 and 06h00 (corresponding with the duration of the 2 night monitoring shifts, from 19h00 – 24h00 and 24h00 - 06h00). Peak activity was found between 19h00 – 02h00, with Emergence Event numbers staying roughly consistent through that period with a peak at 24h00. Emergence activity in the Night Study Area 2009/10 dropped dramatically after 02h00.

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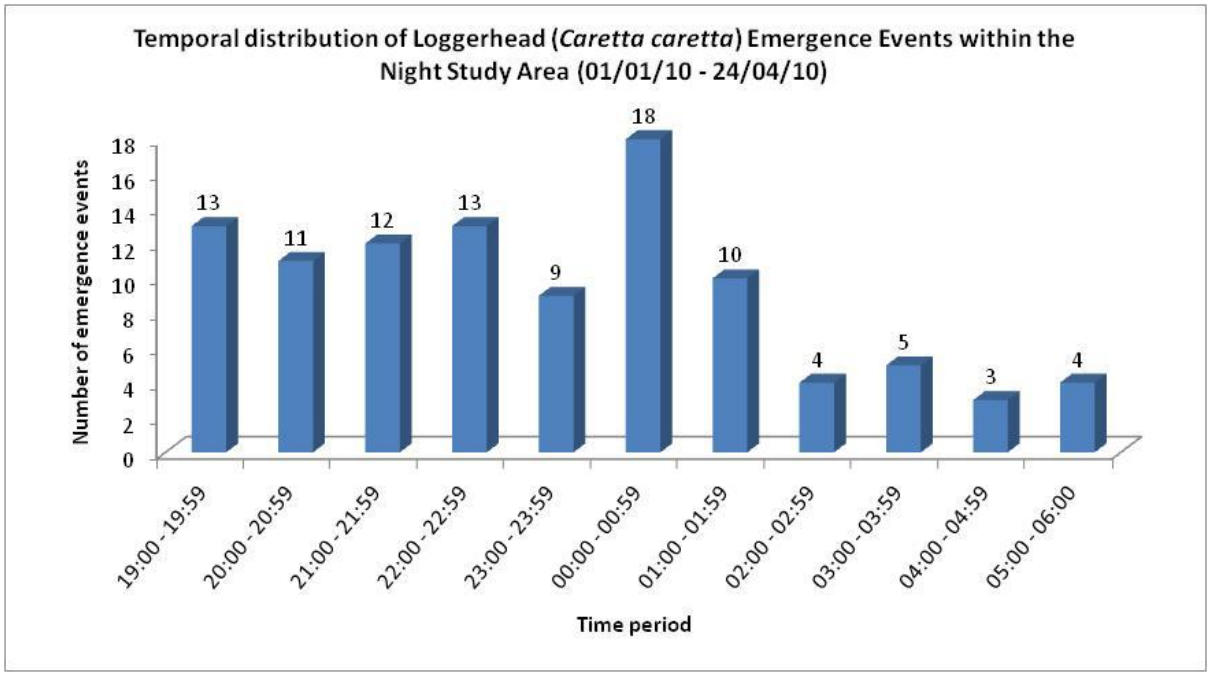

Figure 24: Temporal distribution of Loggerhead (*Caretta caretta*) Emergence Events within the Night Study Area (01/01/10 - 24/04/10)

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6.2 Discussion

Selection of Night Study Area 2009/10

The Night Study Area 2009/10 [from Beach Point 8 Marker (**BP8**) to Beach Point 9 Marker (**BP9**)] was chosen due to its high concentration and density of nests within a relatively small area, relative to the other areas patrolled by the Day research team.

Nest emergence success rates within Night Study Area 2009/10, including location impacts

The number of hatched nests in the Night Study Area 2009/10 was 49/285 making the nest emergence success rate 16.8. The nest emergence success rate within the Night Study Area 2009/10 is lower than observed at–Loggerhead rookeries on the Eastern Australian coastline where success rates varied from 65 - 82% respectively at the Mon Repos and Heron Island rookeries (Limpus 2009). The high level of egg chamber disturbance, particularly by Golden ghost crabs (*Ocypode convexa*) and the high incidence of inundation in certain sections of the Night Study Area 2009/10 may explain this finding.

The Night research team found that while a large number of nests was laid within the Night Study Area 2009/10 (285 inclusive of all species), the nests that were observed to hatch were predominantly limited to the southern section of the Night Study Area 2009/10. Nests dug in the northern section of the Night Study Area 2009/10, in Turtle Bay (predominantly between the latitudes of 23.724°S and 23.728°S), had a greatly diminished success rate. Factors that could contribute to the low success rate of nests dug in this area include abiotic factors such as flooding / inundation by tides and storm surges, lethal sand temperatures, erosion, obstruction (such as roots within the nest or compacted sand above the nest from shifting sand dunes) and biological factors such as disturbance, predation, microbial invasion and problems with the nesting female such as infertility (Limpus 2009).

Likewise, the reasons why the southern section of the Night Study Area 2009/10 spawned relatively greater emergence success rates are unknown but from the night findings 2009/10 it was concluded that it could be due to one of, but not limited to, the following reasons;

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- large, level sand flats with limited large topographical features, such as a high sheer dune complexes;
- amount of daily solar radiation received;
- ease of conducting research in the area which would minimise the amount of non-observed emergences;
- limited inundations from tides or storm surges.

Disturbance percentages (Egg chambers) in Night Study Area 2009/10

Observed disturbances of egg chambers totalled 89.5% of the 285 nests within the Night Study Area 2009/10 over the period 01/11/09 – 24/04/10, inclusive of Golden ghost crab (*Ocypode convexa*), Fox (*Vulpes vulpes*) and environmental disturbances. Golden ghost crab (*Ocypode convexa*) disturbances were observed in 46.7% (133/285) of all nests within the Night Study Area 2009/10. Fox (*Vulpes vulpes*) disturbances were observed for 9.5% (27/285) of all nests within the Night Study Area 2009/10. Crab and fox disturbances of turtle egg chambers have not previously been studied at Gnaraloo and as such comparative analyses of the 2009/10 crab and fox disturbance results within the Night Study Area 2009/10 are not possible.

Sea turtle rookeries in Australia subject of short or long term research efforts that had elevated predation levels have been able to put into effect egg chamber anti-predation measures against both ghost crabs and mammalian predators such as foxes, armadillos and racoons (Antworth et al. 2006; Glen et al. 2005). Whilst fox baiting and control measures are well established, and continually carried out at Gnaraloo through the *Gnaraloo Fox Control Program*, preventative measures against ghost crab egg chamber predation are less common, but mainly involve anti-predator screens placed over developing nests (Antworth et al. 2006; Glen et al. 2005). Anti-predator screens have been found to be successful on a number of sea turtle species in the United States, with predation rates found to be correlated with screening effort (Antworth et al. 2006). However, this process has been found to be less successful with Loggerheads (*Caretta caretta*) than other sea turtle species as they dig shallower nest chambers which are more easily predated (Antworth et al. 2006).

Environmental factors, such as inundation by high tide levels or storm surges, disturbed 32.3% (92/285) of all nests within the Night Study Area 2009/10. Significant losses of entire egg clutches due to environmental factors have been recorded in Eastern Australian rookeries. For

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example, losses of entire egg clutches at Mon Repos in the 1970's due to environmental factors were found to average 13% per year, but could range from 8.4 - 83.0% (Limpus 2009). Environmental conditions, such as weather, high tide levels, storm surges and dune position, may vary widely from year to year. Consequently this study cannot definitively say whether environmental disturbance levels observed during 2009/10 are representative at Gnaraloo. As such, additional and regular surveys over a number of years are required to establish baseline for this data.

The impact of predator disturbances on sea turtle egg chambers at Gnaraloo remains unknown. Although the percentage of observed hatched nests within the Night Study Area 2009/10 was low (44/285) (15.4%), it is only hypothesised that predator disturbances may have played a role in this. While there may be a correlation between incidences of predator disturbance of egg chambers and unhatched nests, of the 49 nests that hatched within the Night Study Area 2009/10 during the research period, 18 of these (36.7%) had previous incidences of disturbance (inclusive of environmental and predator disturbance). A significant proportion of all observed hatchlings (44.9%) also came from these disturbed nests. This data proves that although a nest may have been observed to have been disturbed (be it by predators or environmental factors) it does not necessarily equate to the destruction of a nest.

Predation percentages (Hatchlings) in Night Study Area 2009/10

The success rate of hatchlings observed to emerge from the 44 nests observed to hatch within the Night Study Area 2009/10 was 72.8% (judged on the basis of 1,126 / 1,547 hatchlings reaching the water). This is less than the hatchling success rates of 98% and 99% found respectively at the Queensland rookeries of Mon Repos and Capricorn-Bunker Cays. However, the latter are island based rookeries without terrestrial predators.

Over the period 01/01/10 – 24/04/10, observed predation rates of hatchlings were found to be 12.3% of the hatchlings observed to hatch within the Night Study Area 2009/10 (190/1,547 hatchlings from 44/285 nests), inclusive of both Golden ghost crab (*Ocypode convexa*) and Fox (Vulpes vulpes) predation. Golden ghost crab predation equalled 12% and Fox predation 0.3%. This predation rate of hatchlings within the Night Study Area 2009/10 (by Golden ghost crabs and Foxes) of 12.3% and it is not recommended that any action be presently undertaken to decrease

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the levels of Golden ghost crab predation of hatchlings at Gnaraloo until crab population impacts on Gnaraloo rookeries are better understood.

Foxes are non-indigenous invasive inhabitants which pose particular threats to native endemic Australian fauna. The conservation issues concerning foxes have long been established and as such there is no acceptable threshold for fox predation of sea turtle rookeries in Australia. Best attempts should be made to reduce fox disturbances and predation of turtle rookeries to zero. Although fox predation of hatchlings within the Night Study Area 2009/10 was limited (0.3%), as the Gnaraloo sea turtles are either critically or endangered (IUCN Red List), the intensive *Gnaraloo Fox Control Program* should be continued in future.

It should be noted that fox and crab predation levels of hatchlings recorded within the Night Study Area 2009/10 may have been influenced by the presence of researchers within the study area as well as the high percentage of hatchlings that emerged but whose fate was unknown (231 / 1,547). The impact of human presence on predation levels is difficult to measure and as predation of hatchlings still did occur; it has not been taken into account here. The number of hatchlings whose fate were unknown have been attributed to the difficulty of observation at night due to the terrain (high dunes with obscured line of sight to the water), low level of red light used during research so as not to disorientate the hatchlings, and low light levels experienced on the beach, particularly during the periods around a new moon or when the moon only appeared part way through nightly monitoring periods.

Findings from the night research work 2009/10 indicated that hatchlings were less likely to be predated by terrestrial predators if they emerged in large groups (>20) (observed predation of 5.46%) compared with those that emerged individually or in smaller groups ≤ 20 (observed predation of 38.4%). This is backed up by work by Glen et al. (2004) which also found that percentage predation of sea turtle hatchlings was decreased when they emerged in smaller group numbers.

Incubation periods for hatched Loggerhead nests in Night Study Area 2009/10

The incubation periods for hatched Loggerhead (*Caretta caretta*) nests within the Night Study Area 2009/10 was found to be between 55 - 82 days, with the highest frequency of hatching at 60 - 70 days (31/49) (63.3%). Mean incubation time was 67.3 days. This varies from research conducted on Loggerheads in Eastern Australian rookeries where incubation periods ranged

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from 50 - 60 days (Dial 1987) and 45 - 70 days (with a mean of 55.2 days) (Limpus 2009). Cooler temperatures could explain the extended incubation periods at Gnaraloo.

Analysis of the mean monthly incubation periods found that nests dug earlier in the season (during November – December 2009) had longer incubation times (70.5 – 77.2 days) compared to those laid later in the season (during January – February 2010) (63.2 – 64.7 days). This may be due to the rise in daily average temperature at Gnaraloo from November - March. This snapshot of Loggerhead incubation times in the Night Study Area 2009/10 may not be representative of the entire Gnaraloo coastline as abiotic nesting conditions, such as possible differences in sand temperatures, presence of flats, presence and size of dune complex, shading by dune complex and tide wash with associated cooling on flat beach sections, may be highly variable in such a large area with topographically distinct regions.

Confirmation of species identification by Day team

Hatchling identification during the night survey work was a secondary way to verify the conclusions drawn from the Day program's track monitoring efforts. As track monitoring is a widely used, and an accepted form of species identification, it is important to establish any margins of error to ascertain the amount of training needed prior to future track monitoring at Gnaraloo.

This was able to be undertaken for 15.4% of the nests within the Night Study Area 2009/10 (44/285). Of these, 12.3% (35) were correctly identified by the Day team based on track analysis with 3.1% (9) being misidentified [6 nests were incorrectly identified as Hawksbills (*Eretmochelys imbricate*) and 3 were misidentified as Green turtles (*Chelonia mydas*). All 9 nests were in fact Loggerhead (*Caretta caretta*).

It is recommended that a larger sample size of hatched nests than 44 nests be used in future to determine if the margin of error in predictive track identification / analysis is significant.

Temporally discrete emergences in Night Study Area 2009/10

Although Loggerhead (*Caretta caretta*) nest emergences were observed primarily as single occurrences, temporally discrete Emergence Events were also observed within the Night Study Area 2009/10. There were single Emergence Events where hatching occurred within a single

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night (30/48 – 62.5%) as well as multiple Emergence Events where emergences occurred over 2 days up to 6 days after the initial hatching (18/48 – 37.5%).

Although primarily single nest emergences have been observed at loggerhead rookeries on the Eastern Australian coast (Witherington et al. 1990), considerable asynchrony in emergences has also been recorded (Glen et al. 2005; Witherington et al. 1990). Loggerheads have been recorded as emerging up to 11 days after initial hatching (Glen et al. 2005). The results at Gnaraloo for the Night Study Area 2009/10 is similar to that found by Glen (Glen et al. 2005), who found that there was a peak in emergence over 1 day followed by a decrease in number of emergences following subsequent nights. This asynchronous pattern of emergence could be the result of eggs in the same clutch incubating at different temperatures (Glen et al. 2005).

In the past, it has been assumed that mass emergence events were important for the maximum potential survival of as many individuals as possible due to predator dilution (Davenport 1997). The results show that percentage predation was significantly higher for hatchlings that emerged in smaller groups (20 or less) than larger groups (more than 20). However, it is now believed that evolution may also favour asynchronous emergences where emergences may continue over several nights rather than in one single event, which was observed within hatched nests within the Night Study Area 2009/10. Although evolution would favour mass emergences in order to decrease the probability of an individual being predated through predator dilution, this has only been found with terrestrial predators. With marine predation, the reverse has been found as predation levels with offshore predation levels increasing with increasing numbers of hatchlings (Stewart & Wyneken 2004). This may explain why hatchlings are observed emerging in groups, but rarely emerge as a whole clutch 100% of the time (Glen et al. 2005).

Temporal distribution of Emergence Events in Night Study Area 2009/10

Emergence Events during the Night monitoring period were observed across all time periods between 19h00 - 06h00. Although the study found emergences only between this period, daylight Emergence Events may have occurred, but were not recorded due to the research period being limited to 19h00 - 06h00. A distinct peak was noted with 84.3% (86/102) emergences occurring between 19h00 - 02h00.

Studies have shown that although emergences can occur during the daytime they are mainly limited to nocturnal events: Davenport (1997) with Glen et al. (2005) finding that 79.5% of

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Loggerhead (*Caretta caretta*) hatchings occurred at night, with the remainder occurring in early morning hours. This temporal emergence is thought to be confined to hours of darkness due to the evolution away from diurnal emergences. Daily temperatures that occur across sea turtle rookeries may be high enough to kill diurnally emerging hatchlings or will severely lower the activity level of hatchlings leaving them vulnerable to predators (Witherington et al. 1990). Thermal cues have consequently developed to cause nest hatchings to occur at night. A critical temperature which causes hatching, a rapid decrease in temperature and the formation of a negative thermal gradient where the sand above the nest is cooler than sand within the nest have all been demonstrated as important factors in hatchling emergence (Moran et al. 1999; Witherington et al. 1990). A critical temperature is thought to be the most important, but with all three cues playing a role (Moran et al. 1999). Statistical analyses of the Gnaraloo findings need to be undertaken to ascertain whether the peak found in Emergence Events at Gnaraloo Loggerhead nests is significant or not. In addition, continual research over successive seasons should be carried out in order to establish the true peak hours for hatchling emergence at Gnaraloo.

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6.3 Conclusions

Night Study Area 2009/10

Beach Point 8 Marker (**BP8**) to the Beach Point 9 Marker (**BP9**) was used for the Night Study Area 2009/10 due to its high concentration and density of nests within a relatively small area.

Nest emergence success rates within Night Study Area 2009/10, including location impacts

The nest emergence success rate was found to be low compared to other Loggerhead (*Caretta caretta*) rookeries in Australia. Only successive research seasons and specific scientific study can determine the definitive causes for this trend and whether these findings are a regular observance from season to season or an isolated incident.

If these findings are found to be consistent findings at Gnaraloo, then abiotic data from sand data loggers and weather stations would be vital to determine the causes of the trends. A weather station and sand data loggers were used within the Gnaraloo research area 2009/10, but individual data loggers specific to regions with contrasting emergence success rates could be important to verify causes.

Disturbance percentages (Egg chambers) in Night Study Area 2009/10

Before any reactive measures are undertaken to decrease the level of egg chamber disturbance of nests at Gnaraloo, exact egg chamber predation levels must be established. Only through egg counts of nesting females and subsequent nest excavations and exhumation can predation levels definitively be discovered. These are invasive techniques that require government licenses and extra man power to be carried out, but are vital in order to establish exact predation levels of egg chambers.

Predation percentages (Hatchlings) in Night Study Area 2009/10

The high levels of unknown hatchling fates can be solved simply. A greater number of researchers on the beach would alleviate this problem. Gnaraloo protocol is that two researchers observe an emerging nest; one member counting emerged hatchlings behind the nest stake, and the other on the shoreline counting successful and predated hatchlings. However, this was not

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always possible in practice due to quick Emergence Events or a researcher happening upon an already emerging nest. In these instances, one researcher only had to collect data for the emergence, often with line of vision to the water line obscured by high dunes or dark conditions. Although emerging hatchlings often work their way down to the shore as one unit, occasionally this unit may fan out over a wide area. When hatchlings emerge in small groups, individuals lacking this group behaviour have been seen to locate the shore in widely differing directions. In both these cases, an increased number of researchers by the shore line, counting the hatchlings entering the water, and an increased number of researchers at various points between the shore and the nest, monitoring for predation, would lessen the number of hatchlings with unknown fates and increase the accuracy of results.

The problem of human presence effecting predator predation levels is less easy solve. The actual impact the researchers are having is unknown as it is difficult to measure predation without a human presence on the beach. Methods such as minimal movement and minimal light should continue to be used, to reduce the effect that researchers have on recording accurate predation levels.

Incubation periods for hatched Loggerhead nests in Night Study Area 2009/10

In many research studies, observation of nests is usually discontinued after a period of 70 days (Engeman et al. 2003; Engeman et al. 2005). At this point, it is believed that the eggs are no longer viable and therefore can be exhumed and excavated for research purposes. However, with the Gnaraloo research recording incubation periods up to 82 days, with more than 28.6% (14/49) of nests having an incubation period 70 days or more, it is suggested that observation of nests is continued past that date and only discontinued after 100 days.

Confirmation of species identification by Day team

Track monitoring is a useful and cost effective way of species identification. This should be continued in conjunction with hatchling identifications from the night monitoring surveys in order to confirm the accuracy of this technique at Gnaraloo. Further training of volunteers should be undertaken each season to ensure a low margin of error and a consistent monitoring technique.

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Frequency of hatched nests with previous recorded disturbance in Night Study Area 2009/10

18/49 hatched nests in the research area came from nests with previous predatory or environmental disturbance. This, combined with the high proportion of hatchlings observed from these nests (695), indicates that nests should continue to be monitored for possible emergences even if they have been recorded as disturbed.

Temporally discrete emergences in Night Study Area 2009/10

Multiple emergence events from single Loggerhead (*Caretta caretta*) nests at Gnaraloo emphasises the need for continued observance of nests, even after their first emergence. This is significant for accurate data collection at the Gnaraloo Loggerhead rookery during future research seasons.

Temporal distribution of Emergence Events in Night Study Area 2009/10

Findings during 2009/10 demonstrate the importance of night research from dusk until dawn as high incidences of Emergence Events occurred throughout this period, although there was a peak between 19h00 and 02h00. As such it is recommended for future seasons that night survey work continues to be carried out between these periods.

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7 RECOMMENDATIONS

The following section outlines recommendations by the GTCP Day and Night teams 2009/10 for future monitoring seasons at Gnaraloo. To ensure monitoring continues successfully at Gnaraloo in future, the design, format and feasibility of the night program in particular should be considered prior to the commencement of onsite monitoring activities. Limitations need to be considered such as the size of the selected research area, ease or difficulty of access to this area, accommodation and logistical arrangements for the required number of volunteers and safety. The scope of the program in future seasons will again be tailored to reflect available resources. Alternatives to expanded research by GTCP volunteer teams, such as external projects and studies by university, should also be considered.

7.1 Day

Day monitoring program 2010/11

Following recommendations from the 2008/09 season, the formal monitoring season for the Day research at Gnaraloo was amended to operate from 1 November 2009 – 28 February 2010. This worked very well and seemed to encompass the majority of the nesting activity; however, there was a lull of 2 weeks at the beginning of the season where no turtle activity was recorded. Perhaps this was normal, and it would be beneficial to begin monitoring at the same time during 2010/11 to ensure the annual turtle nesting season at Gnaraloo does in fact begin round about 15 November.

The Day monitoring season should again operate for 4 months during 2010/11, ending at the end of February 2011. As only a few new nests were still being recorded in late February 2010, it is indicative of the end of the sea turtle nesting season at Gnaraloo. Additionally, it is recommended that the formal training in West Australian track monitoring and data management protocols be organized in a similar fashion to that undertaken during the 2009/10 season, with a week of formal training prior to the season start and on-ground monitoring activities by the Day team(s) (to commence onsite at Gnaraloo during the last week of October).

It is recommended to maintain a Day team of at least 2 members during 2010/11. The Revised Day Study Area 2009/10 was very manageable for 2 people on foot. It is also beneficial to have

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at least 2 people for the Day team(s) for safety reasons (i.e. vehicle break-downs or flat tyres, snake or scorpion bites) as well as maintaining team morale over a period of daily work for 4 months. As the Revised Day Study Area 2009/10 was much shorter than the Total Study Area 2008/09, a quad bike or ATV is not required for the daily monitoring activities.

As the Day monitoring area was shortened during 2009/10 to exclude BP9 – BP10, the monitoring area consisted of 2 smaller subsections (GBN – BP6 & BP6 – BP7) with a larger northernmost subsection (BP7 – BP9). Results indicated that there was a significant difference in nesting frequency between the southern and northern portion of BP7 – BP9, with the northern portion experiencing a much higher density of nesting females than the southern portion. For this reason, the Night teams 2009/10 split BP7 – BP9 into two smaller subsections, namely BP7 – BP8 & BP8 – BP9. It is recommended that the Day team 2010/11 follow this guidance and divide BP7 – BP9 in the same manner in order to be able to fully capture differences within the total monitored area.

Nest disturbances and predation by crabs

The extent of turtle predation by all crab species should continue to be investigated in future monitoring seasons, during both the nesting period and the hatching period.

During 2009/10, only Golden ghost crabs (*Ocypode convexa*) were observed interfering with turtle nests and hatchlings. However, it would be beneficial to further investigate the interactions of all crab species observed on Gnaraloo rookeries within future study areas with turtle nests and hatchlings.

This could be done through monitoring efforts of GTCP volunteer teams (as occurred during the 2009/10 season) or as university research projects into crab populations and their impacts on Gnaraloo rookeries.

7.2 Night

Night monitoring program 2010/11

Night teams during 2009/10 were composed of 4 members, divided into 2 teams that split the night shifts. If possible, it is advised that the number of night researchers be increased should the program be repeated in its current format during 2010/11. This would enable more persons

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on the beach for more accurate research and would allow night researchers to have 1 rest day per week. Currently night researchers work 7 days a week for 4 months, with 12 hours spent on the beach collecting research between 19h00 and 06h00, and additional hours spent daily to manage, analyse and report data. Researchers also interact with Gnaraloo's Environmental Advisor concerning technical issues as well as produce monthly blogs of their survey activities and results for posting on the Gnaraloo website. Researchers would benefit from a night off per week as by the end of the season they are physically exhausted from the range of project activities. Towards the end of the season, the importance of data analysis and formal reporting of results and conclusions increases and the free time and sleeping researchers have, when combined with the ongoing nightly beach survey shifts, are reduced. By allowing night researchers a night off per week, the quality of the nightly beach data collection (which often involves long periods of survey in cold conditions with no or little hatching activity), data analysis and formal reporting should remain consistent throughout the research period. If the night researchers were better rested, it would also benefit the formal reporting and editing process in Geraldton, immediately after close-out of the on-ground works period at Gnaraloo, which is labour intensive, time consuming and demanding.

As this was the first season for night research at Gnaraloo, the program was carried out without any prior recommendations. It is suggested that the scope of the night program be narrowed in future to focus on specific research targets. If permits are obtained, research targets may be limited to precisely identify nesting success rates and predation levels, by using egg counts and exhumations. In this way, rather than monitoring all the nests in the Night Study Area 2009/10, to enable more accurate research, a sample size of nests may be monitored from the date it is laid to approximately 10 day after the first recorded emergence or in the case that a nest does not emerge, to approximately 100 days after nest was laid. Night time sampling of nests would cease once a large enough sample size was reached. A representative sample size of nests may consist of 60 - 80 nests. However, such a proposal would require night researchers to commence research at the beginning of the nesting season, in conjunction with the Day team. Night research would then be finalised 100 days after the final chosen sampled nest was laid. It is recommend that if sampling of nests is undertaken in this fashion in future seasons, that at least one researcher with relevant and extensive previous experience in such research techniques be recruited. Alternatively, this type of study may be suited as an external university research project.

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Nest disturbances and predation

The number of hatched nests compared to the number of dug nests within the Night Study Area 2009/10 was relatively low with respect to global Loggerhead (*Caretta caretta*) nest hatching success figures (Spoitila 2004). Further research is required to establish the success percentage of dug nests at Gnaraloo. As well as observation of emerging hatchlings other techniques could be used to determine this success rate. Exhumations of nests with egg counts of nesting females, combined with hatched nest data, would give a more accurate representation of the success rate of Loggerhead nests at Gnaraloo. The research area at Gnaraloo would, however, have to be analysed in order to determine whether it is feasible to carry out such invasive work. Limitations such as the extent of the night research area, difficulty of access to the night research area, safety considerations and ability of Gnaraloo to house the required number of scientific researchers and support volunteers to carry out the night research techniques would have to be assessed and considered. If night monitoring at Gnaraloo is going to head in this direction, it should be noted that any associated permits should be obtained from the relevant authorities prior to the commencement of monitoring. Alternatively the undertaking of more invasive studies at Gnaraloo should be considered as university research projects.

Protection of the egg chambers against crab disturbance could be considered. Methods such as wire or plastic screens over incubating nests and continued human presence have been used in the past (Stewart & Wyneken 2004) and there is no reason why some or all of these procedures could not be used or trialled at Gnaraloo for the successful protection against egg chamber disturbance by crabs. The invasive techniques discussed above would also be important to evaluate the extents that crab disturbance effects incubating eggs. Currently although crab disturbance research data has been collected, it is unknown whether this disturbance is superficial or whether it has any significant impacts on Loggerhead nesting success at Gnaraloo.

The research conducted during the 2009/10 night research season found fox disturbance to egg chambers to have a lesser impact compared to ghost crab disturbance. However, this is not to say that fox disturbance has a more minimal impact on the Loggerhead nest success at Gnaraloo. Fox disturbance may be lower due to the implemented specialized *Gnaraloo Fox Control Program* and, as such, it is recommended that the Gnaraloo fox program be continued in future. The true extent of egg chamber disturbance by foxes would also only be possible with more invasive research techniques, as discussed above.

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Hatchling predation

Although onshore predation of hatchlings within the Night Study Area 2009/10 by crabs and foxes was found to be relatively low (12.3%), it is recommended that the night monitoring of hatchling predation be continued in future. Results in the Night Study Area 2009/10 indicated higher crab predation rates than recorded during the 2008/09 research season. Investigation over several nesting seasons are needed to formulate more concrete evidence on the levels of crab predation of hatchlings.

Predation of hatchlings within the Night Study Area 2009/10 by foxes was found to be minimal (0.3%), but still occured, therefore the *Gnaraloo Fox Control Program* should be continued, ideally at an intensity to reduce the fox population to zero.

Vehicle access to sea turtle study area(s) at Gnaraloo

It is recommended that vehicle access to the night monitoring area be improved. Currently vehicles must be parked approximately 1.2 kilometres away from the Night Study Area 2009/10. Therefore, each night team must walk an additional 2.4 kilometres each night between the study area and the night monitoring vehicle. Having better access would improve night monitoring efficiency and would reduce night team fatigue. Improved access would also improve safety in the case of an emergency during night monitoring field work. Should night research during 2010/11 again be in BP8 – BP9, the track may be extended closer to the BP8 marker to allow for four wheel drive access. Alternatively, should night research during 2010/11 involve an alternative research area, vehicle access needs to be considered.

7.3 Overall

Future sea turtle research at Gnaraloo

Review of this report by Dr Mark Hamann during July 2010 provided the following recommendations. As possible future Honours (10 months) or Master (1.5 years) research projects, investigation into:

- Temperature and climate
  a) What is the vulnerability of Loggerhead turtles (*Caretta caretta*) in Western Australia to increased air and sea temperatures?

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b) What is the sex ratio of sea turtle hatchlings produced at Gnaraloo?

- Egg, clutch and hatchling survival
  a) How does nest site selection at Gnaraloo influence egg and hatchling survivorship? Compare nest sites with factors such as distance from tidal ranges and bottom of beach. Map beach heights. Compare sites of successful and unsuccessful nests at Gnaraloo.
  b) Do ghost crabs change abundance and distribution patterns during the turtle nesting season at Gnaraloo?
- Ecology
  a) How many clutches do Loggerheads (*Caretta caretta*) at Gnaraloo lay in one season? Combine satellite tracking and turtle tagging at a high density beach at Gnaraloo.

Onsite turtle co-ordinator at Gnaraloo

It is strongly recommended that an onsite turtle co-ordinator be appointed for the 2010/11 season. Duties of this person may include: onsite training of volunteers, maintaining high quality scientific research and ensuring the research carried out is working to the GTCP's scientific objectives, liaising with the Gnaraloo Environmental Advisor and the Gnaraloo leaseholder and reporting on the GTCP. This would provide an onsite representative of the GTCP for volunteers and increase the organisation of the program.

Currently researchers provide their own laptops for research and data management. Whilst this should be encouraged, a site computer and/or external hard drive are advocated as this would create an organisational system for all the data collected. From the site computer and/or external hard drive, all turtle research data may be stored and managed from year to year. This would also reduce the impact on researchers' computers which, at the moment, are used in all aspects of the program, including being taken out into the field to collect abiotic data for the weather station.

Future recruitment of GTCP team members

It is envisaged that recruitment of team members in future would be carried out in a similar fashion to the 2009/10 and 2008/09 seasons. The number of team members recruited for future seasons at Gnaraloo would be determined according to the scope of the program at the time. Previous experience working with sea turtle research and monitoring is highly desirable and should be sought out when seeking future team members. It is also strongly recommended that

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recruited team members are highly competent with Microsoft Word and Excel. One team member with previous experience and knowledge of GIS software must be recruited for future seasons at Gnaraloo unless maps are to be produced externally. If a new Gnaraloo specific Microsoft Access database is to be developed for future monitoring seasons, it is imperative that at least one team member be recruited who possesses skills in creating and maintaining Microsoft Access databases.

It is also essential that team members arrive onsite prior to the commencement of formal monitoring activities to allow enough time for training and program set-up.

Equipment

It is recommended during future seasons that team members again complete inventories of all monitoring equipment prior to the commencement of formal monitoring activities as well as at the end of the seasonal program, when hand-over occurs to the Gnaraloo leaseholder.

Equipment required for monitoring activities should be purchased at the start of the season before formal monitoring commences. It should be noted that some spare equipment such as clipboards should be obtained as they deteriorate under the conditions at Gnaraloo over the season and may need to be replaced.

Community involvement

Over the 2009/10 monitoring season, members of the community occasionally accompanied GTCP team members during execution of their monitoring duties. Community involvement and education is an extremely important component of sea turtle conservation (Gulko & Eckert 2004), however, this placed extra responsibility and strain on GTCP team members. It is therefore recommended that an onsite turtle co-ordinator be appointed in future to co-ordinate such involvement, including necessary training and possible monitoring assistance by community volunteers. Should members of the community wish to accompany GTCP team members during their monitoring activities, from time to time, it should only occur on certain days and GTCP team members be provided with sufficient prior notice of same.

Recording disturbance and predation

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During the 2009/10 season, there was conjecture over whether or not nests that displayed signs of disturbance by Fox (*Vulpes vulpes*) and/or Golden ghost crabs (*Ocypode* spp.) actually had predated egg chambers.

It is therefore strongly recommended that prior to the commencement of future monitoring seasons a clear distinction be made between 'disturbed nests' and 'predated egg chambers' and data be recorded accordingly and consistently by both Day and Night teams. Predation of egg chambers can usually be confirmed by observing eggshell fragments or whole eggshells around a disturbed nest. However, care must be taken to ensure that the eggshells originated from the disturbed nest which is to be recorded. Furthermore, training for future seasons should include any changes made relating to determining the difference between 'disturbed nests' and 'predated egg chambers', including the associated Definitions (refer Glossary for definitions used during the 2009/10 season) and the recording of related data.

Fox activities in the rookeries could also be analysed during future seasons to determine whether:

- fox presence and/or disturbances increase during the nesting period and again just prior to nests being ready to hatch;
- there is any relationship between fox disturbances (diggings) to nests and the incubation times of disturbed nests (i.e. causes premature emerges).

Additional training in predator track identification

During the 2008/09 and 2009/10 seasons, debate occurred over recorded fox predation data in the Gnaraloo rookeries, the extent and prevalence of such predation. Therefore, it is imperative that team members during future seasons receive additional training in recording fox presence (tracks), disturbance and predation within Gnaraloo rookeries. Refer discussion immediately above concerning the distinction to be drawn between fox disturbance and predation.

It is also important that team members be trained and able to distinguish the difference between fox, feral cat and wild dog tracks, particularly in the windy conditions prevalent at Gnaraloo during the annual turtle breeding season, which often result in wind-blown tracks that present a challenge to identify correctly.

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Refer to the recommendations in the November 2009 and February 2010 reports by Animal Pest Management Services.

Pre-season training and Species identification

It is recommended that track analysis for species composition and distribution again be used during future seasons of monitoring at Gnaraloo, with secondary verification of accuracy by the night program's identification of hatchlings.

To ensure accurate identification across both Day and Night programs, it is imperative that thorough training of all volunteers in both track and hatchling identification again occur immediately prior to formal monitoring activities.

Gnaraloo Fox Control Program

Although fox control efforts were consistent throughout the monitoring season, they failed to completely eradicate fox presence, even temporarily. This indicates that the Gnaraloo coastline fox population is quickly replenished from unbaited areas of young foxes finding new territory. These young foxes had not yet developed the ability and knowledge to locate and unearth turtle nests, and were not as destructive to the turtle nests within the study area, although they did exert predatory pressure on emerging hatchlings.

Structured fox baiting events were undertaken by Animal Pest Management Services (**APMS**) during November 2009, December 2009 and February 2010. Gnaraloo conducted support baiting during December 2009 – February 2010. It is recommended that formal records be kept in future for the support baiting done by Gnaraloo. Important information to record would be the date, location and number of baits laid.

Approximately 9.5% of egg chambers within the Night Study Area 2009/10 were seen to be **disturbed** (as distinguished from predated) by foxes. With formal records kept, management of the fox population may be standardized by increasing the number of formal fox baiting events by APMS and/or providing more training for support baiting, as required, in order to reduce the number of nests being dug up, eggs being taken and hatchlings being predated.

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GIS mapping software

The GIS (**Geographic Information System**) software used during the 2009/10 season was obtained as a trail version only and expired upon completion of the monitoring during April 2010. It is recommended that for the 2010/11 season a GIS software licence be purchased as this would allow unlimited use of the software during following seasons. It is also recommended that the aerial imagery and required base maps for the Gnaraloo study area be purchased which would allow for unlimited future use and would improve the quality of maps as currently lower quality geo-referenced images are being used, which are less accurate and of lower quality.

Teams for future seasons should include at least one member with previous experience in the use of GIS. GIS is quite complex and, without prior knowledge and experience in GIS operation and data management, it would be difficult to navigate in order to produce essential maps of the season's research findings.

GIS software providers should be contacted before the season's start during 2010/11 to enquire whether the GTCP qualifies for any concessions for conservation related work. For example, not-for-profit organisations often receive heavily discounted software under certain conditions.

Gnaraloo Weather Station

The weather station at Gnaraloo was installed during December 2009. When it was originally installed, the data logger component of the station was left off the console. There were also problems associated with software (Weatherlink) compatibility of the weather station with team members' personal computers. As a consequence, the weather station did not start logging data until mid February 2010.

The Gnaraloo Weather Station was dismantled at the end of the monitoring season 2009/10, to protect it against the corrosive weather elements during a prolonged period of non-use. The station must be re-installed prior to the commencement of the 2010/11 monitoring season and calibrated to log data before the start of formal monitoring activities. The Weatherlink software must also be installed on relevant computer(s) of team members, which needs to be compatible with the Weatherlink software requirements. For instructions on how to undertake these activities, refer to the Weather Station instructions and the Turtle Monitoring Procedure 2009/10.

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Gnaraloo specific Sea turtle database

As occurred during 2008/09, during the 2009/10 monitoring season, Day data and results were recorded in a Microsoft Access Database (an extension of the Access Database of the *Ningaloo Turtle Program* in Exmouth) and several Microsoft Excel databases. Night data and results were entered into several other Microsoft Excel databases. It is recommended that for future seasons the combining of Day and Night data into a single database be investigated. This would potentially strengthen the relationship and reduce some conjecture between Day and Night monitoring data as well as reducing the need for repeated entry of the same data into multiple databases.

In order to achieve this, it is recommended that consideration occur of the use of a Microsoft Access database designed specifically to encompass the scope of the entire monitoring program at Gnaraloo. A suggested approach to designing such a database may involve linking individual nests (with specific nest identification codes) to other attributes such as disturbance, emergence events and incubation times. This would alleviate some issues experienced during 2009/10 with querying data in the Day Access Database based on the Ningaloo Turtle Program. For example, when querying 'fox disturbance', the database did not (could not) distinguish between 'fox presence' (tracks) and 'fox disturbance' (e.g. diggings) which resulted in skewed results until the error was identified and corrected during final data analysis and report writing at the end of the season.

In order to tailor a database specifically for monitoring at Gnaraloo, it is recommended that at least one future GTCP team member possess proficient skills in creating and maintaining Microsoft Access databases. Alternatively, a suitable database may be created specifically for GTCP by an external party such as a tertiary institution, university or research body.

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8 GLOSSARY

BP6	The Beach Point 6 permanent marker, being the vertical white pvc pipe at the 6Mile public parking area.
BP7	The Beach Point 7 permanent marker, being the vertical light blue pvc pipe at the 7Mile vehicle parking site for the Day team.
BP8	The Beach Point 8 permanent marker, being a vertical white pvc pipe on the primary dunes.
BP9	The Beach Point 9 permanent marker, being a vertical metal star picket on the primary dunes (delineates the northernmost boundary of the Revised Day Study Area 2009/10 and Night Study Area 2009/10).
BP10	The Beach Point 10 permanent marker, being a vertical metal star picket on the primary dunes (in front of 10Mile pastoral vehicle parking area) (delineates the northernmost boundary of the Total Study Area 2008/09).
Clutch	All of the eggs laid in a single nest.
DEC	Department of Environment and Conservation.
Egg chamber	Location in which eggs are deposited; a deep hole dug into the primary body pit using the turtle's back flippers.
Egg chamber **disturbance** by crabs (Night)	Sightings of a crab burrow(s) into a nest (the area 2 metres in front of the stake, in a 180° radius) **with** turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface. **Alternatively**, sightings of **5 or more** crab burrows into a nest with or without turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.
Egg chamber **disturbance** by foxes (Night)	Sightings of fox digging(s) into a nest with or without turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.

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Emergence Event	One or more hatchling(s) emerging from a focal point more than 30 minutes after the previous emergence event (also referred to as a nest hatching).
Emerging track	The track left by a turtle as it goes from the sea to the land.
False crawl	Refer to 'unsuccessful attempt' in Glossary.
Fox **disturbance**	Evidence of fox burrowing into the egg chamber of a nest, egg shells may be present.
Fox **predation** (Night)	Observation of a fox actively taking a hatchling.
Fox **presence** (Day)	Evidence of fox tracks and/or visual of an individual fox; may or may not include evidence of 'fox disturbance'.
GBN	The GBN permanent marker, being the vertical yellow *Gnaraloo Bay North Marine Sanctuary Zone* marker (delineates the southernmost boundary of the Revised Day Study Area 2009/10 & of the Total Study Area 2008/09).
GTCP	Gnaraloo Turtle Conservation Program.
GTPG	Female Green (*Chelonia mydas*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10.
Hatchling	A newly hatched turtle.
Hatchling **predation** (Night)	Actual sighting of a predator consuming a hatchling.
Hatchling success	Entry of a hatchling into the sea (i.e. making it to the water).
HTPG	Female Hawksbill (*Eretmochelys imbricata*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10.
Incubation period (days)	Time from when a nest is laid to the time of hatchling emergence (including the time from nest hatching to hatchling emergence).
LTPG	Female Loggerhead (*Caretta caretta*) turtle population at Gnaraloo in the Revised Day Study Area 2009/10.

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Monitoring season	The entire time period during which volunteers monitor sea turtle nesting and hatching events.
Nest **disturbance** by crabs (Day)	Sightings of a crab burrow(s) into a nest with or without evidence of nest disturbance (for example, turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface, or an exposed egg chamber).
Nest **disturbance** by environmental conditions (Day and Night)	Inundation and/or erosion by tides, storm surges or wind-blown shifting dunes.
Nest **disturbance** by foxes (Day)	Sightings of fox digging(s) into a nest with or without turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.
Nest success	A clutch that hatches and emerges.
Night Study Area 2009/10	Entire region monitored daily by night team; the area consisting of the Beach Point 8 (BP8) marker north to the Beach Point 9 (BP9) marker.
Neonatal predation	Taking of a newly hatched turtle.
Neonate	Newly hatched and/or emerged turtle.
NTP	Ningaloo Turtle Program.
Returning track	The track made by a turtle as it returns from the land to the sea.
Revised Day Study Area 2009/10	Area monitored daily by Day team, from Gnaraloo Bay North (GBN) to Beach Point 9 (BP9).
Rookery	A significant breeding area for a large number of animals.
Successful nesting attempt	Turtle activity that results in a clutch being deposited.
Total Study Area 2008/09	Gnaraloo Bay North (GBN) to Beach Point 10 (BP10).
Turtle activity	Includes both successful turtle nests and false crawls.
Unsuccessful attempt	The emergence of a turtle from the sea that does not result in the laying of eggs.

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	Review comment by Dr Mark Hamann to Gnaraloo during July 2010 was that the term 'false crawl' is not used in Australia as a female will try to lay a clutch each time she comes ashore. At times, conditions do not favour her and she returns to sea without laying eggs. The terms 'successful attempt' and 'unsuccessful attempt' are used in Australia.
Unsuccessful nest	Nests that have not hatched within the probably incubation period.

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MAPS

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DAY MONITORING RESULTS BY SUBSECTION

FIGURES

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Day monitoring results by subsection

GBN - BP6

The Gnaraloo sub-section extending from the Gnaraloo Bay North Marker (**GBN**) to Beach Point 6 (**BP6**) recorded 30 nests and 14 false crawls throughout the 2009/10 study season (refer Figure A1 below).

The turtle activity in this sub-section was predominantly Loggerhead (*Caretta caretta*) with 20 nests and 11 false crawls, followed by Hawksbill (*Eretmochlys imbricata*) with 8 nests and 2 false crawls. Two nests and 1 false crawl could not be identified with certainty.

As can be seen in Figure A1, Green (*Chelonia mydas*) turtles were not present at all on the beach in this sub-section.

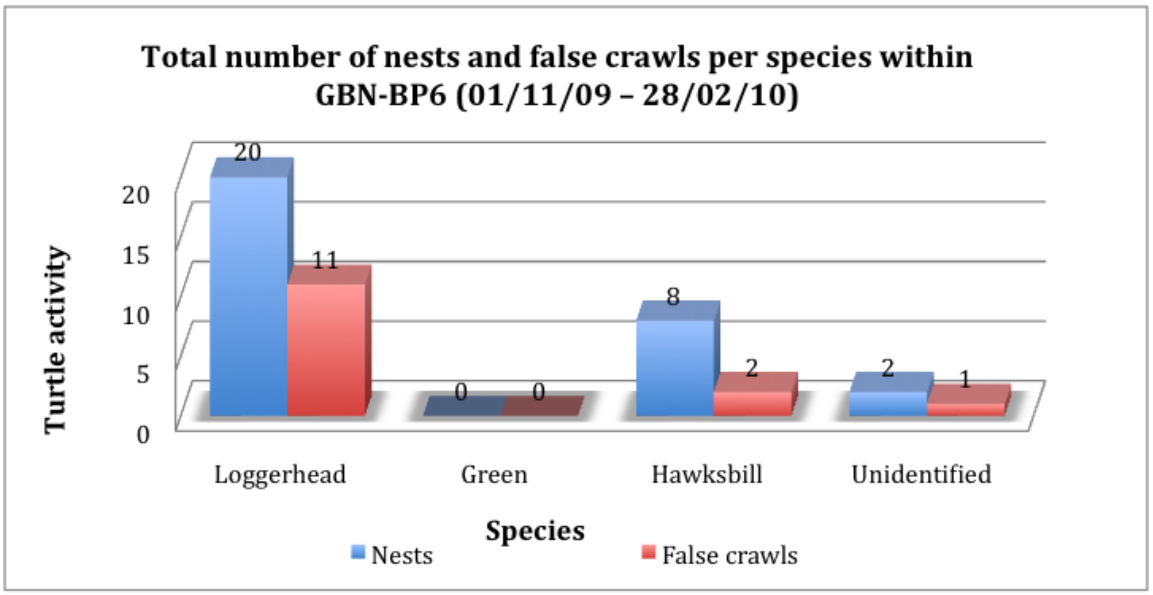

Figure A1: Total number of nests and false crawls per species within GBN-BP6 (01/11/09 – 28/02/10)

The nesting activity in the **GBN-BP6** sub-section was far slower than the other sub-sections, with turtle nesting activity (green line) peaking in early January 2010 before declining until the end of the Day study season on 28 February 2010 (refer Figure A2).

As can be seen in Figure A2, false crawl (blue line) and total turtle activity (red line) trends followed this trend.

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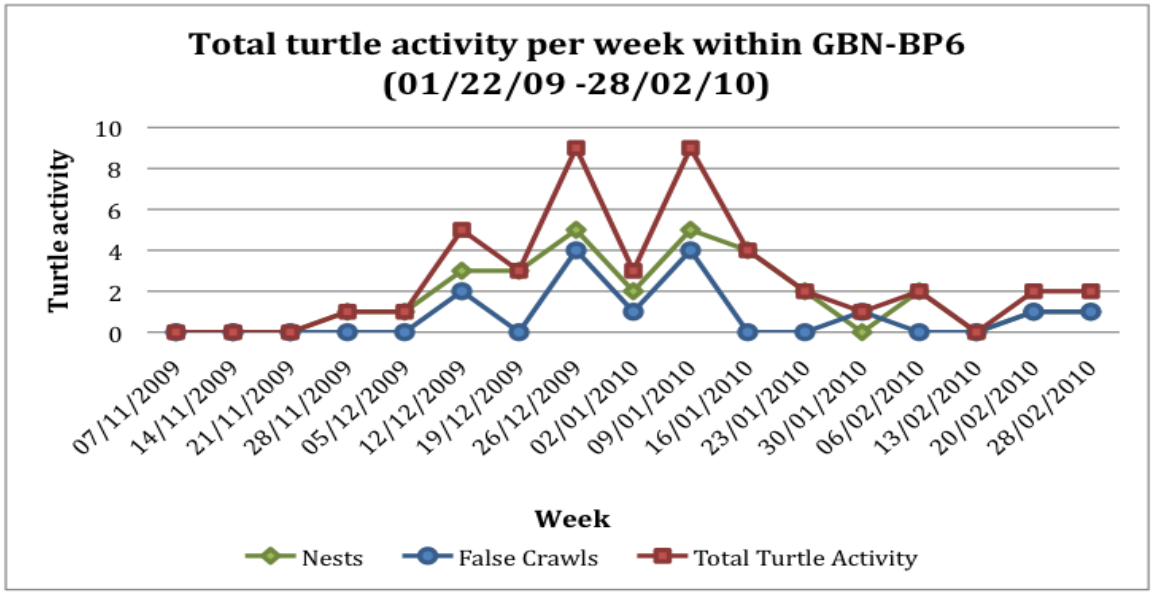

Figure A2: Total turtle beach activity per week within GBN – BP6 (01/11/09 – 28/02/10)

The nesting activity in the **GBN-BP6** subsection was far slower than the other subsections, with total turtle activity peaking in early January before declining until the end of the study season. As can be seen in Figure A2, false crawl trends followed this trend.

BP6 - BP7

The Gnaraloo sub-section extending from Beach Point 6 (**BP6**) to Beach Point 7 (**BP7**) recorded 135 nests and 66 false crawls throughout the 2009/10 study season.

Loggerhead (*Caretta caretta*) turtles were again the predominate species in this sub-section, with 95 nests and 43 false crawls (Figure A3). Hawksbill (*Eretmochlys imbricata*) and Green (*Chelonia mydas*) turtles followed in smaller numbers with 30 nests and 18 false crawls and 9 nests and 5 false crawls, respectively.

There was only 1 unidentified nest in this sub-section.

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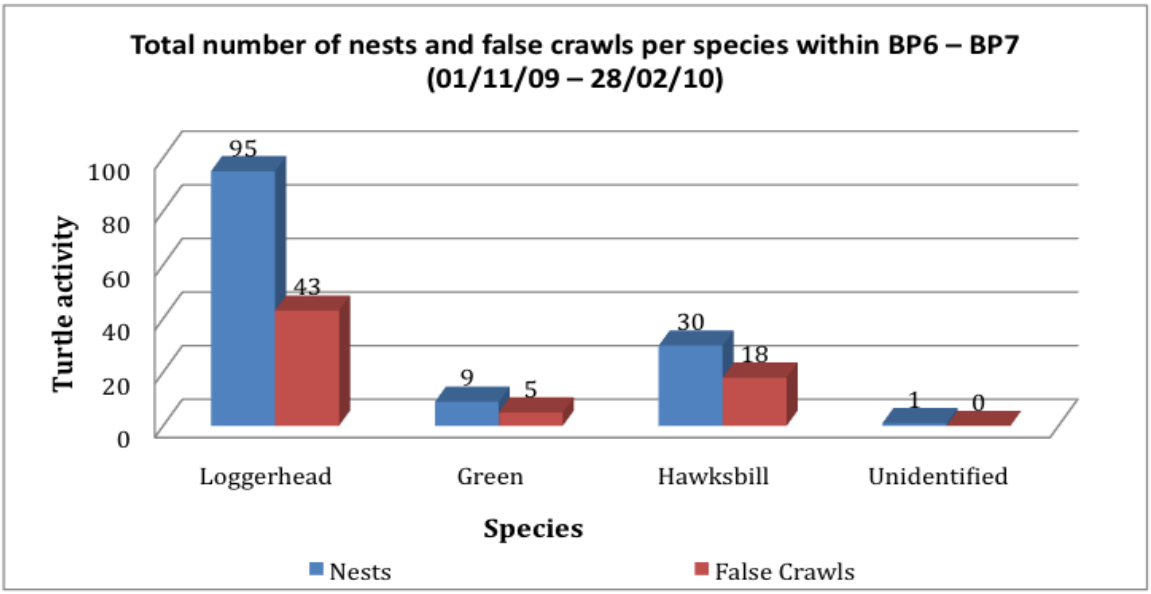

Figure A3: Total number of nests and false crawls per species within BP6 – BP7 (01/11/09 – 28/02/10)

BP6 - BP7 was the second busiest sub-section with nesting activity (green line) peaking mid-December 2009 and again in mid-January 2010 before declining until the end of the Day study season on 28 February 2010 (refer Figure A4).

False crawls (blue line) follow the same trend.

As the total turtle activity combines both successful nesting attempts and false crawls, the red line in Figure A4 represents all turtle beach activity. This section experienced a peak in total turtle beach activity in mid-January 2010 before declining until the end of the study season.

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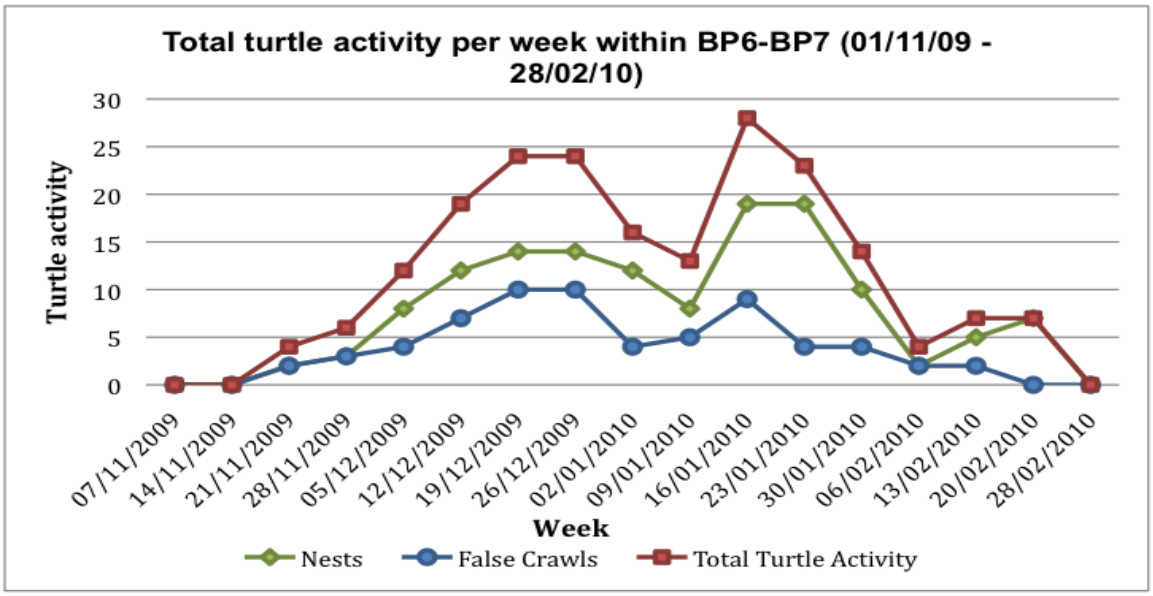

Figure A4: Total turtle beach activity per week within BP6 – BP7 (01/11/09 – 28/02/10)

BP7 - BP9

The Gnaraloo sub-section extending from Beach Point 7 (**BP7**) to Beach Point 9 (**BP9**) recorded 357 nests and 211 false crawls throughout the 2009/10 study season.

Following the trend of the other sub-sections, the turtle activity in this sub-section was predominantly Loggerhead (*Caretta caretta*) with 287 nests and 153 false crawls, followed by Hawksbill (*Eretmochlys imbricata*) with 40 nests and 24 false crawls. As can be seen in Figure A5, Green (*Chelonia mydas*) turtles were responsible for 21 nests and 25 false crawls.

Nine nests and nine false crawls were unable to be identified due to wind erosion of the turtle tracks.

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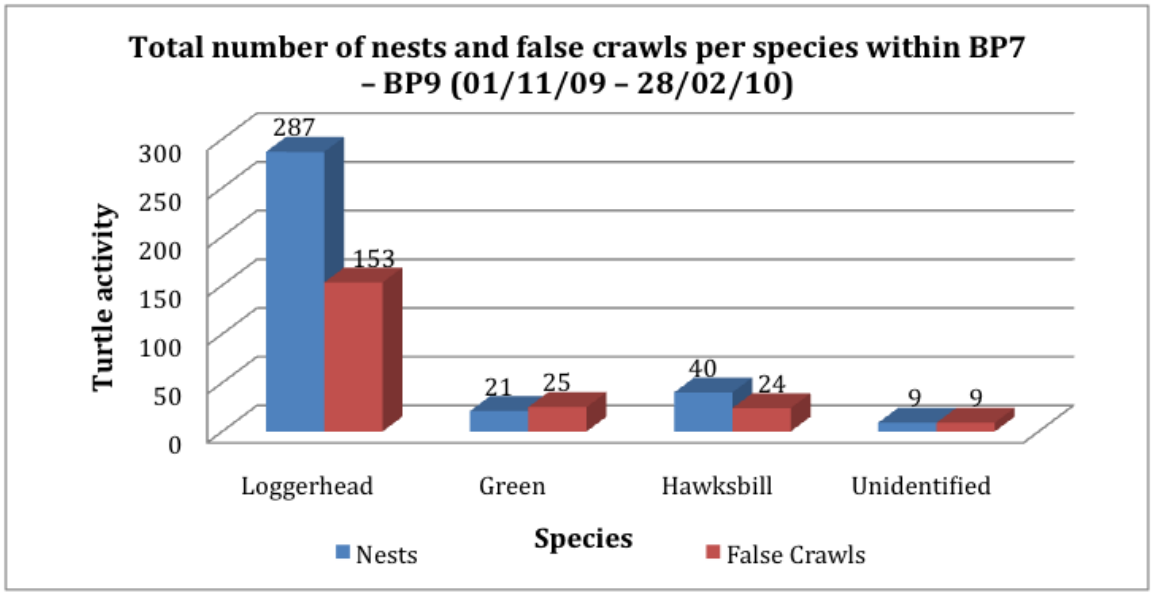

Figure A5: Total number of nests and false crawls per species within BP7 – BP9 (01/11/09 – 28/02/10)

Nesting activity in the **BP7-BP9** sub-section by far outnumbered that of the other sub-sections, with total turtle activity peaking in late January 2010 before declining until the end of the Day study season on 28 February 2010 (refer Figure A6).

As can be seen in Figure A6, false crawl numbers followed this trend.

As total turtle activity combines both successful nesting attempts and false crawls, the red line in Figure A6 indicates a peak in total turtle beach activity in early December 2009 and again in late January 2010.

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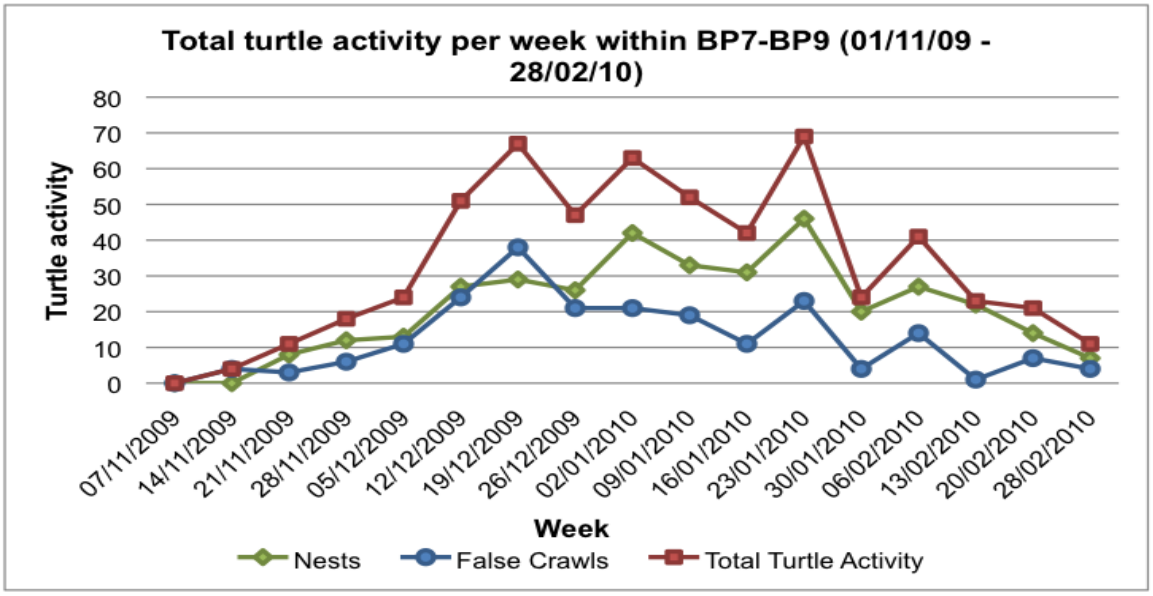

Figure A6: Total turtle beach activity per week within BP7 - BP9 (01/11/09 – 28/02/10)

BP9 - BP10

Monitoring of the Beach Point 9 (**BP9**) to Beach Point 10 (**BP10**) sub-section was discontinued on 15 November 2009, due to logistical issues and constraints experienced with distance and functionality of quads. The quad bikes used to monitor this section were unable to handle the soft, wet sand they had to manoeuvre due to the topography of the mobile dune system near BP9 and the high tides in that area.

Up until discontinuation of monitoring of this sub-section, there was no recorded turtle activity in BP9-BP10 (Figure A7).

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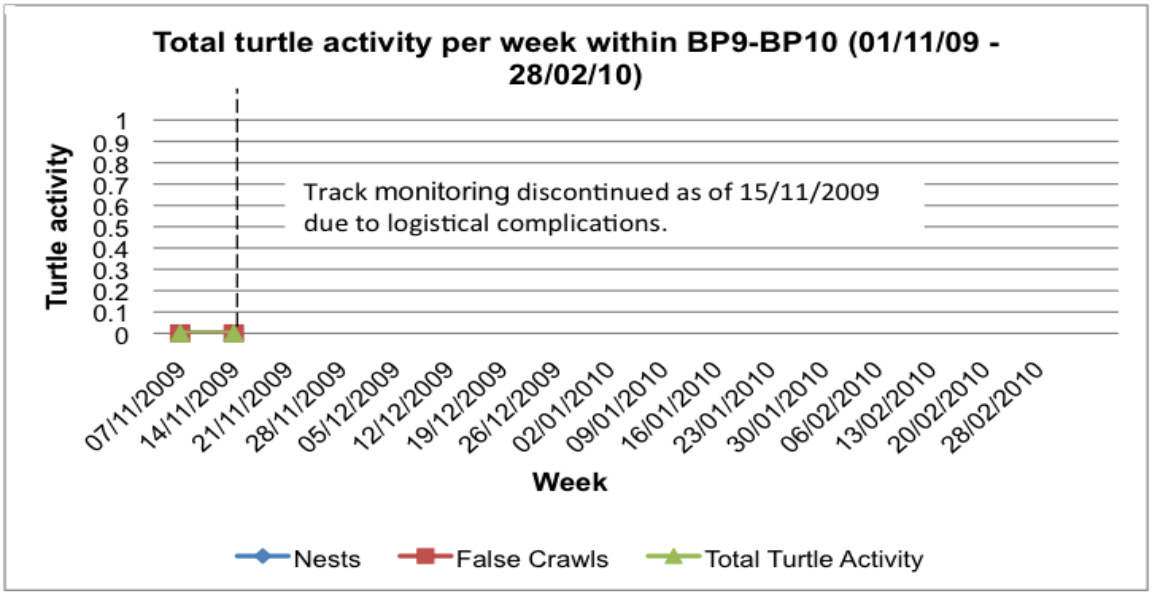

Figure A7: Total turtle beach activity per week within BP9 - BP10 (01/11/09 – 14/11/09)

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GNARALOO WEATHER STATION DATA

NOTES

At the bottom of each report, the following monthly information is summarised:

Max >= 32.0 : ##	The number of days on which the daily high temperature was 32°C or above.
Max <= 0.0 : ##	The number of days on which the daily high temperature was 0°C or below.
Min <= 0.0 : ##	The number of days on which the daily low temperature was 0°C or below.
Min <= -18.0 : ##	The number of days on which the daily low temperature was -18°C or below.
Max Rain: ## ON [Date]	The maximum daily rainfall during the month.
Days of Rain: ## (>0.2 mm), ## (> 2mm), ## (> 20mm),	The number of days on which rainfall exceeded 0.2mm, 2mm, or 20mm is displayed

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MONTHLY CLIMATOLOGICAL SUMMARY FOR FEBUARY 2010

DAY	MEAN TEMP °C	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN (MM)	AVG WIND SPEED (MPH)	HIGH	TIME	DOM DIR
15	23.8	26.1	14:30	21.7	00:00	0	5.5	0	6.1	27	16:00	NNE
16	24.6	31.8	11:30	20.7	04:00	0	6.3	0	10.1	29	15:00	N
17	24.7	28.1	15:30	21.1	06:00	0	6.4	0	9.5	26	12:30	N
18	25.3	32.4	10:30	20.8	05:30	0	7	0	9.5	29	15:00	NNE
19	28.2	37.1	11:00	23.2	02:00	0	9.8	0	11.4	28	14:30	NNE
20	29.1	41.1	12:30	25.7	21:00	0	10.8	0	12.7	29	15:00	NNW
21	29	39.9	14:30	23.9	00:00	0	10.7	0	13.5	26	08:30	NNW
22	25.3	32.7	11:00	22.2	00:00	0	7	0	11.6	28	13:30	NNW
23	24.3	29.2	09:00	20.8	06:30	0	6	0	3.5	14	15:00	NE
24	24.3	26.9	16:00	21.9	06:00	0	6	0.3	5.5	15	11:00	NE
25	24.7	26.4	12:30	23.5	05:00	0	6.3	0	7.2	20	17:30	ENE
26	24.3	26.1	14:00	22.9	05:00	0	5.9	0	10.8	26	17:00	NNE
27	24.4	26.6	14:30	22.4	04:30	0	6.1	0	10.6	26	16:30	NNE
28	24.9	30	10:00	22.8	06:30	0	6.6	0	9.8	26	15:30	N
	25.4	41.1	20	20.7	16	0	103.1	0.3	8.8	29	16	NNE

Max >= 32.0 : 5

Max <= 0.0 : 0

Min <= 0.0 : 0

Min <= -18.0 : 0

Max Rain: 0.25 ON 24/02/2010

Days of Rain: 1(> 0.2 mm), 0 (> 2 mm), 0 (> 20 mm)

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MONTHLY CLIMATOLOGICAL SUMMARY FOR MARCH 2010

DAY	MEAN TEMP °C	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN (MM)	AVG WIND SPEED (MPH)	HIGH	TIME	DOM DIR
1	24.9	28.2	11:30	22.7	06:00	0	6.6	0	8.8	22	17:00	NE
2	24.8	27.6	15:00	22.8	06:30	0	6.4	0.3	7.8	16	10:00	NNE
3	24.9	28.4	09:30	21.9	06:00	0	6.6	0	10	28	17:30	N
4	27.1	35	12:00	22.7	06:00	0	8.8	0	10.8	28	14:00	NNW
5	26.6	36.7	13:00	21.7	06:30	0	8.2	0	12.2	30	16:30	NNW
6	29.4	38.7	12:00	23.3	04:30	0	11.1	0	10.4	25	16:00	WNW
7	28	35.2	16:00	23	05:00	0	9.7	0	7.2	26	17:00	WNW
8	27.8	36.8	10:00	23.9	07:00	0	9.5	0	6.4	18	16:30	NE
9	33.1	43.2	13:30	25.3	00:00	0	14.8	0	6.9	28	13:00	W
10	25.7	30.4	09:30	22.7	06:30	0	7.4	0	4	14	12:30	W
11	25.5	28.1	16:30	23.3	07:00	0	7.2	0.3	6.9	21	18:30	NE
12	25.4	28.4	15:30	23	02:30	0	7.1	0	6.7	22	18:00	N
13	25.8	30.7	10:00	23.8	23:00	0	7.4	0	8.8	22	18:30	NE
14	26.3	33.2	11:30	22.2	05:30	0	7.9	0	10.3	27	15:30	N
15	25.6	28.3	09:30	23.1	00:00	0	7.3	0	12.9	30	13:00	N
16	25.3	32.1	15:00	22.3	04:00	0	7	0	11.3	32	16:30	NNW
17	25.3	32.9	12:00	20.8	06:30	0	7	0	9.5	23	15:00	NNE
18	25.1	32.6	12:00	20.2	05:30	0	6.8	0	9	27	14:00	N
19	25.2	31.5	11:00	21.7	07:00	0	6.9	0	9.3	26	14:00	N
20	25.4	32.4	11:30	21.5	03:30	0	7.1	0	9.6	27	16:00	NNW
21	23.7	26.2	13:00	20.4	06:00	0	5.3	0	10	25	12:00	NNE
22	23.2	26.6	15:30	19	06:30	0	4.9	0	7.6	19	13:00	NNE

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23	25.2	32.3	11:00	19.9	06:30	0	6.8	0	6.8	21	15:30	NNW
24	28.9	38	15:30	22.9	06:00	0	10.6	0	9.3	23	10:30	NW
25	27.1	39.4	13:30	23.1	05:30	0	8.7	0	11.3	26	17:00	NNW
26	24.6	28.5	11:30	22	06:30	0	6.3	0	9.5	25	14:30	N
27	25.1	28.9	18:00	21.9	03:00	0	6.8	0	10.6	30	13:00	NNW
28	24.9	32.8	13:00	21.2	06:00	0	6.6	0	10.5	28	14:30	NNW
29	25.6	35	10:30	19.7	04:30	0	7.2	0	6.5	21	14:30	NNE
30	24.2	26.6	15:00	22.2	02:30	0	5.9	0	9	23	15:30	N
31	24.1	29.1	09:30	20.9	05:30	0	5.7	0	9.7	29	12:30	NNE
	25.9	43.2	9	19	22	0	235.6	0.5	9	32	16	N

Max >= 32.0 : 16

Max <= 0.0 : 0

Min <= 0.0 : 0

Min <= -18.0 : 0

Max Rain: 0.25 ON 02/03/2010

Days of Rain: 2 (> 0.2 mm), 0 (> 2 mm), 0 (> 20 mm)

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MONTHLY CLIMATOLOGICAL SUMMARY FOR APRIL 2010

DAY	MEAN TEMP °C	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN (MM)	AVG WIND SPEED (MPH)	HIGH	TIME	DOM DIR
1	23.4	25.9	11:30	20.9	00:30	0	5.1	0	11.2	27	12:30	N
2	23.3	26.1	12:00	20.2	00:00	0	5	0	8.9	23	13:00	NNE
3	23	27.4	11:30	19.9	01:00	0	4.7	0	8.8	27	15:30	NNW
4	21.6	28	12:30	18.1	06:00	0	3.3	0	11	30	13:30	NW
5	21.7	29.2	11:30	17	06:00	0.1	3.4	0	10.1	26	14:00	NNE
6	21.7	24.3	14:30	19.3	05:30	0	3.4	2.3	6	25	19:30	NW
7	21.6	24.7	12:30	17.6	06:00	0	3.2	0	8.4	26	14:00	NW
8	22.8	30.2	12:00	17.8	05:30	0.1	4.4	0	8.7	28	14:30	NW
9	24.3	32.3	12:30	20.2	06:00	0	5.9	0	11.5	29	14:30	NW
10	24.1	34.2	13:30	19.1	05:30	0	5.8	0	11.1	28	15:00	NW
11	24.5	32.8	10:00	18.6	06:00	0	6.2	0	6.5	21	10:00	NE
12	22.5	26.3	09:30	18.7	06:00	0	4.2	0	8.9	24	11:30	NNE
13	21.2	25.3	10:30	17	06:00	0.1	3.1	0	5.9	19	12:30	N
14	22.1	24.7	11:30	18.3	22:00	0	3.8	0	7.1	19	15:00	NE
15	21.4	25.6	15:00	16.2	02:30	0.3	3.3	0	7.1	20	13:00	NNW
16	21.9	27.7	12:00	17.6	05:30	0.1	3.6	0	9	31	14:30	NNW
17	21.7	26.8	10:30	16.1	06:30	0.1	3.4	0	5	16	16:00	NNE
18	22.6	25.3	11:00	18.1	03:30	0	4.3	0.3	5	15	15:30	NNE
19	22.8	27.7	11:00	19.9	06:00	0	4.5	0	8.3	25	14:30	NNW
20	22.5	28.1	11:30	18.3	05:30	0	4.2	0	7.3	25	14:00	NNW

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21	23.8	30.3	11:30	20.2	06:30	0	5.5	0	7.4	21	14:30	NNW
22	27.3	35.2	14:30	20.9	06:00	0	9	0	7.6	26	11:30	NW
23	26.9	35.6	12:00	22.2	06:00	0	8.6	0	8.3	20	13:00	WNW
24	27.9	39.2	13:00	22.6	06:00	0	9.6	0	7.5	19	08:30	WNW
25	22.4	24.3	00:30	19.9	06:00	0	1.2	0	1.3	7	00:30	ESE
	23.2	39.2	24	16.1	17	0.7	118.6	2.5	7.9	31	16	NNW

Max >= 32.0 : 6

Max <= 0.0 : 0

Min <= 0.0 : 0

Min <= -18.0 : 0

Max Rain: 2.29 ON 06/04/2010

Days of Rain: 2 (> 0.2 mm), 1 (> 2 mm), 0 (> 20 mm)

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MAPS

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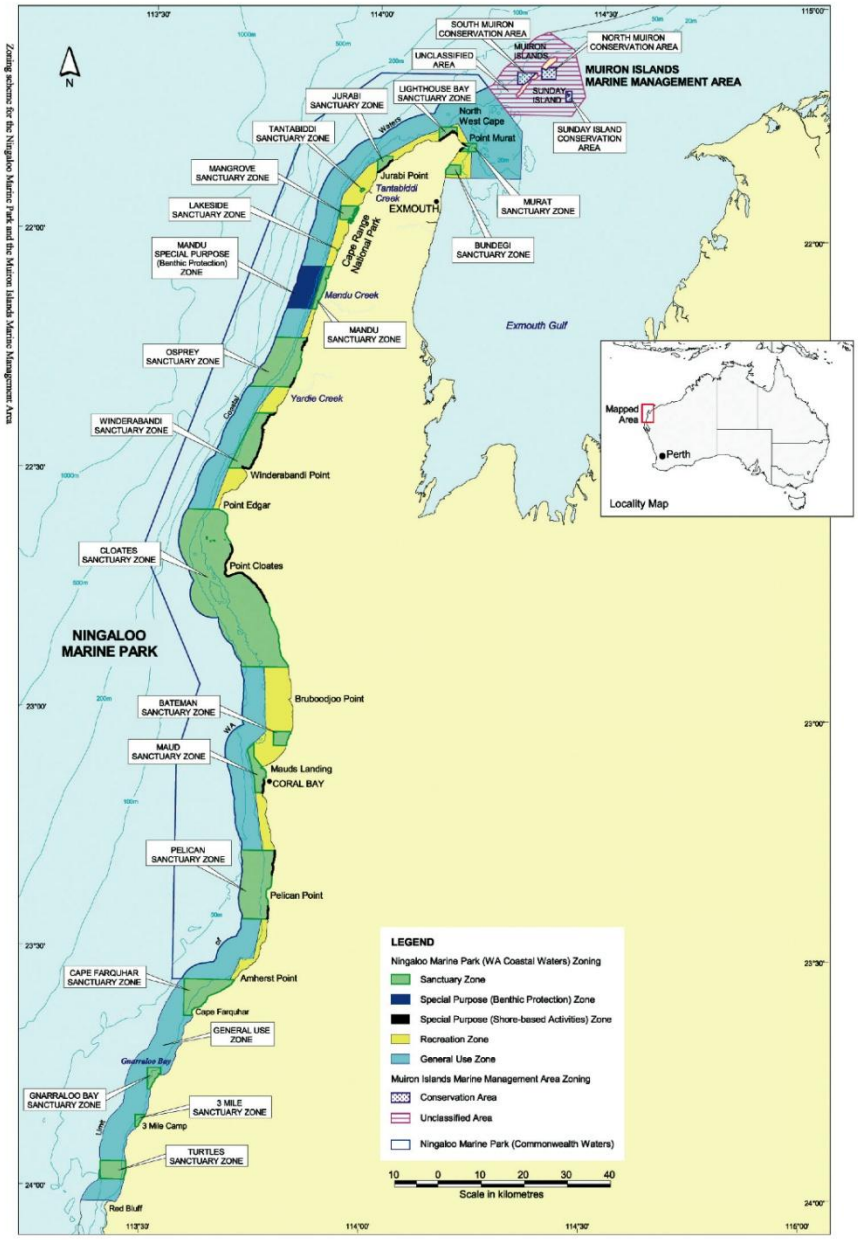

Map 1: Ningaloo Marine Park and Muiron Islands Marine Management Area

Map provided by Department of Environment and Conservation, Western Australia

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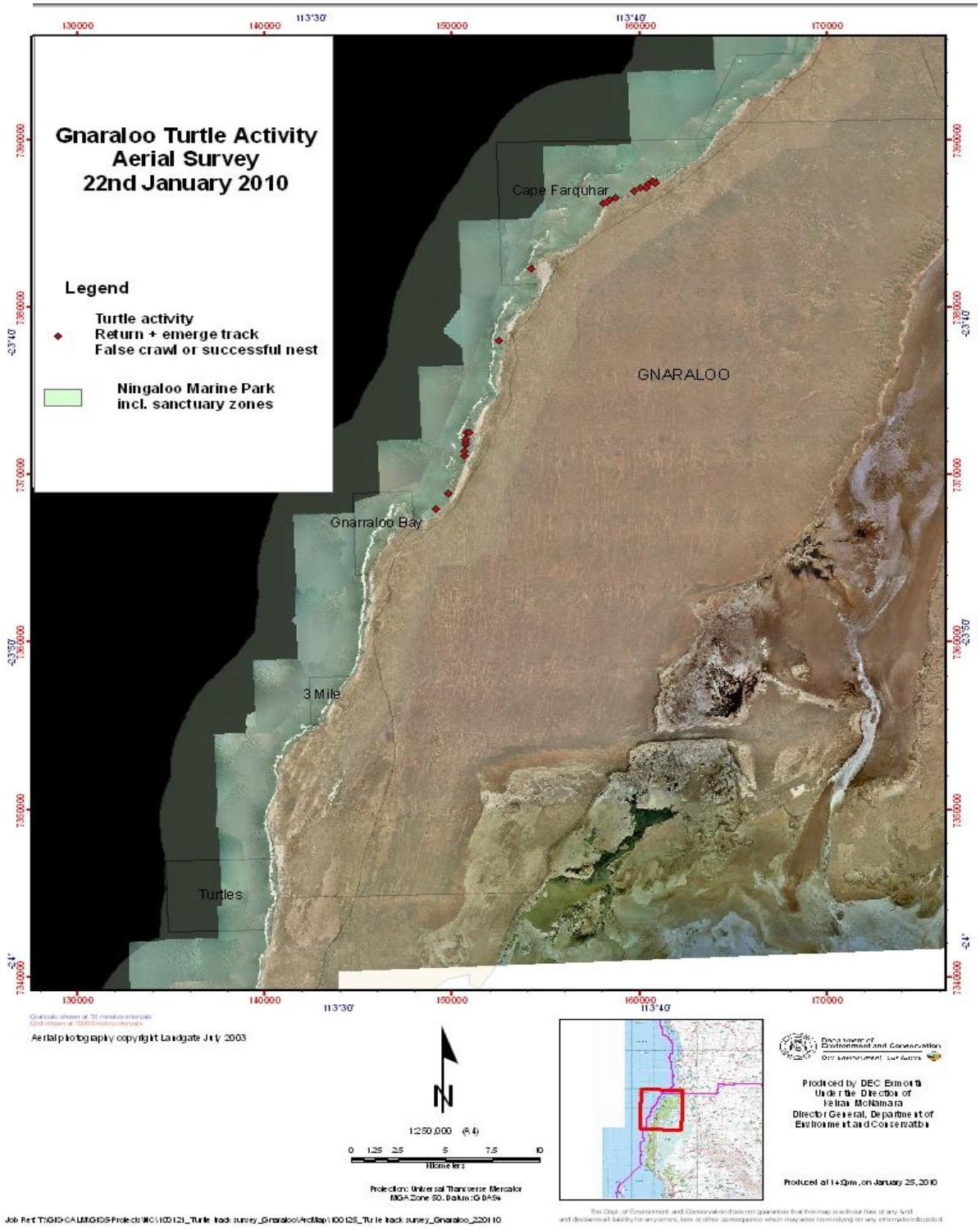

Map 2: Aerial Survey of Gnaraloo turtle activity (22/01/10)

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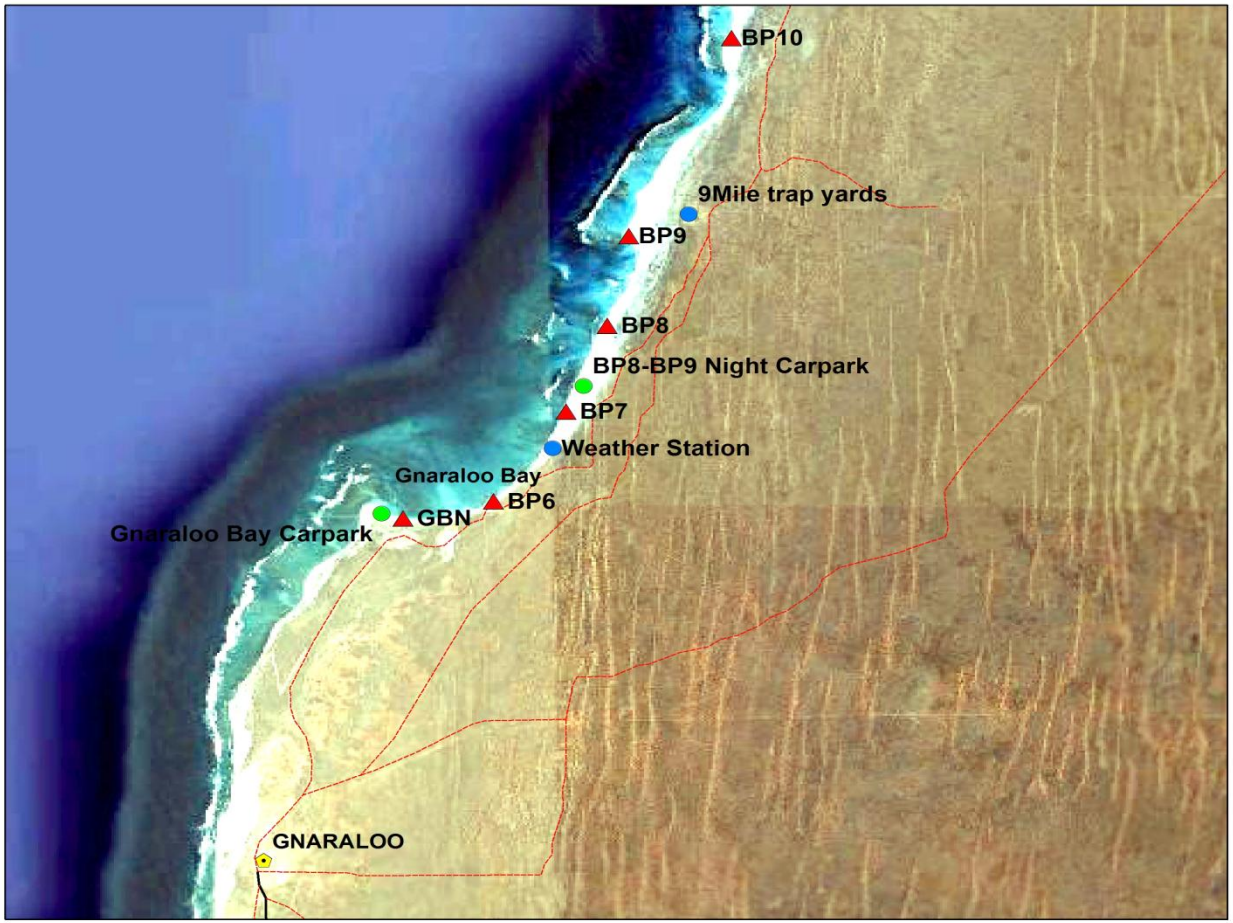
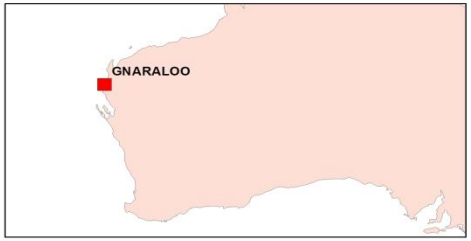
Gnaraloo Turtle Conservation Program Total Study Area 2009-2010





Legend

Minor Road

Track

Gnaraloo Homestead

N

1:50,000

0 0.5 1 2 3 4

Kilometers

Created on 30 April 2010 by Purusha Boelling.
Projected in GCS GDA 1994.
Imagery obtained from Google Earth.
Created using ESRI ArcGIS.

Map 3: Gnaraloo Turtle Conservation Program - Total Study Area 2009/10

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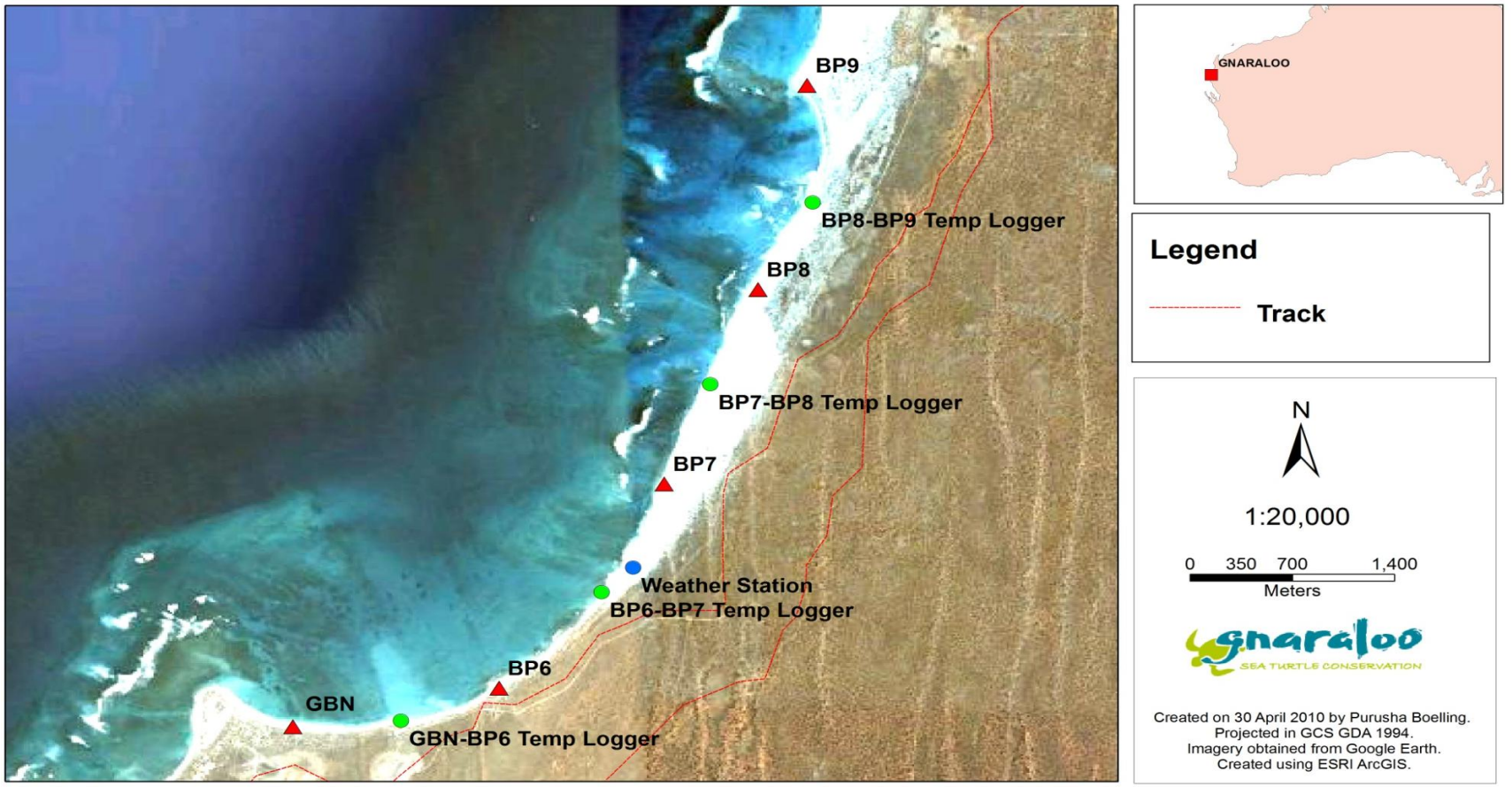
Sand temperature loggers and weather station GBN-BP9 2009-2010



Map 4: Location of Gnaraloo Weather Station and Sand temperature data loggers 2009/10

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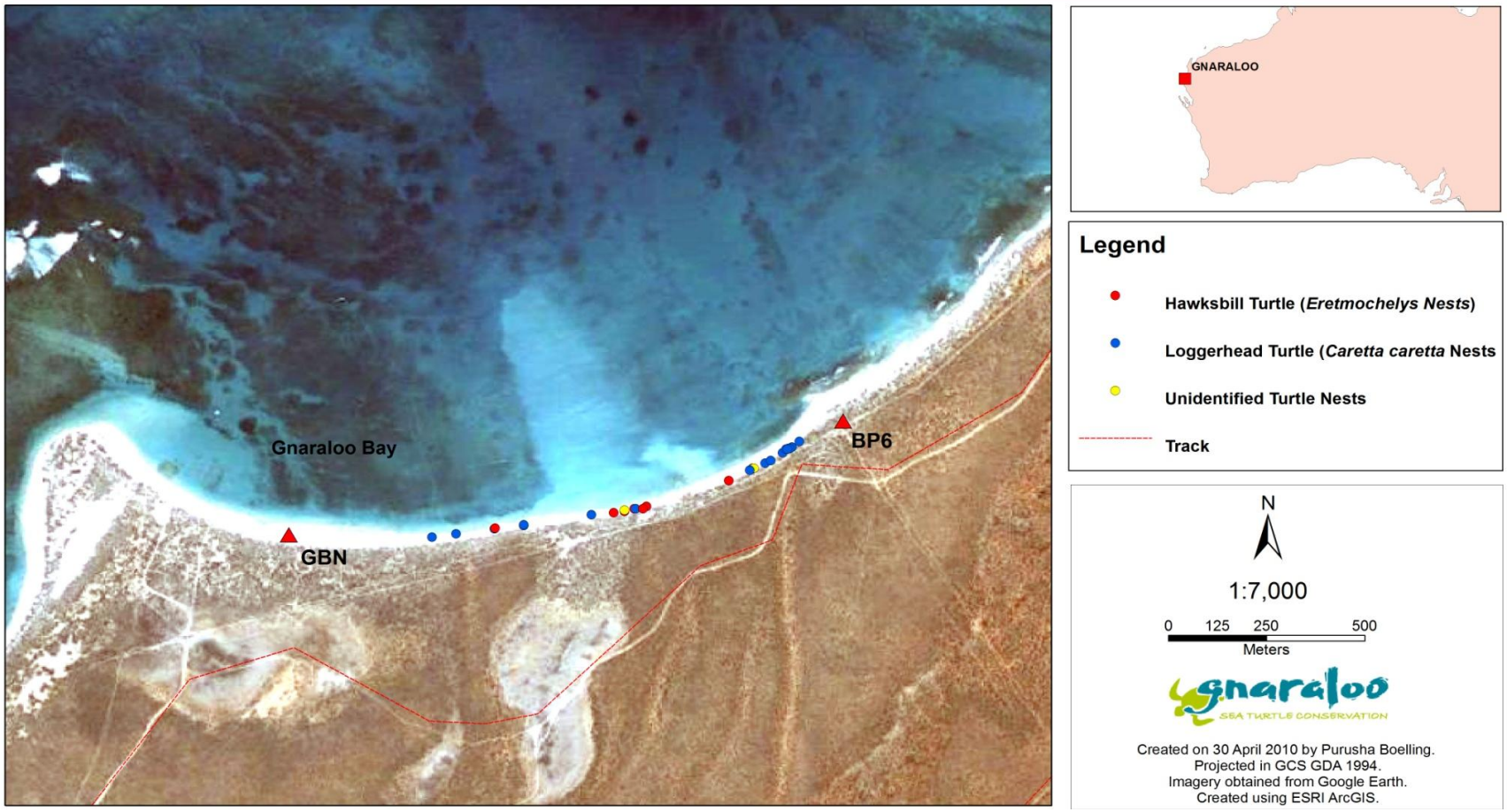
GBN-BP6 nest distribution 2009-2010



Map 5: Nest distribution in Gnaraloo Bay North to Beach Point 6 (2009/10)

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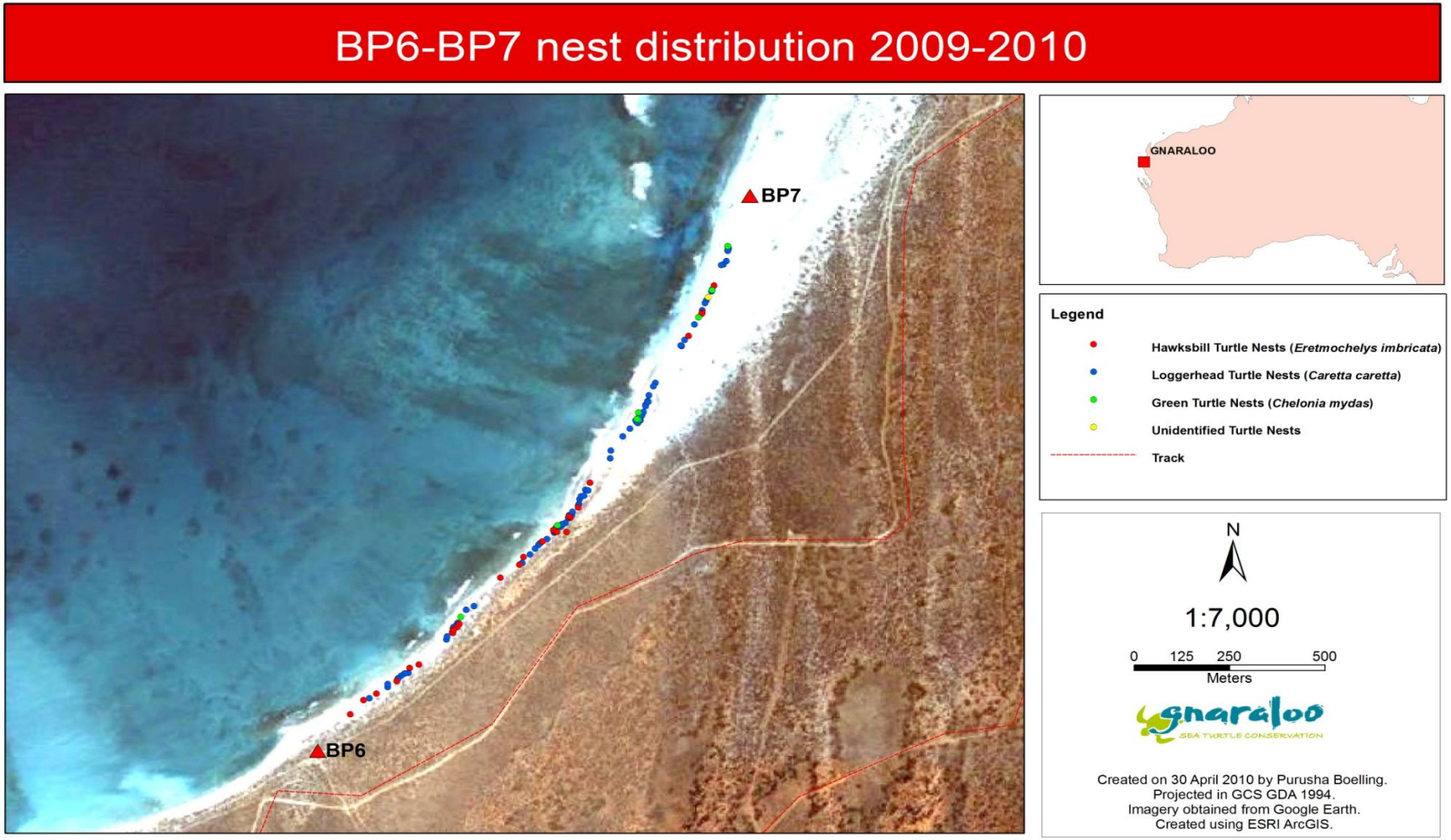

Map 6: Nest distribution in Beach Point 6 to Beach Point 7 (2009/10)

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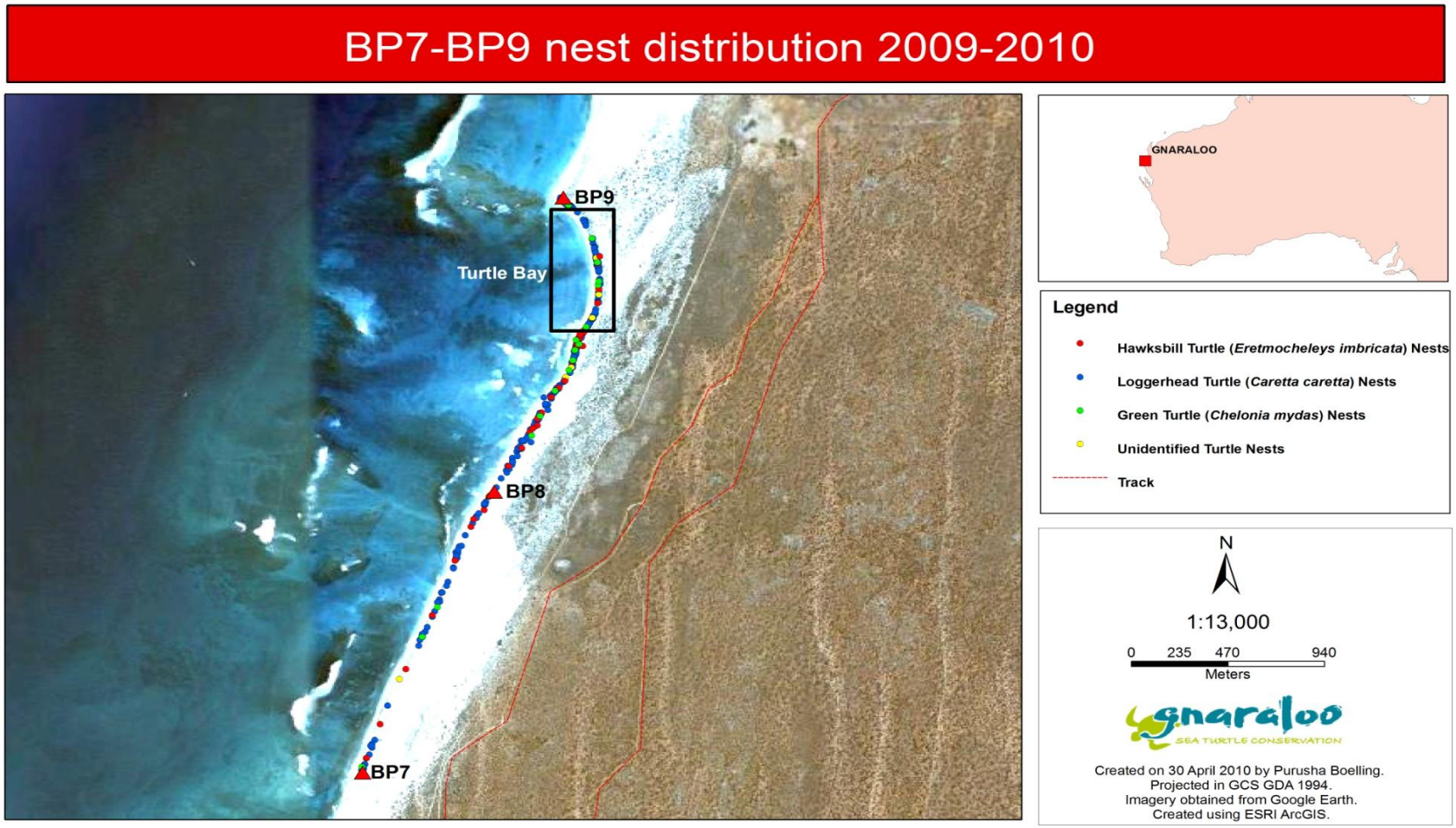

Map 7: Nest distribution in Beach Point 7 to Beach Point 9 (2009/10)

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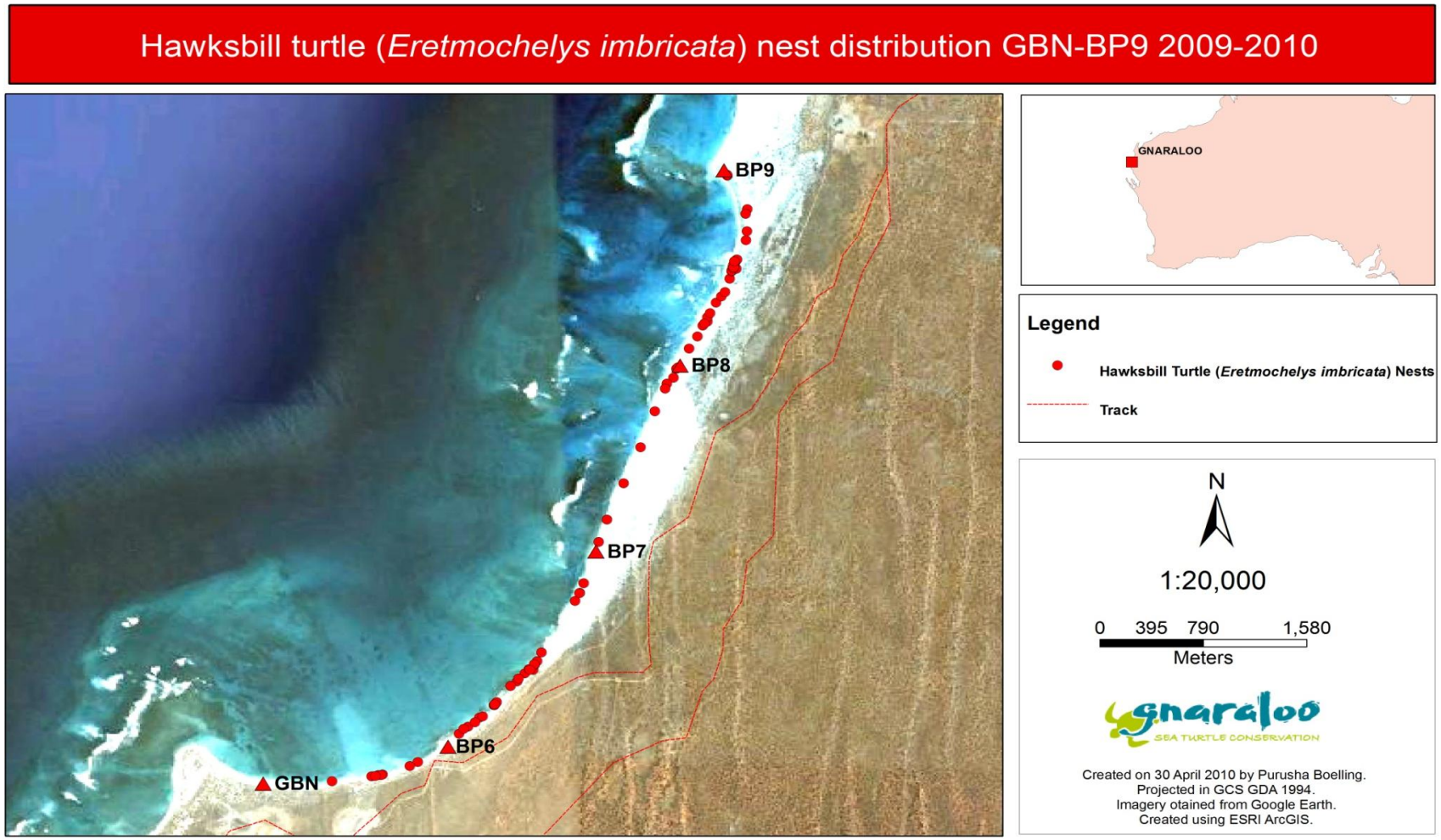

Map 8: Distribution of Hawksbill (*Eretmochelys imbricata)* turtle nests in GBN – BP9 (2009/10)

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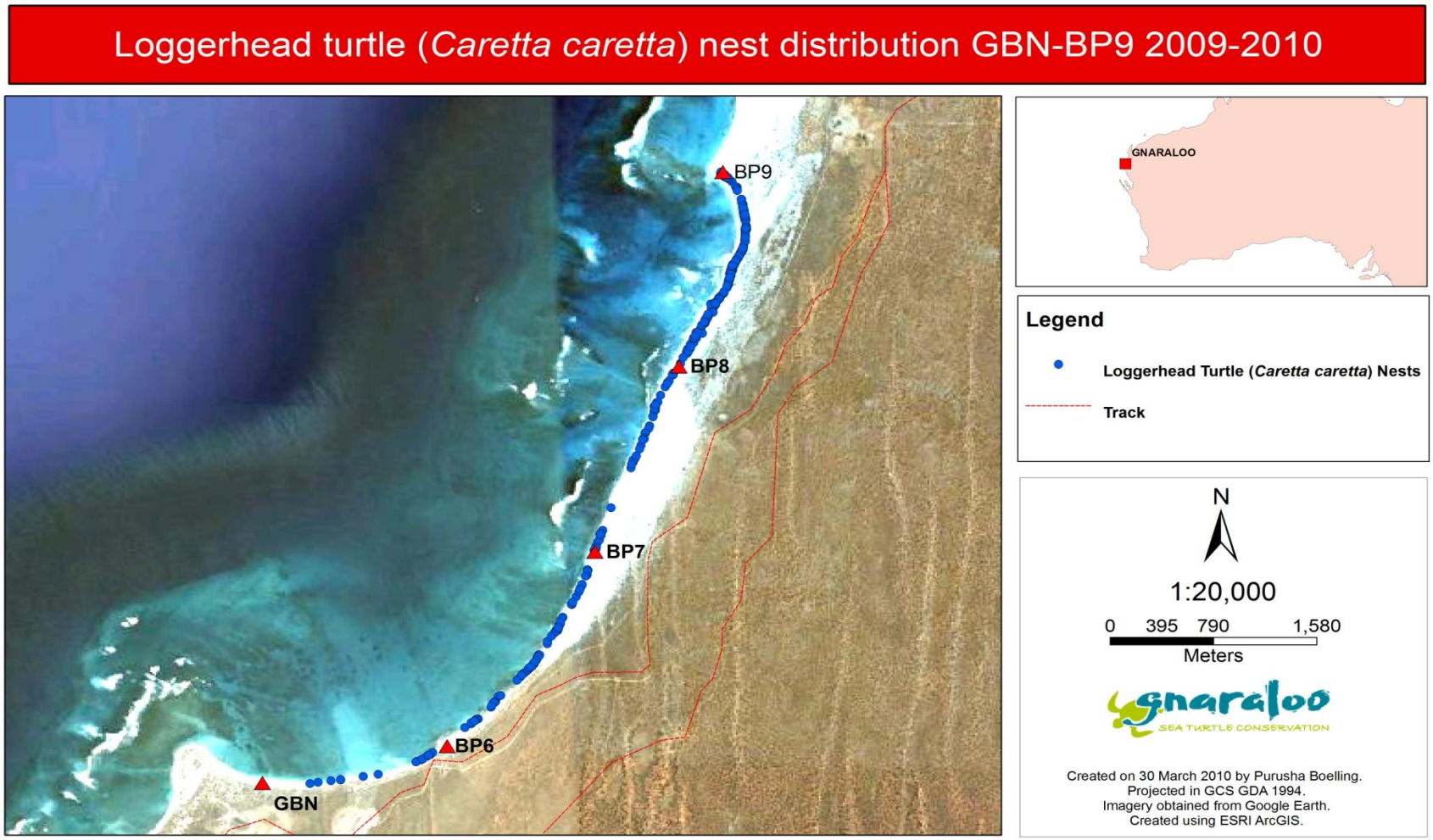

Map 9: Distribution of Loggerhead (*Caretta caretta*) turtle nests in GBN – BP9 (2009/10)

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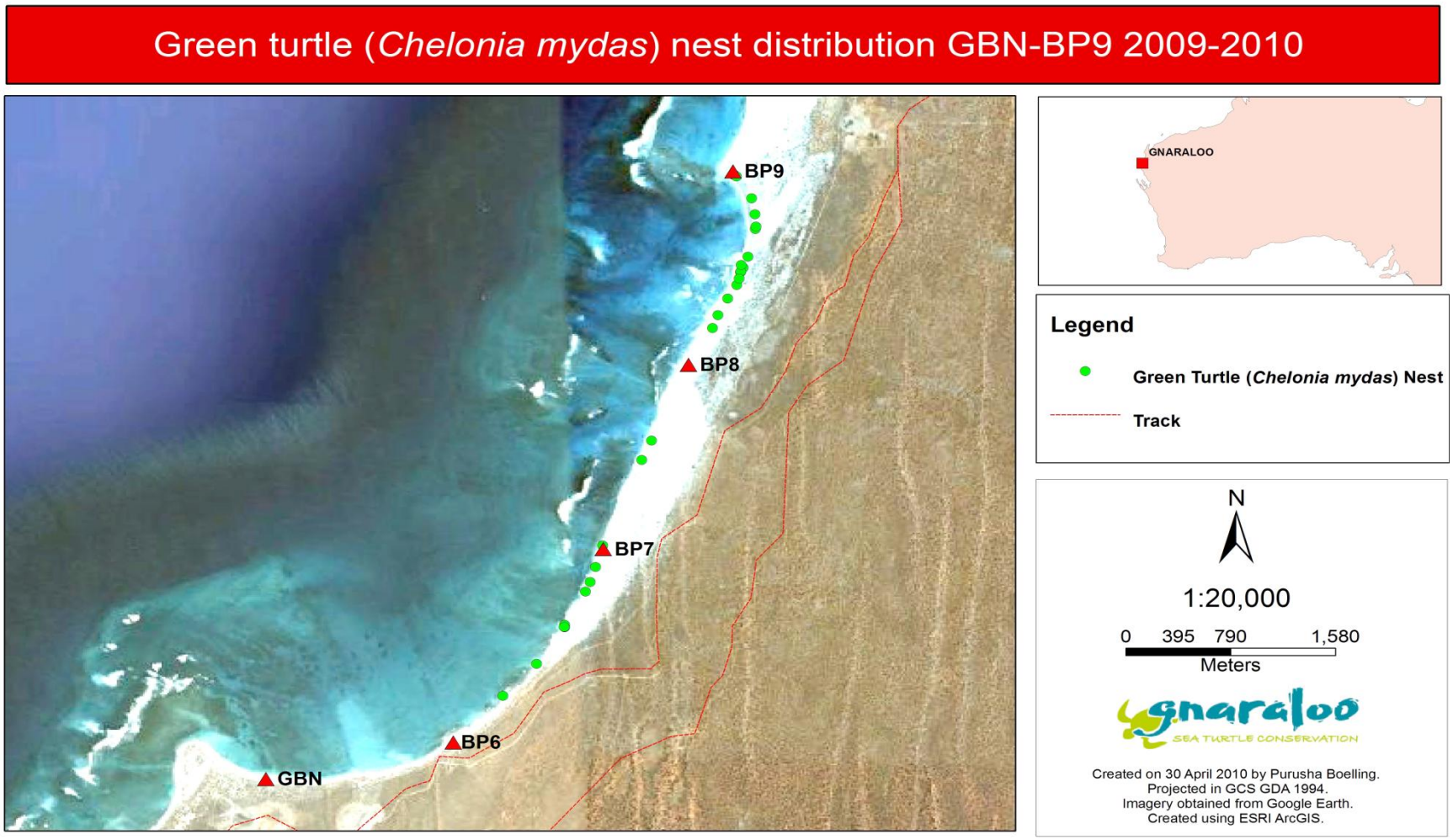

Map 10: Distribution of Green (*Chelonia mydas*) turtle nests in GBN – BP9 (2009/10)

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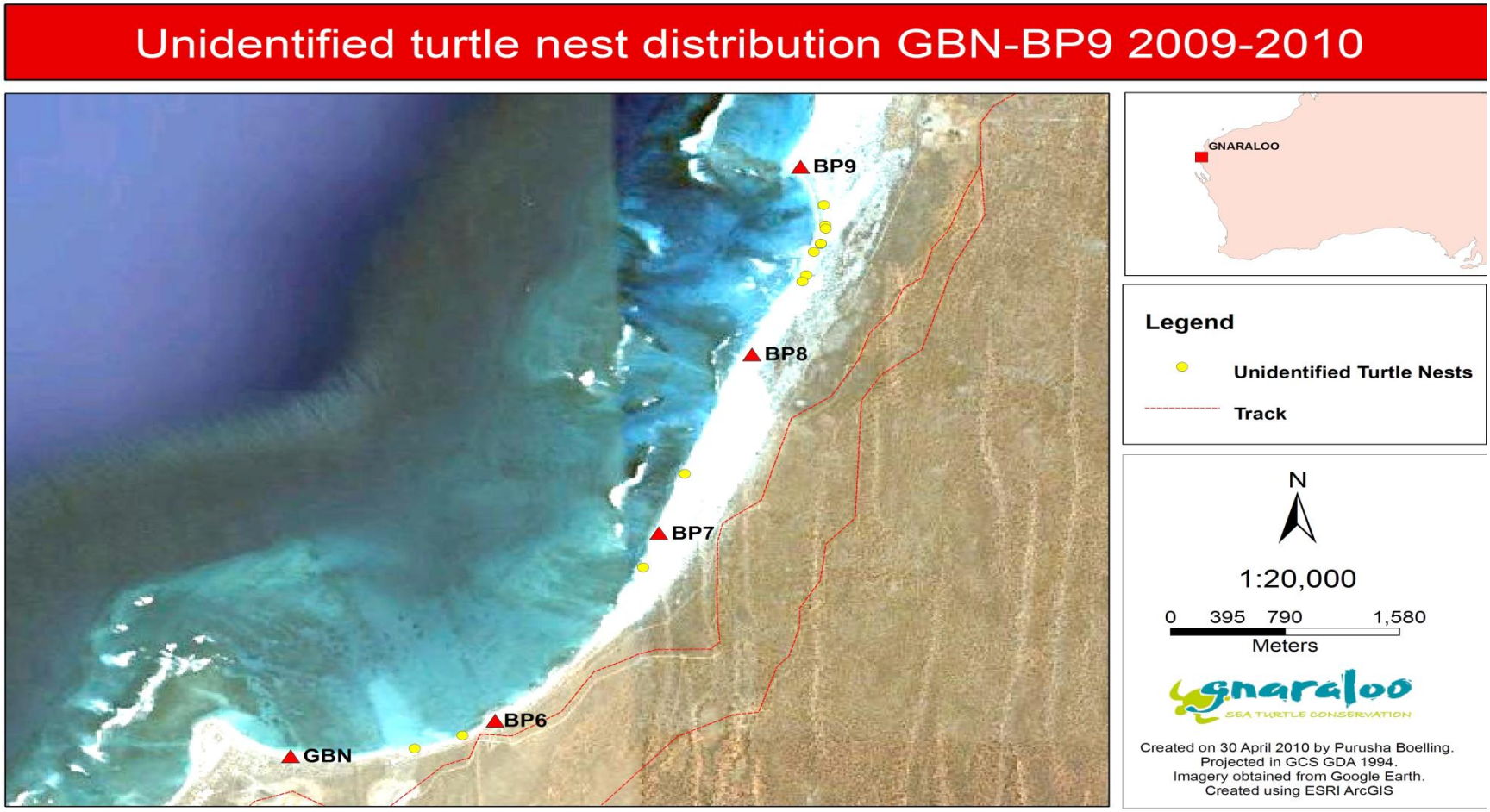

Map 11: Distribution of unidentified turtle nests in GBN – BP9 (2009/10)

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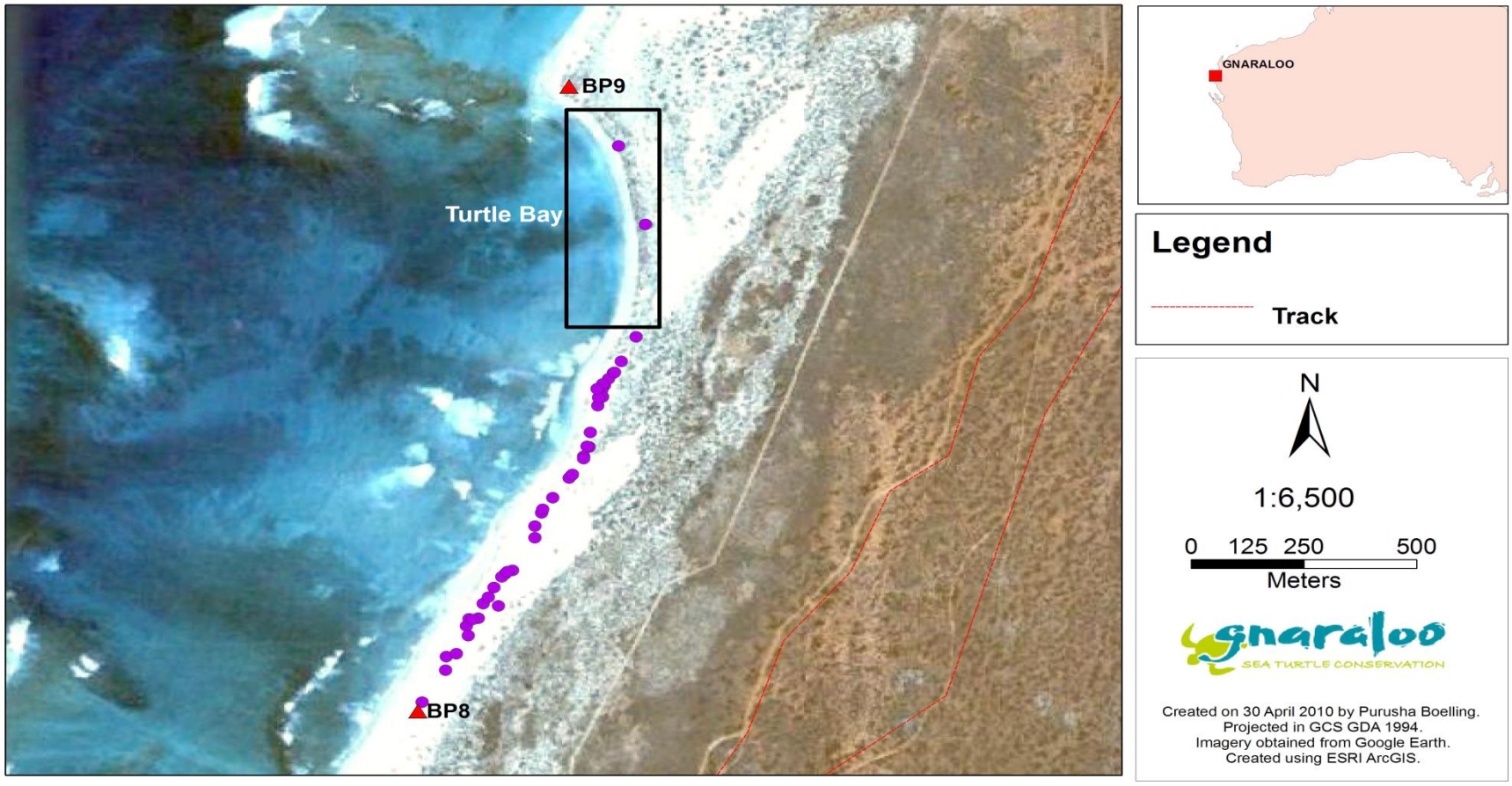
Night survey hatched nests 2009-2010



Map 12: Distribution of hatched nests in Night Study Area 2009/10 (BP8-BP9)

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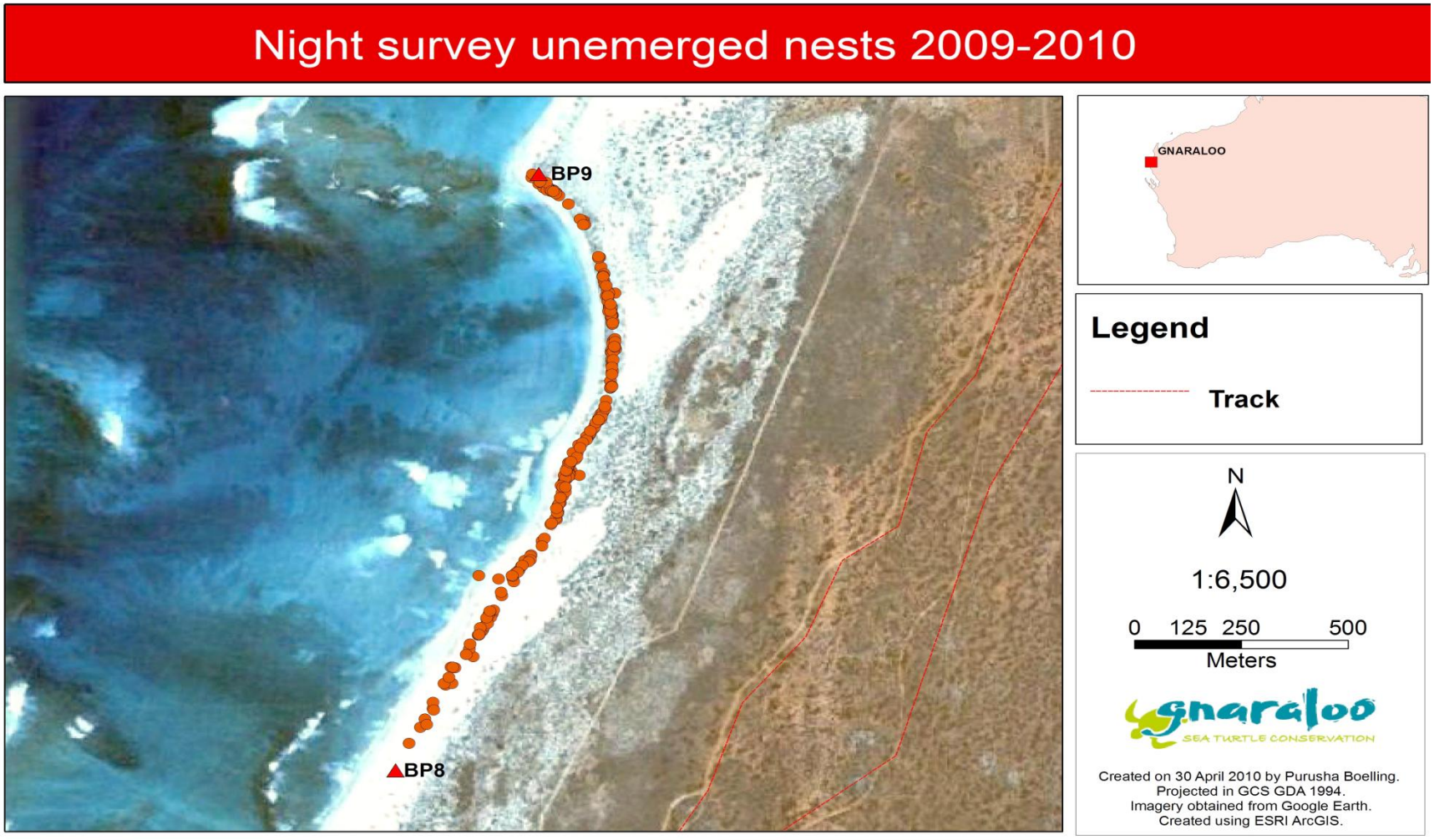

Map 13: Distribution of nests not observed to have hatched in Night Study Area 2009/10 (BP8-BP9)

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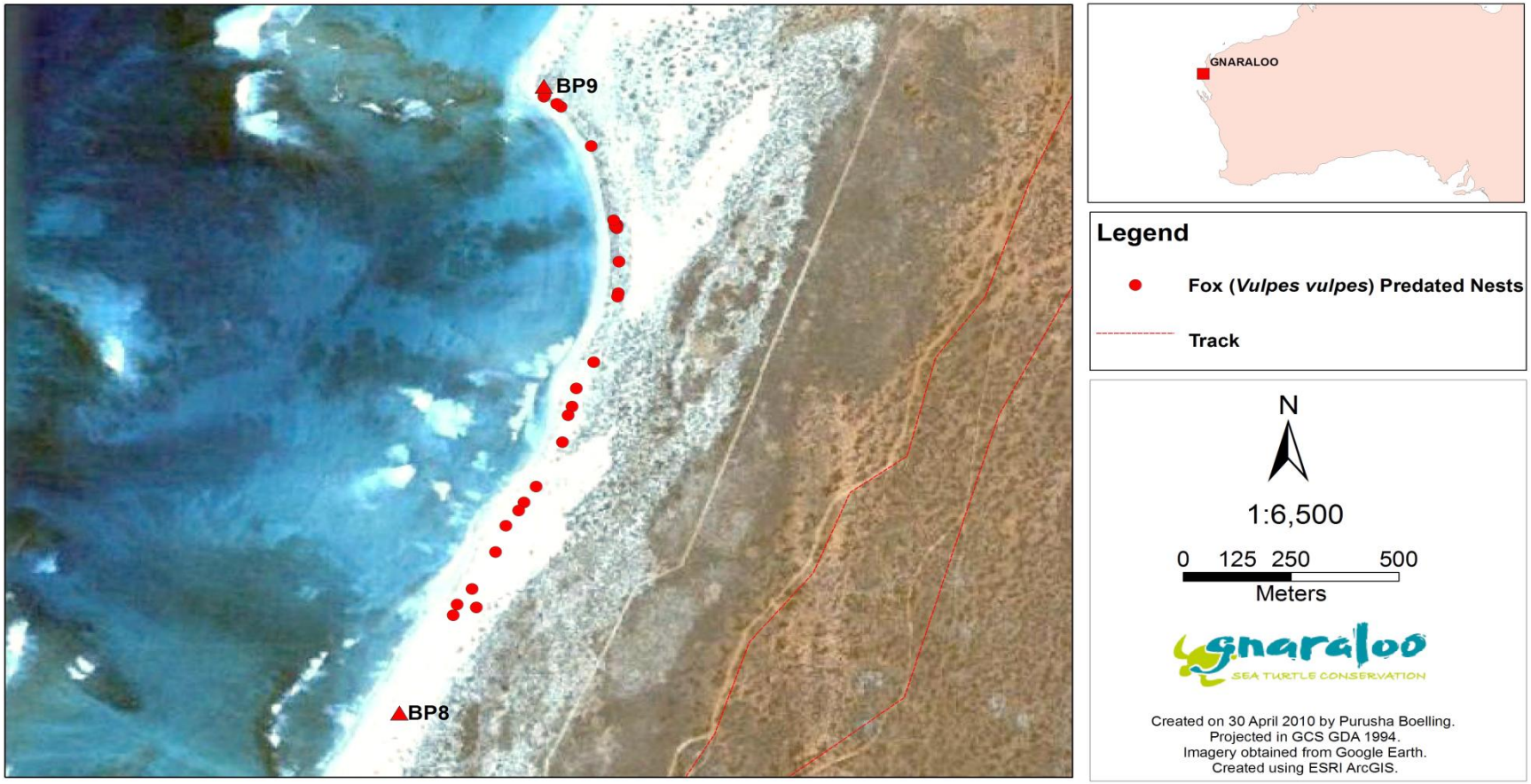
Fox (*Vulpes vulpes*) disturbance 2009-2010



Map 14: Distribution of nests disturbed by Fox (*Vulpes vulpes*) in the Night Study Area 2009/10 (BP8-BP9)

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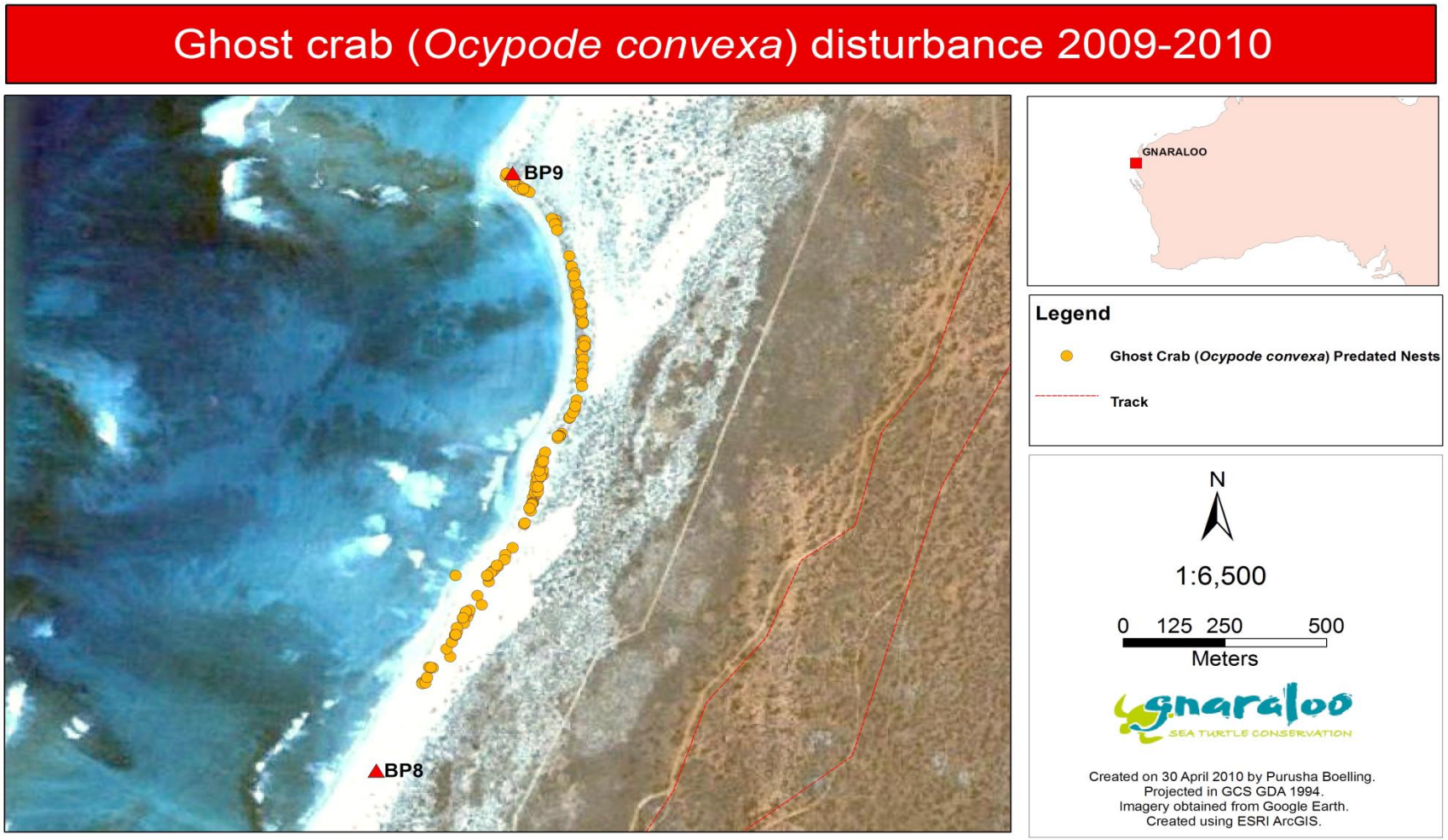

Map 15: Distribution of nests disturbed by Ghost Crabs (*Ocypode convexa*) in Night Study Area 2009/10 (BP8-BP9)

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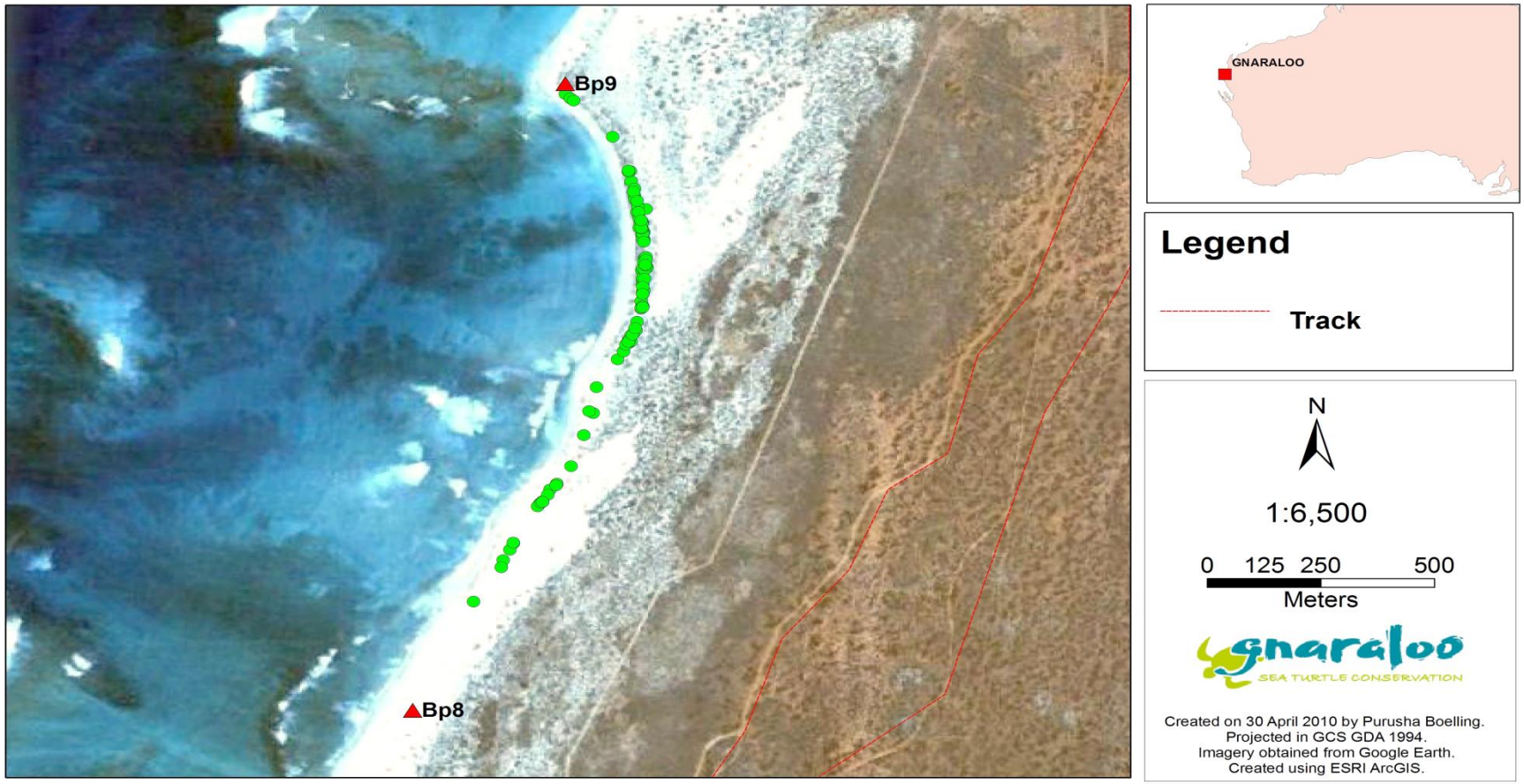
Night survey innundated nests 2009-2010



Map 16: Distribution of nests disturbed by inundation in Night Study Area 2009/10 (BP8-BP9)

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PHOTO PLATES

Photo 1: **Gnaraloo Bay North - Beach Point 6 subsection (GBN - BP6), looking north**

Photo 2: **Beach Point 6 - Beach Point 7 subsection (BP6 - BP7), looking north**

Photo 3: **Beach Point 7 - Beach Point 8 subsection (BP7 - BP8), looking north**

Photo 4: **Beach Point 8 - Beach Point 9 subsection (BP8 - BP9), looking north**

Photo 5: **Turtle Bay (in BP8 - BP9 subsection), looking north**

Photo 6: **Beach Point 9 - Beach Point 10 subsection (BP9 - BP10), looking south**

Photo 7: **Gnaraloo Loggerhead (*Caretta caretta*) female nesting in BP7 - BP9**

Photo 8: **Gnaraloo Loggerhead (*Caretta caretta*) female in BP7 - BP9**

Photo 9: **Volunteer scientist recording Gnaraloo Hawksbill (*Eretmochelys imbricata*) turtle nest data**

Photo 10: **Gnaraloo Loggerhead (*Caretta caretta*) tracks**

Photo 11: **Gnaraloo sea turtle hatchling tracks**

Photo 12: **Gnaraloo Loggerhead (*Caretta caretta*) hatchlings emerging from egg chamber**

Photo 13: **Sea turtle egg chamber eroded and exposed by tidal surges**

Photo 14: **Sea turtle nest disturbed by Fox (*Vulpes vulpes*)**

Photo 15: **Sea turtle egg chamber dug up by Fox (*Vulpes vulpes*)**

Photo 16: **Sea turtle egg chamber dug up by Fox (*Vulpes vulpes)***

Photo 17: **Underdeveloped Gnaraloo Loggerhead (*Caretta caretta*) embryo in predated egg**

Photo 18: **Turtle nest disturbed by Golden ghost crabs (*Ocypode convexa*) (note egg fragments)**

Photo 19: **Turtle nest disturbed by Golden ghost crabs (*Ocypode convexa*) (note egg fragments)**

Photo 20: **Golden ghost crab (*Ocypode convexa)***

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Photo 21: **Running ghost crab (*Ocypode ceratopthalma*)**

Photo 22: **Golden ghost crab (*Ocypode convexa*) with predated sea turtle hatchling**

Photo 23: **Gnaraloo Loggerhead (*Caretta caretta*) hatchling**

Photo 24: **Mass emergence of Gnaraloo Loggerhead (*Caretta caretta*) hatchlings**

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Photo 1: Gnaraloo Bay North - Beach Point 6 subsection (GBN - BP6), looking north

Photo 2: Beach Point 6 - Beach Point 7 subsection (BP6 - BP7), looking north

Photo 3: Beach Point 7 - Beach Point 8 subsection (BP7 - BP8), looking north

Photo 4: Beach Point 8 - Beach Point 9 subsection (BP8 - BP9), looking north

Photo 5: Turtle Bay (in BP8 - BP9 subsection), looking north

Photo 6: Beach Point 9 - Beach Point 10 subsection (BP9 - BP10), looking south

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Photo 7: Gnaraloo Loggerhead (*Caretta caretta*) female nesting in BP7 - BP9

Photo 8: Gnaraloo Loggerhead (*Caretta caretta*) female in BP7 - BP9

Photo 9: Volunteer scientist recording Gnaraloo Hawksbill (*Eretmochelys imbricata*) turtle nest

Photo 10: Gnaraloo Loggerhead (*Caretta caretta*) tracks

Photo 11: Gnaraloo sea turtle hatchling tracks

Photo 12: Gnaraloo Loggerhead (*Caretta caretta*) hatchlings emerging from egg chamber

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Photo 13: Sea turtle egg chamber eroded and exposed by tidal surges

Photo 14: Sea turtle nest disturbed by Fox (*Vulpes vulpes*)

Photo 15: Sea turtle egg chamber dug up by Fox (*Vulpes vulpes*)

Photo 16: Sea turtle egg chamber dug up by Fox (*Vulpes vulpes)*

Photo 17: Underdeveloped Gnaraloo Loggerhead (*Caretta caretta*) embryo in predated egg

Photo 18: Turtle nest disturbed by Golden ghost crabs (*Ocypode convexa*) (note egg fragments)

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Photo 19: Turtle nest disturbed by Golden ghost crabs (*Ocypode convexa*) (note egg fragments)

Photo 20: Golden ghost crab (*Ocypode convexa)*

Photo 21: Running ghost crab (*Ocypode ceratopthalma*)

Photo 22: Golden ghost crab (*Ocypode convexa*) with predated sea turtle hatchling

Photo 23: Gnaraloo Loggerhead (*Caretta caretta*) hatchling

Photo 24: Mass emergence of Gnaraloo Loggerhead (*Caretta caretta*) hatchlings

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