gnaraloo wilderness foundation

gnaraloo

SEA TURTLE CONSERVATION

Gnaraloo Turtle Conservation Program

Gnaraloo Bay Rookery &
Gnaraloo Cape Farquhar Rookery

Report for Field season 2011/12

www.gnaraloo.org

Gnaraloo Wilderness Foundation & Gnaraloo Turtle Conservation Program

gnaraloo wilderness foundation

Gnaraloo

SEA TURTLE CONSERVATION

This report may be cited as:

Hattingh, K., Nielsen, K., Riskas, K., Edman, R. and Morgan, F. (2021). Gnaraloo Turtle Conservation Program. Gnaraloo Bay Rookery & Gnaraloo Cape Farquhar Rookery, Report for field season 2011/12. Gnaraloo Wilderness Foundation, Western Australia, www.gnaraloo.org

Dates in the report concern the Australian fiscal calendar which is annually from 1 July – 30 June.

The Gnaraloo Wilderness Foundation acknowledges and thanks:

The Gnaraloo Station Trust, Paul Richardson and the Richardson family in Northern Ireland and the United Kingdom for meeting the financial and operational requirements of the program.

The Gnaraloo Station staff at Gnaraloo and in Perth for their incredible support and encouragement.

The Australian Government for its support of our community engagement work.

The then Department of Environment and Conservation, Exmouth District, Western Australia, for pre-season training in Western Australian track monitoring protocols.

Esri Australia, Perth, Western Australia.

Mr. Mike Butcher and the team of Animal Pest Management Services.

Mr. Stuart Dijkmans, for GIS support and spatial analysis.

Dr. Mark Hamann, School of Earth and Environmental Sciences, James Cook University (Queensland).

Ms. Linda Reinhold, with the then Department of Environment and Conservation (Shark Bay Division), Western Australia.

Mr. Andrew Hosie, then with the Crustacea Section, Western Australian Museum, Perth, Western Australia.

David and Michelle Davenport.

Pelusey Photography.

Cover design by Claire Guillaume.

Corresponding Author: Karen Hattingh, office@gnaraloo.org

gnaraloo wilderness foundation

Gnaraloo SEA TURTLE CONSERVATION

CONTENTS

1. EXECUTIVE SUMMARY 9
2. BACKGROUND 13
   - 2.1 Program overview 13
   - 2.2 Funding and resourcing 15
   - 2.3 Regulation 17 research licence 15
   - 2.4 Monitoring Procedure 16
   - 2.5 Team and training 16
3. PROGRAM EXPANSION 18
   - 3.1 On-ground surveys of the Gnaraloo Cape Farquhar Rookery 18
   - 3.2 Extra training in feral predator track identification 18
   - 3.3 Data sharing with international databases 18
   - 3.4 Scientific method 19
   - 3.5 Improved GIS mapping 19
   - 3.6 Expanded education and community engagement 21
4. THE IMPORTANCE OF THE GNARALOO TURTLE ROOKERIES 22
   - 4.1 The Gnaraloo loggerheads in context 22
   - 4.2 Conservation status of Gnaraloo turtles 23
5. GBR DAY TRACK SURVEYS 25
   - 5.1 Objectives 25
   - 5.2 Study Area 25
   - 5.3 Materials and methods 26
   - 5.4 Results 27
     - 5.4.1 Track monitoring 27
     - 5.4.2 Nest disturbances and predation 33
   - 5.5 Discussion 33
     - 5.5.1 Study Area 33
     - 5.5.2 Number of nests, distribution trend and nesting activity 34

5.6 Conclusion 36
6. GBR NIGHT SURVEYS FOR DATA VERIFICATION 38
6.1 Objectives 38
6.2 Survey area 38
6.3 Materials and methods 38
6.4 Results 39
6.4.1 Species identification 39
6.4.2 Nesting Activity Determination 41
6.5 Discussion 45
6.5.1 Species identification 45
6.5.2 Nesting Activity Determination 45
6.6 Conclusion 47
7. GBR SAMPLED NEST SURVEYS 48
7.1 Objectives 48
7.2 Study Area 48
7.3 Rationale 48
7.4 Materials and methods 50
7.5 Results 50
7.5.1 Crab impacts on Sampled Nests 52
7.5.2 Fox impacts on Sampled Nests 56
7.5.3 Environmental impacts on Sampled Nests 57
7.5.4 Hatching events of Sampled Nests 64
7.6 Discussion 69
7.6.1 Crab impacts on Sampled Nests 69
7.6.2 Fox impacts on Sampled Nests 70
7.6.3 Environmental impacts on Sampled Nests 70
7.6.4 Hatching events of Sampled Nests 71
7.7 Conclusion 72
8. GBR CRAB SURVEYS 74

8.1 Objectives 74
8.2 Study Area 74
8.3 Materials and methods 74
8.4 Results 76
8.4.1 Density and vertical distribution of crab burrows in GBR 76
8.4.2 Horizontal zonation of crab burrows in GBR 77
8.4.3 Crab species at the GBR 78
8.5 Discussion 79
8.5.1 Density and vertical distribution of crab burrows in GBR 79
8.5.2 Horizontal zonation of crab burrows in GBR 80
8.5.3 Crab species at the GBR 80
8.6 Conclusion 81
9. EDUCATION AND COMMUNITY ENGAGEMENT 82
9.1 Objectives 82
9.2 Results 82
9.2.1 Onsite participation by community volunteers 82
9.2.2 A field excursion by a school group 84
9.2.3 Volunteer participation records 85
9.2.4 Presentations at regional and metropolitan schools 86
9.2.5 Social media and other information sharing 88
9.2.6 Radio interviews 89
9.3 Conclusion 89
10. GLOSSARY 90
11. REFERENCES 96

TABLES

GBR Day track surveys

1 Total nesting activities in GBR during consecutive monitoring seasons, 2008/09 – 2011/12.

2 Loggerhead nest distribution per sub-section, 2010/11 – 2011/12.

3 Nest distribution for all species per sub-section, 2010/10 and 2011/12.

4 Sea turtle species composition in GBR, 2008/09 – 2011/12.

GBR Night surveys for data verification

5 Data correlation of night and day species identification in GBR during the night patrol period, 03/11/2011 – 08/12/2011.

6 Data correlation of night and day species identification in GBR during the night patrol period, 13/12/2011 – 01/02/2012.

7 Discrepancies in Nesting Activity Determination in GBR during the night patrol period, 03/11/2011 – 01/02/2012.

8 Accuracy of Nesting Activity Determination in GBR during the night patrol period, 03/11/2011 – 08/12/2011.

9 Accuracy of Nesting Activity Determination in GBR during the night patrol period, 13/12/2011 – 01/02/2012.

GBR Sampled nest surveys

10 Sampled Nests per sub-section in GBR, 10/11/2011 – 10/01/2012.

11 Species composition of Sampled Nests in GBR, 10/11/2011 – 10/01/2012.

FIGURES

The importance of the Gnaraloo turtle rookeries

1 Percentage of endangered sea turtle species in GBR, 01/11/2011 – 28/02/2012.

GBR Day track surveys

2 Species composition of turtle nests in GBR, 01/11/2011 – 28/02/2012.

3 Nesting activities recorded in GBR, 01/11/2011 – 28/02/2012.

4 Nesting activities per species in GBR, 01/11/2011 – 28/02/2012.

5 Species composition of all nesting activities in GBR, 01/11/2011 – 28/02/2012.

6 Daily loggerhead nest count in GBR, 01/11/2011 – 28/02/2012.

7 Cumulative and weekly loggerhead nests in GBR, 01/11/2011 – 28/02/2012.

8 Loggerhead nesting activities per week in GBR, 01/11/2011 – 28/02/2012.

9 Loggerhead nesting activities per sub-section in GBR, 01/11/2011 – 28/02/2012.

GBR Night surveys for data verification

10 Correlation of Nesting Activity Determination in GBR during the night patrol period, 03/11/2011 – 08/12/2011.

GBR Sampled nest surveys

11 Percentage of Sampled Nests disturbed and predated by crabs in GBR, 10/11/2011 – 28/02/2012.

12 Percentage of Sampled Nests per species impacted by crabs in GBR, 10/11/2011 – 28/02/2012.

13 Percentage of Sampled Nests per sub-section impacted by crabs in GBR, 10/11/2011 – 28/02/2012.

14 Percentage of Sampled Nests per horizontal beach zone impacted by crabs in GBR, 10/11/2011 – 28/02/2012.

15 Percentage of Sampled Nests impacted by environmental conditions in GBR, 10/11/2011 – 28/02/2012.

16 Percentage of Sampled Nests impacted by shifting dunes in GBR, 10/11/2011 – 28/02/2012.

17 Percentage of Sampled Nests impacted by tides in GBR, 10/11/2011 – 28/02/2012.

18 Percentage of Sampled Nests per sub-section impacted by environmental conditions in GBR, 10/11/2011 – 28/02/2012.

19 Percentage of Sampled Nests impacted by shifting dunes in each GBR sub-section, 10/11/2011 – 28/02/2012.

20 Percentage of Sampled Nests impacted by tides in each GBR sub-section, 10/11/2011 – 28/02/2012.

21 Percentage of Sampled Nests impacted by shifting dunes in each horizontal beach zone of the GBR, 10/11/2011 – 28/02/2012.

22 Percentage of Sampled Nests impacted by tides in each horizontal beach zone of the GBR, 10/11/2011 – 28/02/2012.

23 Percentage of Sampled Nests with evidence of hatching observed in GBR during monitoring period, 10/11/2011 – 28/02/2012.

24 Percentage of Sampled Nests impacted by predators and/or environmental conditions per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

25 Percentage of Sampled Nests impacted by crabs per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

26 Percentage of Sampled Nests impacted by environmental conditions per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

27 Percentage of Sampled Nests impacted by shifting dunes per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

28 Percentage of Sampled Nests impacted by tides per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

GBR Crab surveys

29 Average number of crab burrows per transect in GBR, 05/01/2011 – 19/02/2012.

30 Average number of crab burrows per horizontal beach zone in GBR, 05/01/2012 – 19/02/2012.

APPENDICES

A: Maps

B: Gnaraloo Weather Station Data

C: Photo plates

1. EXECUTIVE SUMMARY

This report contains information on sea turtle nesting activities at the Gnaraloo Bay Rookery and the Gnaraloo Cape Farquhar Rookery that were recorded during the field season 2011/12.

The *Gnaraloo Turtle Conservation Program* (**GTCP**) was modified during 2011/12, following the recommendations of the 3 previous years of monitoring (2008 – 2011). In addition, the GTCP's scientific procedure was expanded to include a sampled nest component and out-camp monitoring of the previously unexplored Gnaraloo Cape Farquhar Rookery (**GCFR**). The Community Engagement program developed during the previous season was further developed through the addition of educational presentations to local schools, new community volunteer opportunities, increased GTCP presence on various social networks, and an on-site visit by a school group.

Further research over several seasons is required to establish conclusive baselines for the sea turtle nesting data obtained during 2011/12. It is recommended that data in future years be cross correlated with abiotic data sourced from the GTCP's onsite weather station.

See Maps and Photo plates.

GBR Day track surveys

The GTCP monitoring season 2011/12 consisted of 87 sample days in the Gnaraloo Bay Rookery (**GBR**). The Gnaraloo Bay Study Area 2011/12 consisted of the area between the Gnaraloo Bay North marker and the Beach Point 9 marker (**GBN – BP9**).

From 1 November 2011 to 28 February 2012, a total of 349 turtle nests, inclusive of all recorded turtle species, were recorded in the GBR. The first nest was dug on 2 November 2011 and the last on 22 February 2012. The nesting peak was reached on 3 January 2012.

Approximately 1 out of 2 turtle beach activities within the GBR during the nesting season 2011/12 resulted in a nest.

The dominant nesting species observed in the rookery was the endangered loggerhead (*Caretta caretta*) turtle (~93%). Green turtles contributed to ~7% of nests in the GBR.

Turtle activities were predominantly recorded in the northernmost sub-section BP8 - BP9, with approximately ~58% of total season activity. The sub-section BP7 - BP8 received the lowest levels of beach activities, as occurred in season 2010/11.

GBR Night surveys for data verification

Night surveys at GBR occurred from 6 November 2011 – 8 December 2011 with further spot checks undertaken until 1 February 2012. Night surveys were undertaken to confirm correct species identification and nesting activity determination by comparing data collected during day surveys with the activities observed at night. Night research efforts were confined to the area between Beach Point 8 marker and Beach Point 9 marker (**BP8 - BP9**) given its high density of activities within a relatively small area.

A hundred percent accurate species identification correlation occurred for 10 consecutive monitoring days after 2 misidentifications occurred. The results confirm the accuracy and integrity of the 2011/12 data for species identification and show that several weeks of training in track monitoring are essential to become proficient in species identification.

In terms of nesting activity determination, 83.87% of results positively correlated between the night surveys and the morning track monitoring and 16.13% negatively correlated. This margin of error can be explained by the GTCP field team's initial lack of experience in nesting activity identification at the start of the season, in addition to environmental conditions that can impact both track and nesting activity data collection. The results confirm a good accuracy in nesting activity type determination, but also highlight a non-negligible source of error that has probably led to an under-estimation of the number of Nests (i.e. identified as UNAs through the nesting season, but not checked by night surveys) within the Gnaraloo Bay Rookery during 2011/12.

GBR Sampled nest surveys

A sample set of 65 of nests recorded at the GBR was selected for monitoring during 2011/12 for predator impact, environmental damage and hatching events. These data were then extrapolated to describe impacts on all nests in the GBR.

Of the 65 sampled nests, 95.38% were impacted by crabs. Golden ghost crabs (*Ocypode convexa*) were observed to burrow into nests and predated turtle eggs and hatchlings. Running ghost crab (*Ocypode ceratophthalma*) were witnessed to burrow less frequently than golden ghost crabs into turtle nests and were only observed to prey on turtle hatchlings. Results indicate that crabs do not show a preference for burrowing into nests in any particular sub-section or horizontal beach zone.

Fox tracks were recorded four times within the Study Area during this time. No nests in the GBR were disturbed or predated by foxes during the season 2011/12. This result is due to the continued success of our Gnaraloo Feral Animal Control Program.

Overall, 61.54% of the sampled nests were impacted by environmental conditions (i.e. impacts from shifting dunes and tides). Cyclone Iggy during January 2012 significantly impacted beach profile and eroded large areas of beach within the GBR. This cyclone also impacted approximately half of the sampled nests from tidal flooding and erosion.

Among the three sub-sections, GBN – BP7 received the highest amount of environmental impact even though this sub-section was observed throughout the season to be the calmest and most static sub-section in terms of wave energy and shifting dunes.

Only ~8% of sampled nests were observed to hatch. This low hatch rate may be due to a multitude of factors including the fact that not all sampled nests were monitored for the full incubation period before surveys concluded for the season.

GBR Crab surveys

Crab burrow surveys were conducted in the GBR from 19 December 2011 – 20 February 2012.

Crab burrows were present all along the rookery, from GBN – BP9. The majority of burrows was distributed in the mid to northern section of the rookery (i.e. from approximately 1.2 km south of BP7 - BP9), with the highest density of burrows occurring in the area approximately 1.2 km south of BP7 to 200 m north of BP7. Results 2011/12 did not show a clear correlation between the highest density of crab burrows and the highest density of turtle nests in the GBR.

The highest density of crab burrows occurred in the inter-tidal zone (59%) as was recorded during the season 2010/11. Although most crab burrows were recorded in the inter-tidal, there was still evidence of both disturbance and predation on nests located higher on the beach.

New: GCFR Day track surveys

The year 2011/12 marked the first on-ground monitoring of the Gnaraloo Cape Farquhar Rookery (**GCFR**), located north of the GBR. Three surveys were undertaken during the months of December 2011, January 2012 and February 2012. Sub-sections were demarcated for monitoring during future seasons.

Results from these surveys indicate that the GCFR may support a population of nesting female turtles slightly smaller or equal to that of the GBR. Both loggerhead and green turtle activities and hatchlings were observed in the GCFR suggesting that this rookery is similar in species composition to the GBR.

Because of the proximity of the GBR and the GCFR, it is possible that nesting females use both rookeries during the nesting season which would mean a potential current underestimation of the population size of nesting females at Gnaraloo. Further research needs to be conducted before conclusions can be made.

Three detailed GCFR reports with maps are available at https://gnaraloo.org/our-reports-and-papers/

Education and community engagement

The community engagement program was greatly expanded. Throughout season 2011/12, 29 community volunteers participated in data collection with GTCP researchers at the GBR. In

addition to participating in morning patrols with researchers, this marked the first season in which community volunteers were invited to participate in night patrols.

A further 10 presentations at 8 schools were given throughout WA. These presentations were given to high school students, and for the first time, also to primary students. The primary school presentations were a great success and added to the demographic for community engagement with the GTCP.

For the first time since the commencement of the GTCP in 2008/09, a school group from Nagle Catholic College in Geraldton travelled to Gnaraloo and stayed onsite from 23 – 26 January 2012 to participate in data collection during morning patrols with the GTCP researchers.

The GTCP also expanded its outreach via media outlets, including the GTCP Facebook page which was updated throughout the season 2011/12 and included photos and videos taken onsite during the season as well as new components to make the page more interactive for followers. A new Twitter page for the GTCP was also created to provide brief updates about the program to followers.

Two articles about the GTCP were published in both the Indian Ocean Turtle newsletter and the Coastlines newsletter produced by the State Government. Two radio pieces aired about the GTCP, the experience of monitoring sea turtles on a night survey, and the importance of the research conducted at Gnaraloo.

2. BACKGROUND

Gnaraloo Station is situated on the Ningaloo Coast, approximately 150 km north of Carnarvon. The Ningaloo Coast is home to important sea turtle rookeries of loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtles.

As turtle populations are in decline worldwide, studying these species' nesting sites within Australia is of utmost importance. Studies reveal that only a small percentage of turtle hatchlings survive to sexual maturity, which may take 30 years or more for loggerheads.

Protection of the endangered sea turtles at Gnaraloo is a local issue for the Ningaloo coast, but also one of national and international biodiversity significance.

2.1 Program overview

Gnaraloo spans approximately 65 km of coastline and GTCP researchers consistently monitored an approximately 7 km area within the GBR and 14 km area within the GCFR.

During the season 2011/12, the GTCP was in its fourth year of operation. It conducted 4 months of daily monitoring from 1 November 2011 - 28 February 2012. The research included a day monitoring program, night surveys, sampled nest surveys, crab surveys, and reconnaissance of the previously unmonitored GCFR.

The GTCP Day monitoring component is based on the *Ningaloo Turtle Program* (**NTP**) in Exmouth. The GTCP focusses on loggerhead research, and it contributes to the establishment of baseline data, protection of endangered marine species and critical coastal habitat, biodiversity conservation, informed management activity, community engagement and increased public awareness of conservation issues.

Program activities under the GTCP include attracting and managing the required scientists and community volunteers, daily baseline data collection and entry into required databases, data analyses and production of season-end report with results and findings.

Long-term goals of the GTCP include investigation of the importance of the Gnaraloo turtle rookeries to populations locally, nationally, and globally, as well as development of informed and effective management actions for their conservation and protection. 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:

Overall

- Provide accurate and reliable data, and establish baseline, for the sea turtle rookeries along the Gnaraloo coastline, an area for which there was previously little existing scientifically verified information;

- Identify trends in turtle nesting activities at Gnaraloo.
- Identify the important turtle rookeries along the Gnaraloo coastline and required management activity to assist the conservation of endangered species and biodiversity protection;
- Implement effective protection measures at significant turtle rookeries along the Gnaraloo coastline for protection of important habitat and breeding areas;
- Provide work experience and professional development to scientific interns through seasonal involvement and participation with the GTCP;
- Engage the community through volunteer activity and increase public awareness of sea turtles and coastal conservation issues.

Day track monitoring

- Identify the number of nests, their distribution and the number of female turtles nesting at the GBR;
- Identify the disturbance and predation rates of turtle nests (eggs and hatchlings) by native and introduced predators in the GBR during the monitoring period via the new Sampled Nest component;
- Determine the level of environmental impacts on turtle nests in the GBR via the new Sampled Nest component;
- Report on the conservation status of sea turtle species that use the GBR;
- Determine the significance of the GBR and the GCFR;

Night surveys

- Determine the margin of error in species identification and Nesting Activity Determination via day track monitoring;
- Investigate the possible presence of nesting hawksbill (*Eretmochelys imbricata*) turtles in the GBR by visual identification using morphological evidence.

Crab surveys

- Investigate the evolutionary relationship between the turtle and crab populations in the GBR.

Work under the GTCP 2011/12 was supported by a separate but complimentary predation control program which was managed by the GTCP in conjunction with a specialist pest

contractor, Animal Pest Management Services. The then *Gnaraloo Feral Animal Control Program* (**GFACP**) commenced during 2008, with contributory funding from the Australian Government (*Caring for our Country, Community Coastcare*). The GTCP initiated and developed this predation minimisation program as an essential accompaniment to the GTCP. The sole objective of the feral animal control program was to protect all turtle rookeries at Gnaraloo by reducing critical threats to nests and hatchlings during the annual breeding season. The GTCP identified and addressed the required linkages between the annual turtle and feral animal control programs for Gnaraloo, including essential liaison with the expert 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.

The GFACP resulted in 0% fox disturbance and predation of turtles at the GBR during the season 2011/12. It also had other positive outcomes such as biodiversity protection of native fauna station wide, such as small to medium sized mammals, marsupials, ground nesting birds and reptiles.

Detailed GFACP reports with maps are available at https://gnaraloo.org/our-reports-and-papers/

2.2 Funding and resourcing

During the inaugural GTCP monitoring season 2008/09, the Gnaraloo Station pastoralist and the Australian government (with contributory funding under the then *Envirofund Round 10*) funded the GTCP. During the GTCP season 2009/10, the Gnaraloo Station pastoralist provided all required financial support and in-kind contributions to enable the operation of the GTCP.

During the GTCP season 2010/11, the Gnaraloo Station pastoralist met the required financial and in-kind contributions to the GTCP, including for program planning, on-ground research, technical data analysis, reporting, and project management. The Australian government contributed through its *Caring for our Country - Business Plan 2010/11* to the introduction of a new program element of increased community involvement. Esri Australia, through its *Conservation Grant Program*, generously provided a full licence of ArcGIS software during the season for improved spatial analysis and production of higher quality maps.

During the GTCP season 2011/12, the Gnaraloo Station pastoralist again provided the required financial and in-kind contributions to ensure the ongoing operation of the GTCP. Funds awarded by the Australian government via its *Caring for Country* program contributed to the operation and expansion of the GTCP's community engagement component. Esri Australia again contributed a full licence of ArcGIS 10 software to ensure continuation of high-quality spatial analysis during the season 2011/12. The then Department of Environment and Conservation, Exmouth District, provided high resolution aerial imagery for use in mapping the coastal areas of the Gnaraloo turtle rookeries.

2.3 Regulation 17 research licence

The GTCP 2011/12 was undertaken with approval from the then Department of Environment and Conservation (**DEC**), under a Regulation 17 Licence issued under the *Wildlife Conservation Act 1950* WA and the *Wildlife Conservation Regulations 1970* WA.

At the end of the monitoring season, the GTCP entered the season's results into the web-based 'DEC Fauna Survey Database' (https://secure.dec.wa.gov.au/apex/pls/fauna/f?p=101:1:1735533654806623::NO). The DEC Fauna Survey Database contains records of Western Australian fauna from sources including historical reports, DEC staff, survey data from major projects, consultants (as part of the scientific licence procedure) and the general public. It is an online system of data entry, maintenance and distribution that is accessible to licence holders which is managed by DEC. The information is available for viewing and use by scientists, researchers and the public, who may access data relating to the distribution of fauna by using the DEC NatureMap website. The DEC NatureMap contains data from the DEC Fauna Survey Database and a range of other datasets, including the WA Museum FaunaBase database.

2.4 Monitoring Procedure

Methodologies and protocols followed by the GTCP researchers throughout the 2011/12 season adhered to that of the *GTCP Monitoring Procedure 2011/12* (Hattingh *et al.,* 2012).

GTCP day monitoring procedures are based on those developed and used by the Ningaloo Turtle Program. The GTCP also adhered to the *Turtle Monitoring Field Guide* (CCG 2007) and *Guide to Track Beach Monitoring in Australia* (Department of Environment and Conservation, Lewis *et al*, 2008). Protocols for crab surveys and night monitoring were developed by the previous GTCP researchers and are to Australian and international standards.

2.5 Team and training

The GTCP 2011/12 was undertaken under the direction of an experienced environmental scientist and project manager who ensured the overall planning, development, co-ordination, and adaptive management of the GTCP and GFACP for responsible protection of the Gnaraloo rookeries. This person is responsible for all monitoring activities by the seasonal GTCP field teams as well as for the experimental design, scope of work, data collection, analysis, reporting and project management from year to year.

The GTCP's *Scientific Intern Recruitment Program* was again used during 2011/12 to recruit capable candidates from local, national, and international fields. The GTCP recruitment process was competitive, with qualified and skilled applicants from Australia and overseas.

The GTCP research team 2011/12 comprised of:

- *Project Manager and Lead Scientific Officer:* Ms. Karen Hattingh (MPhil Environmental Science South Africa), with extensive private sector experience;

- *Field Team Leader:* Ms. Kimmie Riskas (BSc Environmental Systems/Ecology, Behaviour & Evolution USA) with previous experience working with sea turtles in California and Florida (USA), Cape Verde (West Africa), as well as biological survey experience in Baja California (Mexico) and throughout Costa Rica;

- *Community Volunteer Co-ordinator*: Mr. Robert Edman (BSc Biological Sciences USA) with previous research experience with sea turtles (Florida, USA) and salamanders (Virginia, USA); and

- *GIS Cartographer*: Ms. Fiona Morgan (BSc in Marine Science and Conservation Wildlife Biology Western Australia) with experience working with elephants (Thailand) and GIS mapping.

During November 2011, the GTCP field team members received training in West Australian turtle tracking and monitoring protocols by the then Department of Environment and Conservation and the Cape Conservation Group, under the Ningaloo Turtle Program. The field team members travelled to Exmouth for two days of training, which included turtle track identification, nest determination, correct data entry into the monitoring form, and basic beach monitoring protocols. Accompanying the GTCP team was a community volunteer, Mr. Stuart Dijkmans (a GIS expert based in Carnarvon at the time) who continued to participate with the team's monitoring activities onsite at Gnaraloo throughout the season. Each GTCP field researcher and Mr. Dijkmans successfully completed the training and assessment program.

3. PROGRAM EXPANSION

Below is an overview of the new elements introduced to the GTCP during 2011/12.

3.1 On-ground surveys of the Gnaraloo Cape Farquhar Rookery

Following the recommendation made in the GTCP Report 2010/11, the GTCP field team conducted on-ground monitoring of the northern most rookery on Gnaraloo, now renamed the Gnaraloo Cape Farquhar Rookery (**GCFR**). Monitoring took place over the course of three reconnaissance excursions throughout the season, in which GTCP researchers identified areas of high turtle activity to evaluate the importance of the GCFR. Refer to the GTCP's three separate GCFR reports for complete descriptions of the reconnaissance excursions and results. Each of these reports also include maps with the location of the specific sub-sections monitored during each survey.

3.2 Extra training in feral predator track identification

On 18 – 20 November 2011, a team of specialists from Animal Pest Management Services (**APMS**) surveyed targeted areas on Gnaraloo for signs of foxes, feral cats and wild dogs and baited these areas with 1080 poison baits as part of the *Gnaraloo Feral Animal Control Program*. During the onsite visit, APMS also provided on-ground training to the GTCP field team members in feral predator track recognition. Accurate identification of predator tracks was critical to protect the Gnaraloo Bay Rookery from nest disturbance and predation, and to provide immediate feedback to the Gnaraloo pastoralist and to APMS in regard to the success of baiting efforts. Receiving onsite training in predator tracking represented a significant program improvement from past years, where the GTCP field teams learned to identify animal prints based only on catalogued photos in the *GTCP Photo Training Database*.

3.3 Data sharing with international databases

Data collected by the previous GTCP research teams (2008/09 - 2010/11) were released to the *State of the World's Sea Turtles* **(SWOT)** as well as to the *Indian Ocean - South East Asian Marine Turtle Memorandum of Understanding* **(IOSEA)** for posting on their international databases so that researchers external to Gnaraloo may access, share and use the information. SWOT works to fill critical data gaps by compiling current data from conservation organisation around the world. It is a partnership among Conservation International (**CI**), the IUCN Marine Turtle Specialist Group (**MTSG**), Duke University's OBIS-SEAMAP, and an ever-growing international team of local organizations, scientists and conservationists. IOSEA is a specialized intergovernmental agreement concluded under the auspices of the Convention on the Conservation of Migratory Species of Wild Animals, and works to implement conservation measures through the IOSEA Conservation and Management Plan.

3.4 Scientific method

Under the guidance of the GTCP's Project Manager, the GTCP team 2011/12 further developed the GTCP's scientific procedure, protocols and data management. This included changes to the GTCP Day Monitoring Form 2010/11 and the GTCP Night Monitoring Form 2010/11 to reflect additions to the monitoring procedure made in the season 2011/12. The GTCP Crab Burrow Monitoring Form 2011/12 was created to standardize data collection and recording methods during scheduled crab burrow surveys.

As part of a new monitoring component, the GTCP Sampled Nest Monitoring Form 2011/12 was created and used to record disturbance and damage to sampled nests, which were monitored daily for predator and environmental impacts. To facilitate daily monitoring of sampled nests, a separate Sampled Nests Checklist was created to ensure that every sampled nest was checked for damage, regardless of whether any damage was recorded. The checklist contained a list of all sampled nests in each of the three sub-sections, their GPS coordinates, and their beach position (I, H, E, or D). Having this checklist enabled the monitors to determine if any stakes were missing due to shifting dunes, tidal inundation, or the actions of other nesting turtles.

The draft of the *GTCP Monitoring Procedure 2011/12* (Hattingh *et al.,* 2012) continued to be updated and revised throughout the season and was finalised during the GTCP's Project Manager's onsite visit to Gnaraloo in February 2012. This represented a considerable achievement in formalising the GTCP's data collection procedures and protocols that were essential for consistent, replicable results from year to year.

The Excel databases used for the monitoring season 2011/12 were remodelled and refined to reflect the updated scope of GTCP research, including new scientific components, and to ensure linkages between monitoring forms and database entries. A new excel database was created for recording data on the sampled nest set during the monitoring season 2011/12.

3.5 Improved GIS mapping

The GTCP Report 2010/11 recommended ('Recommendations: GIS software and spatial analysis during 2011/12', page 80):

'*it is strongly recommended that an analysis be undertaken of the risk of tidal inundation of turtle nests in the Gnaraloo Bay Rookery, through using buffers of 10m, 20m and 30m to classify the alternative risk zones. This was attempted during the season 2010/11, but due to GPS inaccuracy, when the nests were mapped in the ArcGIS software, the data plots did not correlate to the actual position of nests on the beach. This was due to large variability in the GPS readings ... These difficulties may be overcome in future through use of more accurate GPS units to record nest data ...*

*The possibility of also producing and integrating a Digital Elevation Model (**DEM**) into the risk assessment of tidal inundation of turtle nests should be assessed in future. This may also be a*

potential way of mapping environmental impacts on turtle nests, such as sand accretion and erosion. Data to create a DEM should be available after the end of the JCU BSc. Honours project 2010/11 that investigated factors that influence nest site selection and preferences of female turtles (by Ms. Taylor Bodine under the supervision of Dr. Mark Hamann)'.

The GTCP's Project Manager commissioned the production of a Digital Elevation Model (**DEM**) of the GBR (at 2m intervals) during the season 2011/12 (refer Maps).

The DEM provides a helpful visual impression of the coastal habitat and adjacent terrestrial environment at the GBR. It allows for a better understanding of the physical environment for use during the assessment and planning of future sea turtle research and management activities at the GBR.

With assistance from Esri Australia, including provision of ArcGIS (Arc Editor) software, and from the then Department of Environment and Conservation (Exmouth District) who provided high quality aerial imagery of Gnaraloo and given technical support by Mr. Stuart Dijkmans, when requested, the GTCP Project Manager and the GTCP GIS Cartographer developed the maps for the season 2011/12, building on the work from previous GTCP seasons. Esri Australia also provided access to its technical support services which was valuable when needed.

The GTCP Report 2010/11 recommended the following ('Essential program equipment 2011/12', page 76):

'*It is strongly advised to replace the current GPS devices (x3) with more accurate models (1m accuracy). A significant margin of error associated with use of current GPS equipment during 2010/11 resulted in reduced data quality and difficulty of cross-correlation of data in the GTCP Excel Database 2010/11. For example, damaged, predated or hatched nests encountered throughout the season could often not be successfully cross correlated with the original nest ID code, as the variability in the 2 sets of GPS readings was too large. GPS devices with increased accuracy would be highly beneficial to the program, allowing the development and use of a more detailed GTCP database*'.

The GPS devices referred to above are Garmin E-trek GPS devices that were used by the GTCP. The GTCP GIS Cartographer 2011/12 acted on the recommendation and, via Esri Australia, secured a loan from Tough-Corp of 2 new Getac PS535 GPS devices with improved technology (including ArcGIS, Microsoft Excel and Internet Explorer), however, unfortunately due to certain field data requirements of the GTCP the new devices could not be used during 2011/12.

The GTCP team 2011/12 would like to acknowledge and thank both Mr. Tom Gardner of Esri Australia and Mr. James Nelson of Tough-Corp for their help and assistance in providing the Getac PS535 devices to Gnaraloo during 2011/12.

3.6 Expanded education and community engagement

Under the guidance of the GTCP's Project Manager, the GTCP's Community Volunteer Co-ordinator expanded the Education and Community Engagement plan that was developed at the start of the season 2010/11.

Following the advice of the GTCP Community Volunteer Co-ordinator 2010/11, efforts were made to establish ongoing working relationships with local schools, with the intent to arrange yearly educational presentations and possible onsite participation with the GTCP research team. Many presentations were conducted at schools in Western Australia to both primary and high school groups during the season 2011/12. This year also marked the first onsite visit to Gnaraloo by a school group. From 23 – 26 January 2012, students and teachers from Nagle Catholic College (Geraldton) participated with the GTCP research team during morning patrols.

The GTCP team 2011/12 extended the opportunity for community volunteers to participate during night surveys. As a precautionary measure to ensure minimal disturbance to the nesting turtles, all volunteers were required to have first received the official GTCP induction presentation and also participated in a morning patrol. During all patrols, all volunteers respected GTCP instruction and guidelines so as not in interfere with incoming and/or nesting turtles.

The GTCP Facebook page created during the season 2010/11 was maintained throughout the season 2011/12. The page continued to provide updates throughout the season in the form of field diaries, photos, videos and wall posts. In addition, two weekly updates were posted on the page: the weekly Turtle Thermometer and Turtle Trivia Tuesday.

4. THE IMPORTANCE OF THE GNARALOO TURTLE ROOKERIES

4.1 The Gnaraloo loggerheads in context

The largest loggerhead populations in the world include:

1. Oman (Masirah Island) (est. 14,600 – 29,200 females per season) (Tucker *et al*., 2018);
2. Florida and the eastern United States (>10,000 females per season) (Ehrhart *et al*., 2014);
3. Cape Verde Islands (West Africa) (est. >10,000 females per season) (Marco *et al*., 2011); and
4. Western Australia (est. >2,500 females per season) (Casale *et al*., 2015).

For more information regarding the global loggerhead populations, refer to Baldwin *et al*., 2003; Ehrhart *et al*., 2003; Kamezaki *et al*., 2003; Limpus and Limpus, 2003; Monzón-Arguëllo *et al.*, 2010; Salm 1991.

The loggerhead turtles that nest on the Gnaraloo coastline, adjacent to the Ningaloo Marine Park in Western Australia, belong to one of the largest loggerhead populations in the world; however, population estimates and trends in this region remain unknown (Casale *et al*., 2015). Continued monitoring of nesting loggerhead females in Western Australia, including in the Gnaraloo rookeries, is critical for understanding the conservation status of this subpopulation.

Western Australia is believed to hold all loggerhead nesting in the southeast Indian Ocean (Conant *et al.,* 2009; Dodd, 1988), with nesting sites spanning from the Shark Bay World Heritage Area through the Ningaloo Marine Park to the Muiron Islands north of Exmouth (Conant *et al.,* 2009). The population of loggerheads nesting in Western Australia is the largest in the country, eclipsing Australia's other loggerhead populations, which nest primarily in Queensland (Conant *et al.,* 2009; Limpus, 2009).

The main nesting sites for loggerhead turtles in Western Australia are as follows (Ibid.):

1. Dirk Hartog Island (Shark Bay) (1,000 – 3,000 females per season) (Baldwin *et al*., 2003; Hamann *et al*., 2013);
2. Cape Range National Park (Cape Range and Northwest Cape mainland) (population of 1,000 – 3,000 nesting females; no estimate is available for females nesting each season) (Whiting 2016).

3. Muiron Islands (north of Cape Range National Park) (preliminary data suggests that the number of nesting females in the Muiron Islands could sometimes be the same as Bungelup, but estimates remain unknown) (Rob *et al*., 2019); and

4. Gnaraloo Bay and Gnaraloo Cape Farquhar (mainland) (total population of nesting females and the number of females nesting each season still unknown).

The Gnaraloo rookeries are viewed as important mainland rookeries for loggerheads in Western Australia (Hamann *et al*., 2013). Although relatively small, the Gnaraloo Bay Rookery makes an important contribution to the regional loggerhead turtle population, and its isolation, with different environmental and anthropogenic conditions and threats, gives it conservation value. It is important to note that long-term trends in nesting populations at Gnaraloo remain unknown. Formal on-ground monitoring of the Gnaraloo Cape Farquhar Rookery only commenced during 2011/12. Data collected during the season indicate that this rookery may be as large as the Gnaraloo Bay Rookery which means that the size of the female nesting population at Gnaraloo may be underestimated. The newly monitored Gnaraloo Cape Farquhar Rookery increases the available knowledge of how turtles use the area, however the short surveys of the GCFR preclude estimation of the number of individuals nesting in this rookery and the significance of the GCFR remains unknown.

There is a pressing need for more data on nesting patterns and threats to marine turtles in the Indian Ocean (Wallace *et al*., 2011). One of the biggest drawbacks to effective provision of advice in support of sustainable development and management is the paucity of long term Western Australian datasets at the scale required by models. Gnaraloo's geographic location is in an area where there is little information available on sea turtles and related system components. This makes the monitoring work at the Gnaraloo rookeries a key source of information that could help to reduce uncertainty about the functioning of the marine and coastal ecosystem as well as conservation management. Continued monitoring of the Gnaraloo sea turtle rookeries is an important ongoing source of data on a vast remote coastline.

4.2 Conservation status of Gnaraloo turtles

Sea turtles are highly migratory animals that are known to traverse entire ocean basins in search of suitable foraging, breeding and nesting sites. As such, a single, global status often does not adequately reflect the varied threats and conservation measures that a species encounters in different parts of its range. Classification efforts by government agencies and international conservation groups produce varying results depending on the scope of individual assessments, which may be parameterised by nesting ecology, population trends, threats, and genetic analysis.

The IUCN Red List of Threatened Species (www.iucnredlist.org, 2012) assigns sea turtle conservation status globally and considers each sea turtle species as a single entity across its entire range. The IUCN Red List assessment of loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtles have remained unchanged from the GTCP monitoring season 2010/11, namely 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. This is based on criteria related to observed population reduction caused by any number of factors.

Under IUCN Red List classifications, loggerheads have remained endangered from 2008/09 – 2011/12, while the classification of greens was revised from vulnerable in 2008/09 to endangered from 2009/10 – 2011/12.

For the purposes of this report, reference to the conservation status of the sea turtles found at Gnaraloo will use the IUCN Red List classification, unless otherwise stated.

As seen in Figure 1 below, the turtle species (loggerheads and greens) known to occur at the Gnaraloo rookeries, comprising of both the Gnaraloo Bay Rookery and the new Gnaraloo Cape Farquhar Rookery are considered endangered. It is highly likely that the activities that were unable to be identified by species (2.08%) also belong to endangered turtles.

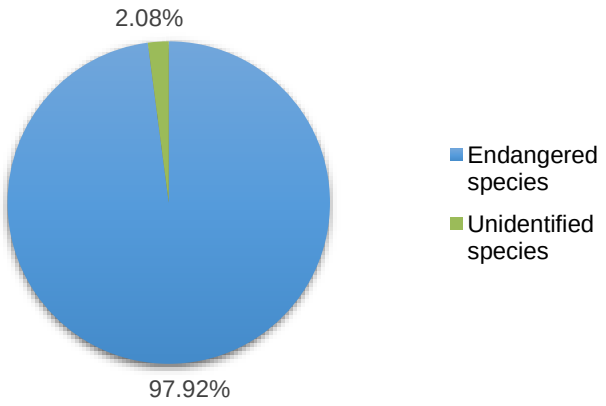

Figure 1: Percentage of endangered sea turtle species in GBR, 01/11/2011 – 28/02/2012.

5. GBR DAY TRACK SURVEYS

5.1 Objectives

The objectives of the day monitoring program during the nesting period 2011/12 (which does not include the entire hatching period) were:

- Collect and interpret data on sea turtle beach activities in the GBR through daily track monitoring;
- Monitor the distribution of turtle species in the GBR and interpret trends;
- Collect and interpret data on disturbance and predation of turtle nests (eggs and hatchlings) by introduced and native predators in the GBR via the new Sampled Nest component;
- Collect and interpret data on disturbance of turtle nests (eggs and hatchlings) by various environmental factors via the new Sampled Nest component;
- Include community volunteers through onsite education and involvement with data collection during beach patrols.

Refer to the section titled 'Background' for more detailed information about the overall objectives of the GTCP.

5.2 Study Area

Monitoring during the season 2011/12 was again carried out in the GBR (refer Maps), which is located between -23.76708° / 113.54584° and - 23.72195° / 113.57750°.

The Study Area measures approximately 6.7 km and consists of the calm, relatively static beach of Gnaraloo Bay, northward to a more dynamic beach topography and mobile dune systems. Throughout the season, it was observed that sub-section GBN – BP7 had a less extensive mobile dune system than the northern sub-sections, as well as lower wave action and a more stable beach profile. By contrast, sub-sections BP7 – BP8 and BP8 – BP9 experienced higher wave energy, an extensive mobile dune system, and substantial movement of sand due to tidal movement. The established sub-sections within the GBR lie adjacent to one another and are demarcated by the GTCP's Permanent Beach Point Markers.

The GTCP's Permanent Beach Point Markers consist of 5 stationary markers that are affixed well above the high-water mark and that remain in place from season to season. These markers are a mix of PVC pipes and star pickets, except for the Gnaraloo Bay North (**GBN**) marker. The latter denotes the southernmost point of the Study Area and comprises of the large yellow Ningaloo Marine Park (**NMP**) marine sanctuary zone pole. Additionally, the wooden signs

created by the GTCP team 2010/11 were erected at each sub-section point, as recommended in the GTCP Report 2010/11.

GBN - BP7

Gnaraloo Bay North to Beach Point 7 (**GBN – BP7**) is located between -23.76708° / 113.54584° and -23.75001° / 113.56871°. The tall metal pipe with PVC cladding at Beach Point 6 (**BP6**) remains in place and is located at the public 6Mile car park area. The decision to assimilate BP6 into the larger sub-section GBN – BP7 was made by the GTCP research team 2010/11, given a low number of activities recorded specifically within the historical sub-section GBN - BP6.

The sub-section GBN – BP7 is the southernmost sub-section of the Study Area. The Permanent Beach Point Marker at BP7 is a white PVC pipe affixed atop a fore dune.

The sub-section GBN – BP7 measures 2.35 km and can be covered on foot in approximately 1 hour.

BP7 - BP8

Beach Point 7 – Beach Point 8 (**BP7 – BP8**) is located between -23.75001° / 113.56871° and -23.73631° / 113.57448°. The Permanent Beach Point Marker at BP8 is a white PVC pipe that sits atop a fore dune. This sub-section is immediately north of the sub-section GBN - BP7.

The sub-section BP7 – BP8 measures 1.63 km and can be covered on foot in approximately 30 minutes.

BP8 - BP9

Beach Point 8 – Beach Point 9 (**BP8 – BP9**) is immediately north of BP7 – BP8. It is located between the coordinates -23.73631° / 113.57448° and -23.72195° / 113.57750°. The Permanent Beach Point Marker at BP9 is a star picket atop a small dune, inside the vegetation.

The BP8 – BP9 sub-section measures 1.72 km and can be covered on foot in approximately 30 minutes.

5.3 Materials and methods

The equipment used and methodology employed during the monitoring period 2011/12 are described in the *GTCP Monitoring Procedure 2011/12* (Hattingh *et al.,* 2012).

As recommended by the GTCP Report 2010/11, the monitoring period 2011/12 began on 1 November 2011 and ended on 28 February 2012.

All beach patrols are conducted on foot, as vehicle and quad bike driving is not allowed on the beaches at Gnaraloo.

5.4 Results

5.4.1 Track monitoring

During the monitoring season 2011/12, a total of 349 nests were recorded in the GBR.

Loggerhead (*Caretta caretta*) turtle nests were predominantly recorded in the Study Area. In total, out of the 349 nests recorded during the monitoring period (refer Figure 2):

- 324 nests (92.83%) were loggerhead nests; and
- 25 nests (7.16%) were greens (*Chelonia mydas*) nests.

Out of 349 nests recorded, all nests (100%) were able to be identified by species.

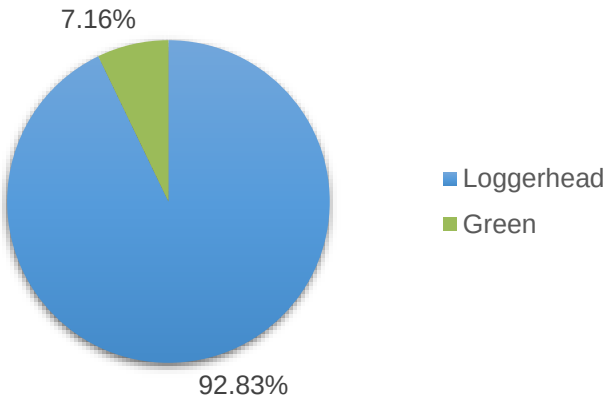

Figure 2: Species composition of turtle nests in GBR, 01/11/2011 – 28/02/2012.

During the monitoring period 2011/12, 769 tracks were recorded in the Study Area, including all nests, Unsuccessful Nesting Attempts (**UNAs**), U-tracks and Unidentified activities. Of the 769 tracks recorded in the Study Area (refer Figure 3):

- 349 (45.38%) were nests;
- 282 (36.67%) were UNAs;
- 127 (16.51%) were U-tracks; and
- 11 (1.43%) were unable to be identified by nesting activity due to difficulties experienced at times in distinguishing between nests and UNAs given field conditions.

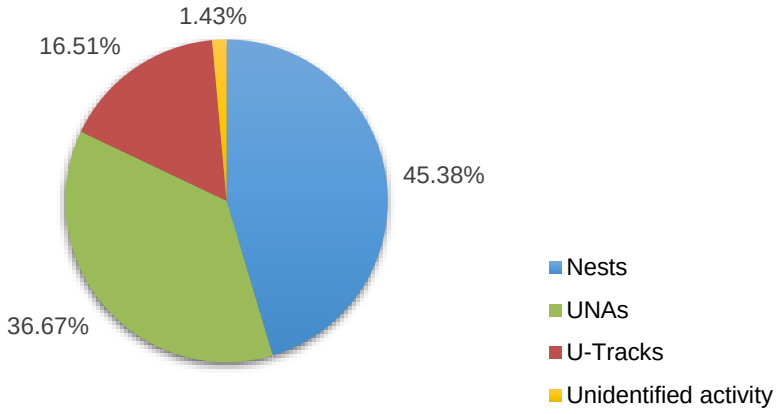

Figure 3: Nesting activities recorded in GBR, 01/11/2011 – 28/02/2012.

45.38% of total beach activities in the Study Area during the monitoring period 2011/12 resulted in a nest, 54.62% (UNAs and U-tracks) did not result in a nest and 1.43% of total beach activities were unable to be identified due to environmental conditions.

Loggerheads were responsible for the majority of total beach activities (refer Figure 4 and Figure 5):

- loggerheads contributed to 700 out of 769 (91.03%) total beach activities;
- green turtles contributed to 53 out of 769 (6.89%) total beach activities; and
- 16 out of 769 (2.08%) were unable to be identified by species due to track erosion.

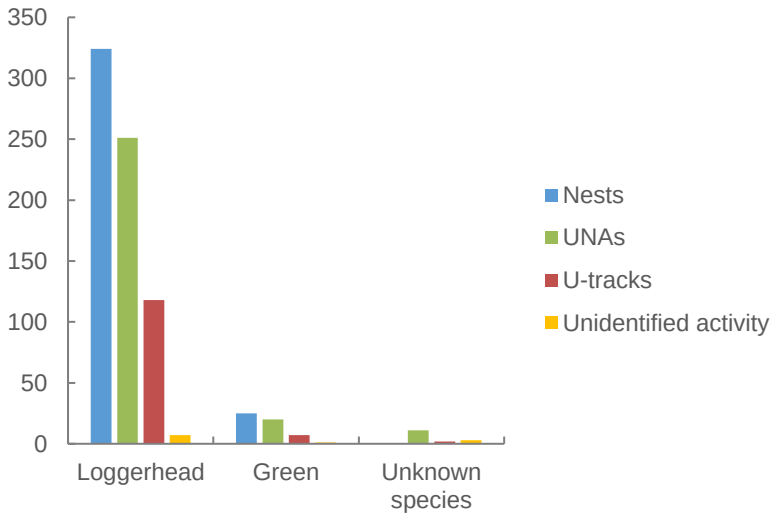

Figure 4: Nesting activities per species in GBR, 01/11/2011 – 28/02/2012.

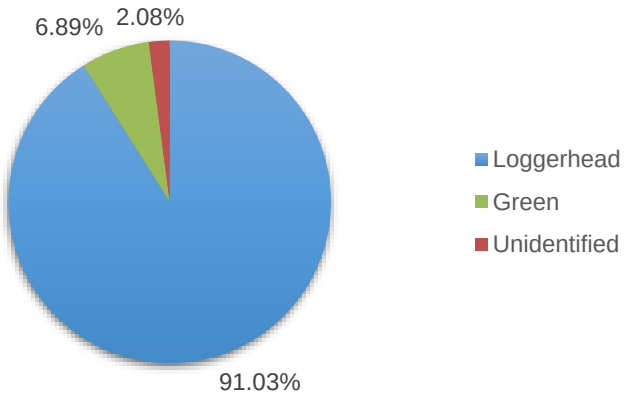

Figure 5: Species composition of all nesting activities in GBR, 01/11/2011 – 28/02/2012.

For the spatial breakdown of nest distribution in the GBR, please refer to Maps.

Given the dominant percentage of loggerhead nests within the Study Area (91.03%), **only data concerning loggerheads will be presented hereafter.**

Loggerhead nesting activity during the monitoring period 2011/12 peaked in early January 2012 (refer Figure 6). The first loggerhead nest was recorded on 2 November 2011. The number of loggerhead nests recorded each day increased steadily from the beginning of the season to reach a maximum value of 12 nests on 3 January 2012. Daily

nesting activity subsequently decreased through the month of February, with 1 nest being recorded on 22 February 2012. Onsite monitoring ended on 28 February 2012.

Because the number of loggerhead nests fluctuated daily, the polynomial trendline provides an analysis of the progression of the nesting activity.

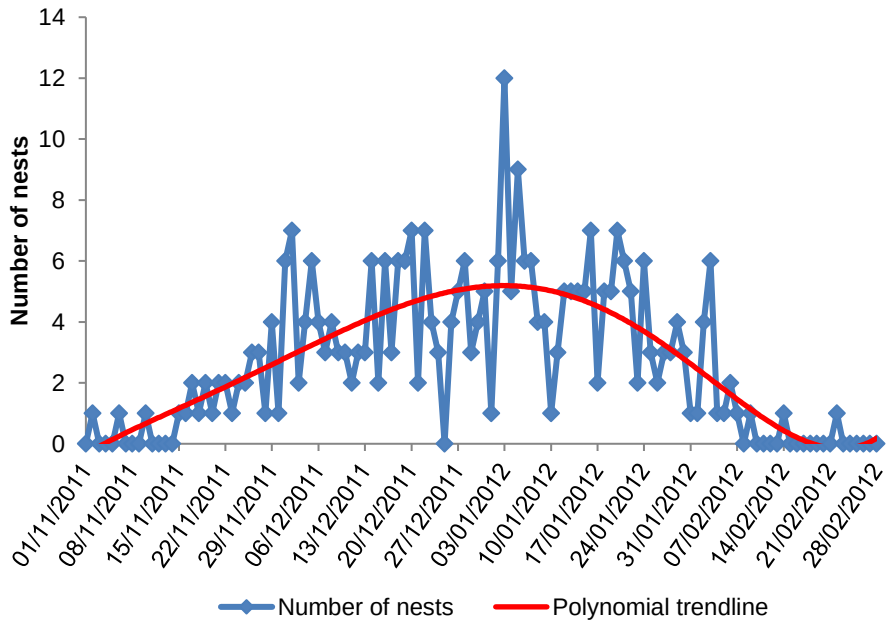

Figure 6: Daily loggerhead nest count in GBR, 01/11/2011 – 28/02/2012.

Note: *No patrols occurred from 11/11/2011 – 14/11/2012 due to training in Exmouth, therefore the number of nests recorded for these dates is 0.*

The cumulative nest total rose sharply from 29 November 2011 until reaching a plateau from 7 February 2012 to 28 February 2012 when the monitoring period ended (refer Figure 7). The first nest was recorded on 2 November 2011. The weekly number of loggerhead nests increased to an average of 33.6 per week from 29 November 2011 until 24 January 2012. The most nests recorded per week were 37 nests from 27 December 2011 until 3 January 2012. The last nest was recorded on 22 February 2012.

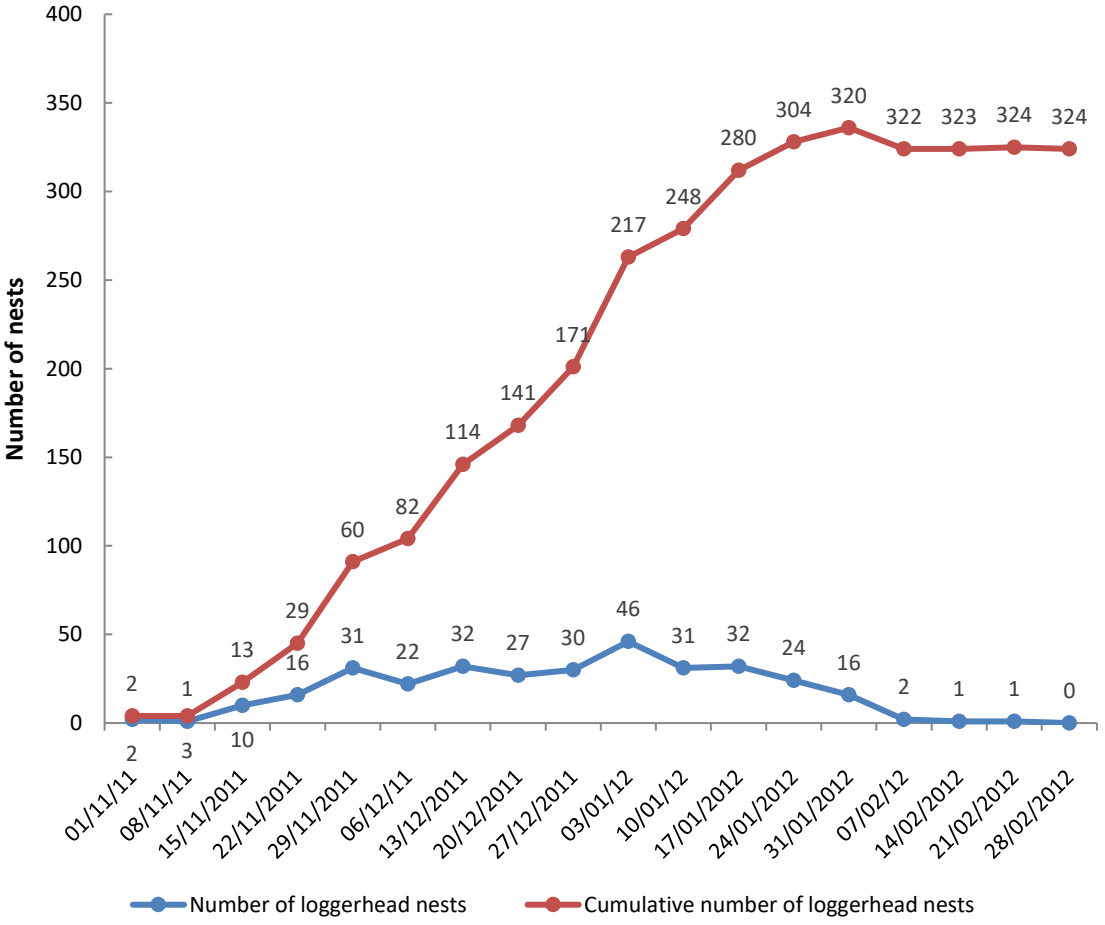

Figure 7: Cumulative and weekly loggerhead nests in GBR, 01/11/2011 – 28/02/2012.

The majority of activities were recorded from 15 November 2012 until 7 February 2012 (refer Figure 8). Total loggerhead activity per week (purple line) shows the combined nest, UNA and U-track activities (respectively the green, red and blue lines). Loggerhead UNA activities peaked from 20 December 2011 until 27 December 2011. Loggerhead U-track activities remained relatively constant between 29 November 2011 until 31 January 2012.

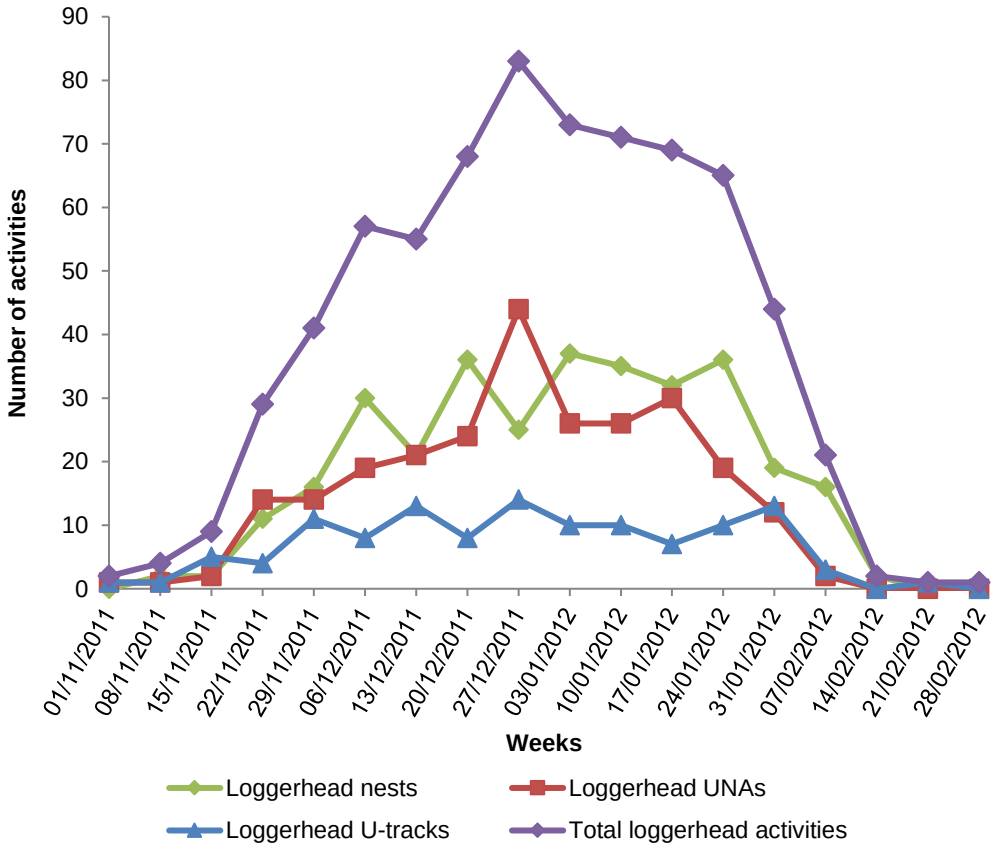

Figure 8: Loggerhead nesting activities per week in GBR, 01/11/2011 – 28/02/2012.

Of the 700 total loggerhead beach activities (refer Figure 9):

- 228 (32.53%) were recorded in the sub-section GBN – BP7. 109 of these activities (47.81%) were nests;
- 68 (9.7%) were recorded in the sub-section BP7 – BP8. 27 of these activities (39.71%) were nests; and
- 405 (57.77%) were recorded in the sub-section BP8 – BP9. 188 of these activities (45.68%) were nests.

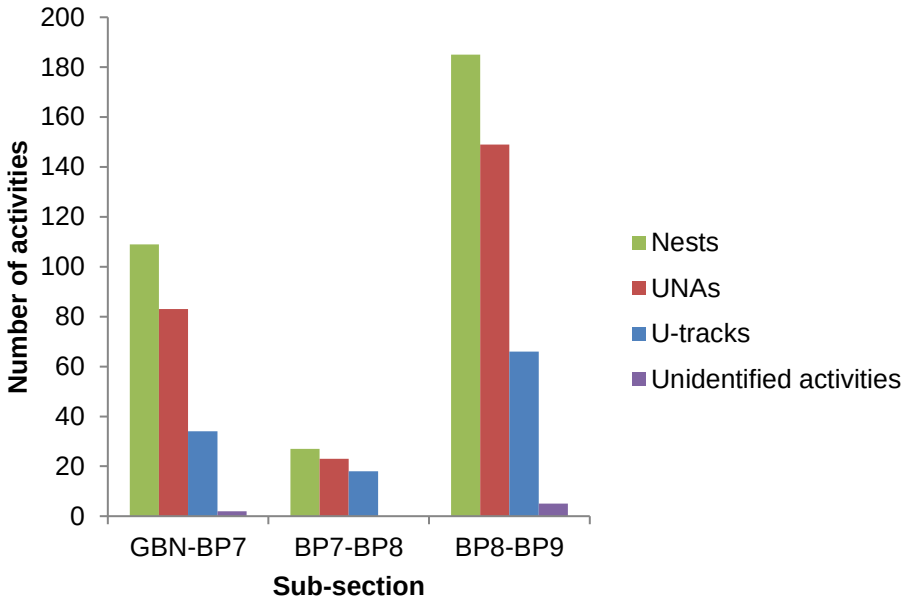

Figure 9: Loggerhead nesting activities per sub-section in GBR, 01/11/2011 – 28/02/2012.

5.4.2 Nest disturbances and predation

A set of selected nests in the Gnaraloo Bay Rookery was monitored daily from 10 November 2011 – 28 February 2012 in the GTCP's first Sampled Nest survey. Nests were monitored for disturbance and predation by crabs, foxes, feral cats and wild dogs, as well as impacts from environmental factors such as shifting sand dunes and tide inundation (refer Chapter "GBR Sampled Nest Surveys").

5.5 Discussion

5.5.1 Study Area

The Study Area was monitored for the fourth consecutive season during 2011/12. This included the area from Gnaraloo Bay North to Beach Point 9 (**GBN – BP9**). The Study Area (6.7 km) has 3 sub-sections, namely:

- Gnaraloo Bay North to Beach Point 7 (**GBN – BP7**);
- Beach Point 7 to Beach Point 8 (**BP7 – BP8**); and
- Beach Point 8 to Beach Point 9 (**BP8 – BP9**).

Whilst GBN – BP7 is frequented by visitors and shore fishermen (especially the southernmost 2 km of beach and around the GTCP's Permanent Beach Point Marker for

historical Beach Point 6), the area BP7 – BP9 is remote with little to no human presence. Vehicle and quad driving on beaches are not allowed at Gnaraloo.

5.5.2 Number of nests, distribution trend and nesting activity

A total of 349 nests were recorded during the monitoring period 2011/12, inclusive of all turtle species. Within the Study Area, 769 beach activities (including nests, UNAs, U-tracks and Unidentified activities) were recorded over the 4 months of daily monitoring, from 1 November 2011 to 28 February 2012.

The Study Area was primarily visited by loggerhead turtles, which were responsible for 91% of total beach activities and 93% of nests recorded. Green turtles were also present in the area, with 7% of total beach activities and approximately 7% of recorded nests. Approximately 2% of total activities were unable to be identified by species due to track erosion by environmental conditions. All 349 nests recorded were able to be identified by species. **Percentages are rounded for discussion purposes; refer 'Results - Track monitoring' for exact figures**.

Nesting activities of loggerheads during the monitoring period 2011/12 commenced on 2 November 2011. Nesting reached its peak from 29 November 2011 until 24 January 2012, with an average of 33.6 nests per week during this period. Nests per week peaked between 27 December 2011 until 3 January 2012. A total of 12 nests were recorded on 3 January 2012, which was the highest of any monitoring day. The last nest was recorded on 22 February 2012.

A detailed comparison of total beach activities (nests, UNAs, U-tracks and Unidentified activities) from 2008/09 – 2011/12 can be found in Table 1.

Table 1: Total nesting activities in GBR during consecutive monitoring seasons, 2008/09 – 2011/12.

	2008/09	2009/10	2010/11	2011/12
Nest	336	522	421 (range 379 - 473)*	349 (range 290 - 402)*
UNA	365*	281*	216 (range 192 - 240)	282 (range 241 - 333)
U-track			157	127
Unidentified activity	15	22	26	11
Total activities	N/A	813	801	769

Notes:
1. *Ranges reflect error margins: 11% for 2010/11 and 16.13% for 2011/12.*
2. *A range is not presented for U-tracks for the season 2010/11 or 2011/12 because U-tracks were not misidentified between night and morning patrols during these seasons (refer GTCP Report 2010/11 and Chapter 'Data verification through night surveys 2011/12').*
3. *UNAs and U-tracks were recorded together as 'false crawls' during seasons 2008/09 and 2009/10, after which the GTCP adopted the UNA and U-track classifications.*

Nesting decreased by almost 19% throughout the entire GBR between season 2010-11 and the season 2011/12 (refer Table 2). In sub-section GBN – BP7, the number of loggerhead nests increased from the season 2010/11, while loggerhead nesting in the remaining two sub-sections (namely BP7 – BP8 and BP8 – BP9) decreased by as much as 27.69%.

Table 2: Loggerhead nest distribution per sub-section, 2010/11 – 2011/12.

	2010/11	2011/12	Percent change
Number of loggerhead (*Caretta caretta*) nests (GBN - BP7)	103	109	2.91%
Number of loggerhead (*Caretta caretta*) nests (BP7 - BP8)	36	27	- 22.86%
Number of loggerhead (*Caretta caretta*) nests (BP8 - BP9)	260	188	- 27.69%
All sub-sections	399*	324	- 18.80%

Note: *The GTCP Report 2010/11 lists 402 loggerhead nests for the season 2010/11, which includes nests located outside the Study Area 2010/11.*

Table 3 below shows the changes in distribution of total nesting activities (inclusive of all species) in each sub-section between seasons 2010/11 – 2011/12. The percent changes for each sub-section are very similar to the percent changes in loggerhead nesting activities (refer Table 2), indicating that changes in total nesting trends are driven primarily by loggerheads. While loggerhead presence has been formally documented on the Gnaraloo coastline since 2008, this analysis further supports the hypothesis that Gnaraloo supports a predominately loggerhead rookery.

Table 3: Nest distribution for all species per sub-section, 2010/11 – 2011/12.

	2010/11	2011/12	Percent change
Number of nests (GBN – BP7)	111	116	4.50%
Number of nests (BP7 – BP8)	40	31	- 22.50%
Number of nests (BP8 – BP9)	270	202	- 25.16%
All sub-sections	421*	349	- 17.10%

Note: *The GTCP Report 2010/11 lists 426 nests for that season, which includes nests located outside the Study Area 2010/11.*

5.6 Conclusion

Data collected during day monitoring activities in 2011/12 contributes to baseline data recorded by the GTCP since 2008/09 and broadens our understanding of Gnaraloo's sea turtles.

A total of 349 turtle nests, inclusive of all species, were recorded during the monitoring period from 1 November 2011 – 28 February 2012. Loggerheads (*Caretta caretta*) were the dominant species observed (93% of total nests). Greens (*Chelonia mydas*) accounted for the remaining 7% of nests during 2011/12, an increase from the 2% of total nests recorded during 2010/11.

As recorded during the season 2010/11, the sub-section BP8 – BP9 again received the highest density of loggerhead activities, with 58% of total loggerheads activities in the Study Area.

Analysis of changes in distribution of nests between 2010/11 and 2011/12 strongly suggests that the GBR supports a predominately loggerhead rookery.

6. GBR NIGHT SURVEYS FOR DATA VERIFICATION

6.1 Objectives

The objectives of night survey were as follows:

- Improve the knowledge and field observational skills of the GTCP field team members to correctly identify turtle species through tracks and to determine Nesting Activity (particularly the characteristics of nests vs. Unsuccessful Nesting Attempts (**UNAs**)), to increase the accuracy of day monitoring efforts;
- For 10 consecutive monitoring patrols, achieve 100% data correlation between the previous night's observations (based on sightings of actual turtles) and the following morning's species identification and determination of Nesting Activity solely through track interpretation.
- Determine the margin of error in species identification and Nesting Activity Determination through morning track surveys;
- Determine the species nesting within the survey area through visual identification.

Refer to the section titled 'Background' for more detailed information about the overall objectives of the GTCP.

6.2 Survey area

Night patrols during the season 2011/12 were undertaken in sub-section BP8 – BP9. This section had been selected by the GTCP research team 2010/11 as the most suitable area for night patrols due to the high density of turtle activities in previous seasons.

6.3 Materials and methods

Night patrol protocols were followed as set out in detail in the *GTCP Monitoring Procedure 2011/12* (Hattingh *et al.,* 2012). All night patrols were conducted on foot as driving is not allowed on any of the beaches at Gnaraloo.

The GTCP field team 2011/12 conducted night patrols in BP8 – BP9 of the GBR from 3 November 2011 – 1 February 2012.

The following night patrols were undertaken during the period of 3 November 2011 – 8 December 2011 to check the accuracy of species identification and Nesting Activity Determination:

- 3 November 2011 – 8 November 2011 (6 consecutive night patrols);
- 15 November 2011 – 2 December 2011 (18 consecutive night patrols); and
- 5 December 2011 – 8 December 2011 (4 consecutive night patrols).

Additional night patrols were undertaken during the period of 13 December 2011 – 1 February 2012 to ensure a continued high accuracy level of species identification and Nesting Activity Determination (4 night patrols in total were undertaken on 13 December 2011, 30 December 2011, 18 January 2012 and 1 February 2012).

Night patrols occurred between the hours 21h00 – 02h00; however, patrol length varied based on the number and behaviour of the turtles encountered during a particular patrol.

6.4 Results

6.4.1 Species identification

During the night patrols in the period from 3 November 2011 – 8 December 2011, a total of 37 turtles were observed in the survey area. One of these turtles created a U-track on the night of 30 November 2011 that was washed away by the tide before the morning patrol and the track was never recorded during the next morning's patrol. **For this reason, a total of 36 turtles observed for species identification correlation from 3 November 2011 – 8 December 2011 will be reflected through-out this report.** During the 4 additional night surveys another 7 turtles were observed.

The seasonal target of 100% positive correlation between night observations and the following morning's species identification by means of tracks for 10 consecutive monitoring patrols was achieved on the morning of 3 December 2011 (Table 5). Dr. Mark Hamann, School of Earth and Environmental Sciences, James Cook University (Queensland), confirmed that this constituted acceptable statistical proof of accurate species identification. By the morning patrol on 9 December 2011, 100% positive data correlation for species identification was achieved for 14 consecutive monitoring patrols.

Misidentification of species occurred twice during the morning patrols (Table 5). On 18 November 2011, a turtle correctly identified as a green turtle by the night team was misidentified as loggerhead by the day monitor. The second misidentification occurred on 21 November 2011, when the night team correctly identified a loggerhead that was later misidentified as a hawksbill by the day monitor.

Table 5: Data correlation of night and day species identification in GBR during the night patrol period, 03/11/2011 – 08/12/2011.

No. of data verification days	Day patrol dates	Night patrol data	Day patrol data	Species correlation
1	17/11/2011	L	L	✓
2	18/11/2011	L	L	✓
2	18/11/2011	G	L	×
3	19/11/2011	L	L	✓
3	19/11/2011	L	L	✓
4	21/11/2011	L	H	×
5	23/11/2011	L	L	✓
5	23/11/2011	L	L	✓
6	25/11/2011	L	L	✓
6	25/11/2011	L	L	✓
7	26/11/2011	L	L	✓
7	26/11/2011	L	L	✓
8	27/11/2011	L	L	✓
8	27/11/2011	L	L	✓
8	27/11/2011	L	L	✓
8	27/11/2011	L	L	✓
9	28/11/2011	L	L	✓
9	28/11/2011	L	L	✓
10	29/11/2011	L	L	✓
10	29/11/2011	L	L	✓
11	30/11/2011	L	L	✓
12	1/12/2011	L	L	✓
13	2/12/2011	L	L	✓
13	2/12/2011	L	L	✓
13	2/12/2011	L	L	✓
13	2/12/2011	L	L	✓
13	2/12/2011	L	L	✓
14	3/12/2011	L	L	✓
15	6/12/2011	L	L	✓
15	6/12/2011	L	L	✓
15	6/12/2011	L	L	✓
15	6/12/2011	L	L	✓

16	7/12/2011	G	G	✓
16	7/12/2011	L	L	✓
17	8/12/2011	L	L	✓
18	9/12/2011	L	L	✓

Note: *Night data is based on sightings of actual turtles and day data is based only on track interpretation. The grey shading denotes the first 10 consecutive monitoring patrols of 100% positive data correlation for species identification. Table entries only reflect night patrols when actual turtles were witnessed.*

The 100% positive data correlation for species identification continued during the four additional night patrols conducted later in the season, during the period of 13 December 2011 – 1 February 2012 (refer Table 6).

Table 6: Data correlation of night and day species identification in GBR during the night patrol period, 13/12/2011 – 01/02/2012.

No. of data verification days	Day Patrol dates	Night patrol data	Day patrol data	Species correlation
1	14/12/2011	G	G	✓
2	31/12/2011	L	L	✓
2	31/12/2011	L	L	✓
2	31/12/2011	L	L	✓
3	19/12/2011	G	G	✓
3	19/12/2011	L	L	✓
4	02/02/2012	L	L	✓

Note: *Night data is based on sightings of actual turtles and day data is based only on track interpretation.*

6.4.2 Nesting Activity Determination

During the night patrols in the period from 3 November 2011 – 1 February 2012, 44 turtles were observed in the survey area.

100% positive correlation between night observations and the following morning's Nesting Activity Determination was achieved on 23 out of the 28 night patrols between 3 November 2011 and 8 December 2011. 3 out of the 4 additional night surveys also attained 100% correlation. In total, from 3 November 2011 – 1 February 2012, 100% positive data correlation for nesting activity determination was achieved 25 out of the 32 night patrols (Table 7).

11 discrepancies between night observations and the following morning's Nesting Activity Determination occurred during this period (refer Table 7). A discrepancy does not

necessarily equate to a data error, for example, an Unidentified activity observed at night and recorded as a nest, UNA, U-track or Unidentified activity the following morning is not a data error. Vice versa, a nest, UNA, U-track or Unidentified activity observed at night and recorded as an Unidentified activity the following morning is not a data error.

Of the 11 discrepancies:

- 5 out of 23 nests observed at night were misidentified as UNAs during subsequent morning patrols;
- 1 out of 9 UNAs observed at night was misidentified as a U-track during the subsequent morning patrol;
- 3 out of 5 Unidentified activities observed at night were identified as nests during subsequent morning patrols;
- 1 out of 5 Unidentified activities observed at night was identified as a UNA during the subsequent morning patrol;
- 1 out of 5 Unidentified activities observed at night was identified as a U-track during the subsequent morning patrol.

1 Unidentified activity observed during night patrol on 20 November 2011 was also observed as an Unidentified activity during the subsequent morning patrol. This does not appear in Table 7 as there was not a discrepancy between the night and morning patrol. This Unidentified activity was also excluded from the margin of error calculations (refer Table 8).

Overall, the GTCP morning patrols during the survey period (3 November 2011 – 1 February 2012) accurately identified 18 out of 23 nests recorded by the night patrols.

Table 7: Discrepancies in Nesting Activity Determination in GBR during the night patrol period, 03/11/2011 – 01/02/2012.

Number of discrepancies	Day patrol date	Night patrol data	Day patrol data
1	27/11/2011	N (loggerhead)	UNA
2	27/11/2011	UNA (loggerhead)	U-track
3	28/11/2011	N (loggerhead)	UNA
4	28/11/2011	Unidentified activity (loggerhead)	UNA
5	2/12/2011	N (loggerhead)	UNA
6	2/12/2011	N	UNA

		(loggerhead)	
7	2/12/2011	Unidentified activity (loggerhead)	U-track
8	3/12/2011	Unidentified activity (loggerhead)	N
9	7/12/2011	Unidentified activity (green)	N
10	31/12/2011	N (loggerhead)	UNA
11	19/01/2011	Unidentified Activity (green)	N

Note: As a discrepancy does not necessarily equate to a data error, the 5 Unidentified activities during the night patrol period (3 November 2011 – 1 February 2012) in the above table were excluded from the accuracy calculations for nesting activity determination.

During 3 November 2011 – 8 December 2011, a total of 28 night patrols were undertaken. There was an 83.87% positive data correlation for Nesting Activity Determination for all activities (inclusive of nests, UNAs and U-tracks) (Table 8 and Figure 10).

Table 8: Accuracy of Nesting Activity Determination in GBR during the night patrol period, 03/11/2011 – 08/12/2011.

	No. turtles observed during night patrols	Correctly identified during day patrol	Accuracy of Nesting Activity Determination
Nests	20	16	80.00%
UNAs	8	7	87.50%
U-tracks	3	3	100.00%
All activities	31	26	83.87%

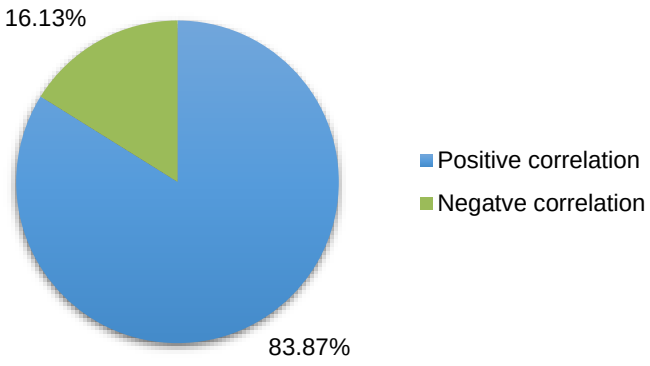

Figure 10: Correlation of Nesting Activity Determination in GBR during the night patrol period, 03/11/2011 – 08/12/2011.

During 13 December 2011 – 1 February 2012, 4 repeat night patrols total were undertaken. There was an 83.33% positive data correlation for Nesting Activity Determination for all activities (inclusive of nests, UNAs and U-tracks) (Table 9).

Table 9: Accuracy of Nesting Activity Determination in GBR during the night patrol period, 13/12/011 – 01/02/012.

	No. turtles observed during night patrols	Correctly identified during day patrol	Accuracy of Nesting Activity Determination
Nests	**3**	**2**	**66.66%**
UNAs	**1**	**1**	**100.00%**
U-tracks	**2**	**2**	**100.00%**
All activities	**6**	**5**	**83.33%**

Note: *While 7 turtles were observed in the survey area during the night patrol period (13/12/2011 – 01/02/2012), the 1 Unidentified activity during this period was excluded from the accuracy calculations for Nesting Activity Determination as it was not relevant to it.*

Given that 28 out of the 32 total night patrols were undertaken during 3 November 2011 – 8 December 2012, and only 4 night patrols were undertaken during 12 December 2011 – 1 February 2012, **the margin of error for Nesting Activity Determination of the former (+/-16.13%) is reflected through-out the report (refer to Discussion).**

6.5 Discussion

6.5.1 Species identification

After 14 data verification days in total, the GTCP researchers reached 100% data accuracy on species identification which is a critical component of the seasonal monitoring program. 100% positive correlation for 10 consecutive monitoring patrols between night observations and the following morning's species identification via track interpretation was achieved on the morning of 3 December 2011. The 100% positive data correlation for species identification continued for 14 consecutive monitoring patrols to the morning of 9 December 2011 as well as during the additional night surveys conducted between 13 December 2011 and 1 February 2012.

The two species identification errors made (a green identified as a loggerhead and a loggerhead identified as a hawksbill) could be attributed to inexperience in track identification by GTCP field researchers early in the season (mistakes were made on 18 November 2011 and 21 November 2011). Errors reduced dramatically as the season continued, suggesting a marked improvement in species identification within the first couple of weeks of monitoring efforts. Environmental factors such as strong winds, rainfall, high tides, crab disturbance, and mobile dunes also served to complicate morning track identification efforts.

Track quality also depended on the behaviour of turtles during the previous night. During the nesting process in the season 2011/12, turtles were observed at times to travel back over their own tracks or other turtles' tracks, attempt to climb steep and collapsing sand dunes, move through soft sand and uproot beach vegetation. All of these activities decreased the amount of track evidence remaining for the following morning, further complicating interpretation.

6.5.2 Nesting Activity Determination

The target set at the beginning of the season 2011/12 of 100% positive correlation between night observations and the following morning's nesting activity determination was not achieved. During the beginning of the season, an 83.87% positive data correlation (error margin of +/-16.13%) for Nesting Activity Determination was achieved on the morning of 9 December 2011. During the night patrol period (3 November 2011 – 8 December 2011), there were 5 out of 28 patrols without 100% positive data correlation.

The GTCP team 2011/12 sought advice from Dr. Mark Hamann regarding the early error margin for Nesting Activity Determination. Dr. Haman confirmed that it was a reasonable benchmark and that it was important that the margin of error had been quantified and recommended additional night patrols during the mid and late season to obtain a more comprehensive data set on Nesting Activity Determination at the Gnaraloo rookeries. The additional 4 night patrols aided in achieving an 83.33% positive data correlation for

Nesting Activity Determination (error margin of +/-16.67%). When compared, there was only a 0.54% difference between the margin of error during the beginning of the season (+/-16.13%) and that during the mid to late season (+/-16.67%). The margin of error for Nesting Activity Determination of the former (+/-16.13%) has been reflected through-out the report.

Accurate Nesting Activity Determination depends on an individual monitor's knowledge, field observational skills and previous turtle track experience. This determination also depends on environmental conditions such as strong prevalent winds, rainfall, high tides, crab disturbance and collapsing sand dunes - all which reduce a monitor's ability to accurately determine nesting activity.

Regarding the difficulties posed by working in areas with strong prevalent winds such as the GBR, adjusting the morning patrol schedule to start earlier in the morning (patrols currently commence on-beach at sunrise) would not address the difficulty of accurate nesting activity determination. Prevalent winds occur at all times at Gnaraloo Bay and are not restricted to daylight hours, therefore monitoring at an earlier time would not be beneficial as there is no guarantee that winds did not occur throughout the night.

The GBR is predominately a loggerhead rookery. Loggerhead nests are often smaller and less conspicuous than those of greens, making them more difficult to identify, even for experienced researchers. It is common for a loggerhead nest to closely resemble a UNA, which could explain why the most frequent mistake was a nest identified as a UNA. Further, all the GTCP researchers 2011/12 were field scientists with limited turtle track experience, ranging from no previous turtle track experience to only two prior years of experience. The training that the GTCP team received in Exmouth at the start of the season 2011/12 focused predominately on the interpretation of green turtle tracks and nests, not loggerheads.

The morning patrols accurately identified 18 out of 23 nests recorded during the night patrol period (3 November 2011 – 1 February 2012). The 5 nests misidentified as UNAs during the day could indicate that the total nest numbers in the GBR may have been underestimated for the season 2011/12.

The UNA identified as a U-track during the day is not factually incorrect and therefore not of concern. The 5 Unidentified activities that were identified as either nests, a UNA or a U-track during the day could be correct and could not be determined without observing a hatching event or excavating the nest later during the season. All the discrepancies identified during the survey period fall in the category of conservative errors or estimates and are therefore not considered significant in terms of the overall data set for Nesting Activity Determination.

By conducting frequent night patrols at the beginning of a monitoring season, a margin of error is provided for the period of least confidence and experience of the GTCP field researchers. A margin of error from continued night monitoring throughout the season

would theoretically be reduced as the field observational skills and level of accuracy in the GTCP field team increased.

There will always be a degree of uncertainty in Nesting Activity Determination during morning patrols when the turtle was not seen during the previous night because GTCP field researchers were not permitted to dig into suspected nests to confirm the presence of egg chambers.

6.6 Conclusion

Accuracy in species identification is vital for the integrity of data analysis, conclusions drawn and management recommendations made for the GBR. The GTCP field researchers reached 100% data accuracy on species identification for 10 consecutive days after 14 data verification days in total. The GTCP team 2011/12 achieved 100% data correlation for species identification for 10 consecutive monitoring patrols on the morning of 3 December 2011 and this accuracy was maintained throughout night patrols to the morning of 9 December 2011 and during additional night patrols later during the season.

Quantification of the error margin in Nesting Activity Determination is critical for meaningful statistical analysis of turtle activity in the GBR.

The GTCP field team 2011/12 conducted 32 night patrols in total, including 28 night patrols during the night patrol period (3 November 2011 – 8 December 2011, beginning of the season) plus 4 additional night patrols (13 December 2011 – 1 February 2012, mid to late season).

The GTCP researchers achieved an 83.87% positive correlation for Nesting Activity Determination for the season 2011/12. The 16.13% margin of error could indicate that the number of nests calculated in the GBR is an underestimate.

7. GBR SAMPLED NEST SURVEYS

7.1 Objectives

The objectives of monitoring a sub-set of Sampled Nests in the GBR were as follows:

- Provide an efficient way to monitor impacts on all nests in the GBR by monitoring a representative sample;
- Record all predator impacts (native and introduced species) on Sampled Nests;
- Record all environmental impacts on Sampled Nests;
- Record all hatching events of Sampled Nests when possible;
- Investigate whether nests in particular sub-sections or horizontal beach zones of the GBR experience more environmental impacts than others; and
- Extrapolate data from Sampled Nests to understand impacts on all nests in the GBR.

Refer to the section titled 'Background' for more detailed information about the overall objectives of the GTCP.

7.2 Study Area

Sampled Nests were distributed throughout the GBR (approximately 6.7 km; refer Maps), located between -23.76708° / 113.54585° (**GBN**) and -23.72195° / 113.57750° (**BP9**).

7.3 Rationale

The GTCP Report 2010/11 (pages 74 – 75) recommended that:

'*...If nests are to be closely monitored during 2011/12 for factors such as predator impact, environmental damages and hatching success, it is strongly advised to select a sample of nests and to mark only these with semi-permanent structures, which would not be affected by tides, sand drift and/or strong winds (e.g. 2m wooden stakes buried 1m deep in the sand). It is advised that metal structures not be used as nest markers'.*

A sample set of up to 80 nests recorded at the GBR was selected for monitoring during 2011/12 for predator impact, environmental damage and hatching events. Only nests dug by 22 December 2011 were selected as Sampled Nests to ensure they could be monitored for the entire length of the expected nest incubation period before the end of the field season on 28 February 2012. The mean incubation time for loggerhead nests recorded in the GBR is

approximately 69 days estimated over a 4 month period (November 2009, December 2009, January 2010 and February 2010), as reported in detail in the GTCP Report 2009/10.

In addition to the nests sampled before 22 December 2011, some nests were chosen for the sample set until 10 January 2012, which corresponded to the expected annual peak of the nesting period at the GBR (as determined by the 8-year trend analysis set out in the GTCP Report 2010/11). This allowed for a broader sample in which a temporal comparison would be possible (i.e. investigating predator and environment impacts and hatching events of nests recorded early in the season versus nest recorded in the middle of the season).

Sampled Nest selection ceased on 10 January 2012 even if the target number of 80 nests had not been reached, however a minimum number of 60 nests would be selected.

To determine how many nests in each of the 3 sub-sections in the GBR (namely GBN – BP7, BP7 – BP8 and BP8 – BP9) would be selected for the sample set 2011/12, the percentage of total nests from the season 2010/11 for each sub-section was calculated using loggerhead nest numbers from the season 2010/11. The 399 loggerhead nests from season 2010/11 were distributed as follows (percentages were rounded for ease of use):

- GBN – BP7: 104 (26%) nests;
- BP7 – BP8: 36 (9%) nests; and
- BP8 – BP9: 259 (65%) nests.

These percentages were used to determine how many out of the 80 Sampled Nests each sub-section in the survey area would receive:

- GBN – BP7: 21 Sampled Nests (0.26 x 80);
- BP7 – BP8: 7 Sampled Nests (0.09 X 80); and
- BP8 – BP9: 52 Sampled Nests (0.65 X 80).

It was also important to ensure that such nests were chosen at random to remove any selection bias on where the nest was located (both vertical and horizontal zonation). To do this, a random number generator (www.randomizer.org/form.htm) was used to select which nests would be sampled. The parameters for the random number generator were based on nest numbers during 2010/11. By 10 January 2011, 343 nests had been recorded in the GBR:

- GBN – BP7: 89 nests;
- BP7 – BP8: 31 nests; and
- BP8 – BP9: 223 nests.

These numbers were used as the maximum number parameter for the random number generator (the minimum number was set as 1). The amount chosen for each number generation was based on how many Sampled Nests would be chosen for that particular sub-section. The parameter that no number shall be repeated in the random number selection was set. After all the parameters were set, the random number generator selected the appropriate amount of nests within the minimum and maximum parameters.

7.4 Materials and methods

Equipment and methodology used for the Sampled Nest survey 2011/12 is set out in the *GTCP Monitoring Procedure 2011/12* (Hattingh *et al*., 2012)

All Sampled Nests were marked with 2m wooden stakes to ensure maximum visibility by monitors, withstand being buried by the shifting sand dunes in the GBR and to allow for consistent monitoring every morning.

Sampled Nests in the GBR were monitored every day from 10 November 2011 – 28 February 2012 during the standard morning period (refer to Chapter 'GBR Day Track Surveys') to record evidence of the following:

- predator impacts;
- environmental impacts; and
- any hatching events. If hatchlings were observed, data were recorded on hatchling numbers, species, the number predated (and the predator type) and the number of hatchlings that reached the water.

7.5 Results

Sampled nests were selected and marked throughout the period 10 November 2011 – 10 January 2012. A subset of 65 nests in the GBR was randomly selected as a representative sample for all nests in the GBR:

- GBN – BP7 (20 Sampled Nests);
- BP7 – BP8 (6 Sampled Nests); and
- BP8 – BP9 (39 Sampled Nests).

Sampled Nests were distributed throughout the 4 horizontal zones of the beach (refer Table 10):

- Inter-tidal zone (**I**) includes the area between the water's edge and below the high water mark;

- High water zone (**H**) includes the area between the high-water mark and the edge of vegetation;
- Edge of vegetation zone (**E**) includes the area between the edge of vegetation and the base of the foredune; and
- Dune zone (**D**) includes the area from the base of the foredune and beyond.

Table 10: Sampled Nests per sub-section in GBR, 10/11/2011 – 10/01/2012.

	GBN – BP7	BP7 – BP8	BP8 – BP9	Total
Inter-tidal (**I**)	0 (0%)	2 (3%)	0 (0%)	2 (3%)
High water (**H**)	11 (17%)	2 (3%)	17 (26%)	30 (46%)
Edge of vegetation (**E**)	5 (8%)	1 (2%)	15 (23%)	21 (32%)
Dune (**D**)	4 (6%)	1 (2%)	7 (11%)	12 (19%)
Total number of Sampled Nests	20 (31%)	6 (9%)	39 (60%)	65 (100%)

Note: *Percentages in the table were rounded for ease of use, therefore columns and rows may not add to equal column and row totals.*

Of the 65 nests sampled in the GBR, 59 (90.77%) were loggerhead nests and 6 (9.23%) were green nests (refer Table 11).

Table 11: Species composition of Sampled Nests in GBR, 10/11/2011 – 10/01/2012.

	GBN – BP7	BP7 – BP8	BP8 – BP9	Total
Loggerhead (*Caretta caretta*)	19 (29%)	6 (9%)	34 (52%)	59 (91%)
Green (*Chelonia mydas*)	1 (2%)	0 (0%)	5 (8%)	6 (9%)
Total number of Sampled Nests	20 (31%)	6 (9%)	39 (60%)	65 (100%)

Note: *Percentages in the table were rounded for ease of use, therefore columns and rows may not add to equal column and row totals.*

The Sampled Nests were monitored for predator impacts, environmental impacts and hatching events from 10 November 2011 – 28 February 2012, the end of the monitoring period 2011/12.

7.5.1 Crab impacts on Sampled Nests

The Sampled Nests were monitored for crab impacts from 10 November 2011 – 28 February 2012, the end of the monitoring period 2011/12.

The golden ghost crab (*Ocypode convexa*) and the running ghost crab (*Ocypode ceratophthalma*) were observed burrowing on the beaches of the GBR throughout the season (refer Photo plates). During the season 2011/12 and past GTCP monitoring seasons, both of these species have been observed to prey on either turtle eggs or hatchlings.

Other species of crabs were also observed in the GBR during the season 2011/12, including (refer Photo plates):

- tropical shore crab (*Grapsus albolineatus*) (mostly in the inter-tidal zone); and
- two other crab species that could not be identified (observed in all horizontal beach zones).

Whilst the two unidentified crab species were observed to burrow near turtle nests in the GBR during 2011/12, it remains unknown whether these and the *Grapsus albolieatus* prey on turtle nests or hatchlings.

Disturbance and predation by crabs were recorded separately (refer Glossary). However, as excavations of turtle nests could not be undertaken as part of the scope of work of the GTCP during the seasons 2008/09 – 2011/12, it cannot be determined with certainty by observation alone whether a crab burrow successfully reached an egg chamber, or, without the evidence of eggshells on the surface of the nest, whether the disturbance resulted in predation.

The number of crab burrows recorded for Sampled Nests at one time during the monitoring season 2011/12 ranged from 1 – 61 crab burrows per nest.

A total of 62 of the 65 Sampled Nests (95.38%) were impacted by crabs during the monitoring season 2011/12 (refer Figure 11):

- 62 (95.38%) were disturbed by crabs; and
- 33 (50.77%) were predated by crabs.

Only 3 of the 65 Sampled Nests (4.62%) were not disturbed or predated by crabs during the monitoring season 2011/12.

Disturbance includes predation, therefore percentages do not add to 100% as nests that were predated by crabs must also have been disturbed by crabs.

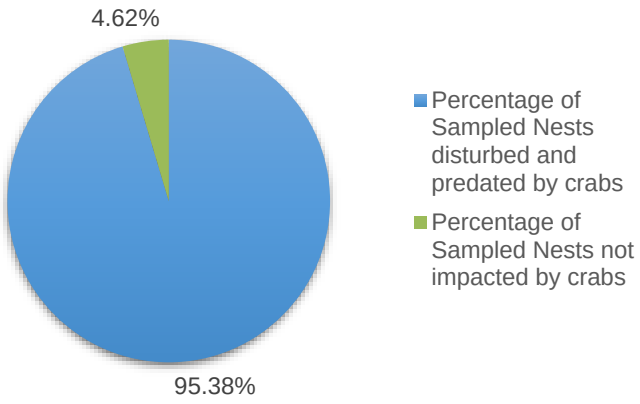

Figure 11: Percentage of Sampled Nests disturbed and predated by crabs in GBR, 10/11/2011 – 28/02/2012.

Crabs disturbed and predated 61 out of 64 (95.31%) sampled loggerhead nests (refer Figure 12):

- 61 (82.43%) were disturbed by crabs; and
- 34 (53.13%) were predated by crabs.

6 out of 6 (100%) sampled green nests were disturbed and predated by crabs:

- 6 (100%) were disturbed by crabs; and
- 1 (16.67%) was predated by crabs.

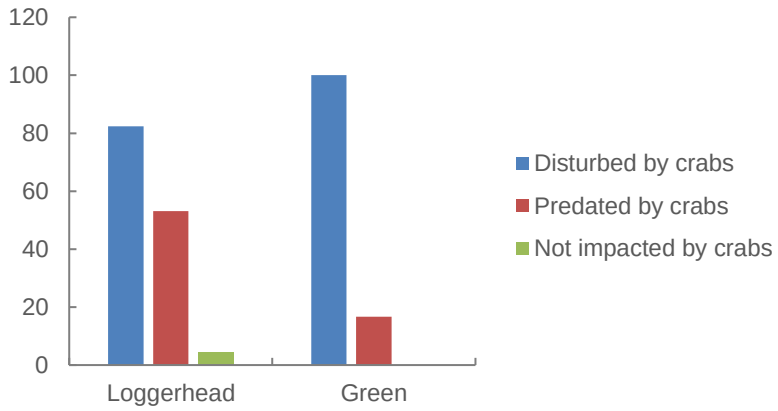

Figure 12: Percentage of Sampled Nests per species impacted by crabs in GBR, 10/11/2011 – 28/02/2012.

Note: *Disturbance shown in the figure includes predation, therefore percentages do not add to 100% per species as nests predated by crabs must also have been disturbed by crabs.*

The following section provides data on crab impacts on Sampled Nests in particular sub-sections of the GBR.

In sub-section GBN – BP7, 20 of the 20 (100%) Sampled Nests were impacted by crabs (refer Figure 13):

- 20 (100%) were disturbed by crabs; and
- 11 (55%) were predated by crabs.

The beach profile in this sub-section is mostly flat and wave energy is low compared to other areas of the GBR.

In the sub-section BP7 – BP8, 5 of the 6 (83.33%) Sampled Nests were impacted by crabs:

- 5 (83.33%) were disturbed by crabs; and
- 5 (83.33%) were predated by crabs.

Some areas of this sub-section contain dynamic beaches and high wave energy.

In the sub-section BP8 – BP9, 38 of the 39 (97.44%) Sampled Nests were impacted by crabs:

- 38 (97.44%) were disturbed by crabs; and

- 17 (43.59%) were predated by crabs.

This sub-section predominantly contains dynamic beaches and locations with high wave energy.

Percentages do not add to 100% per sub-section as nests predated by crabs must also have been disturbed by crabs.

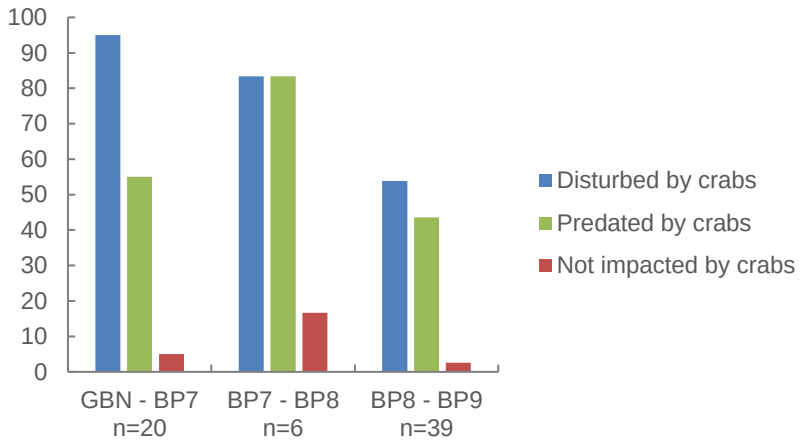

Figure 13: Percentage of Sampled Nests per sub-section impacted by crabs in GBR, 10/11/2011 – 28/02/2012.

Note: *Disturbance shown in the figure includes predation, therefore percentages do not add to 100% per sub-section as nests predated by crabs must also have been disturbed by crabs.*

The following section provides data on crab impacts on Sampled Nests in specific horizontal zones of the GBR.

In the I zone, 2 of the 2 (100%) sampled nests were impacted by crabs (refer Figure 14):

- 2 (100%) were disturbed by crabs; and
- 2 (100%) were predated by crabs.

In the H zone, 29 of the 30 (96.67%) sampled nests were impacted by crabs:

- 29 (96.67%) were disturbed by crabs; and
- 13 (43.33%) were predated by crabs.

In the E zone, 19 of the 21 (90.48%) Sampled Nests were impacted by crabs:

- 19 (90.48%) were disturbed by crabs; and

- 12 (57.14%) were predated by crabs.

In the D zone, 12 of the 12 (100%) Sampled Nests were impacted by crabs:

- 12 (100%) were disturbed by crabs; and
- 6 (50%) were predated by crabs.

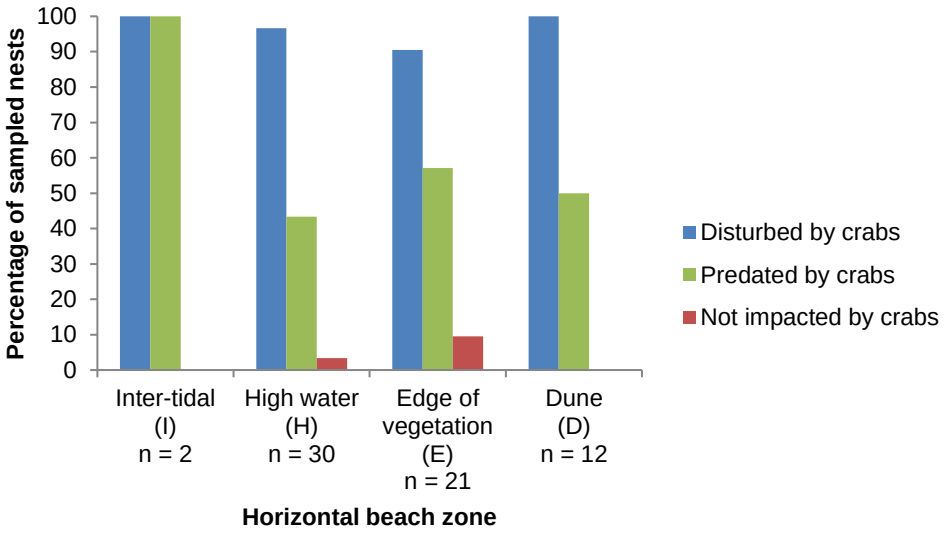

Figure 14: Percentage of Sampled Nests per horizontal beach zone impacted by crabs in GBR, 10/11/2011 – 28/02/2012.

Note: *Percentages do not add to 100% per horizontal beach zone as nests predated by crabs must also have been disturbed by crabs.*

7.5.2 Fox impacts on Sampled Nests

The Sampled Nest set in the GBR was monitored for fox impacts from 10 November 2011 – 28 February 2012, the end of the monitoring period 2011/12.

The GTCP field team 2011/12 undertook daily monitoring of the GBR for any evidence of presence or activity by feral predators (including tracks, disturbance and predation) as part of the GTCP's adaptive management model and these results were provided to the Gnaraloo Feral Animal Control Program 2011/12 for immediate corrective action.

While cat, wild dog and fox tracks were recorded throughout the season, only fox activity is reported here as foxes have historically posed threats to turtles in the GBR.

During the season 2011/12, tracks of the European red fox (*Vulpes vulpes*) were observed 4 times during morning patrols of Sampled Nests, namely:

- GBN – BP7: 29 November 2011 and 9 December 2011; and
- BP7 – BP8: 15 February 2012 and 17 February 2012.

One of the fox tracks was recorded near a Sampled Nest in the sub-section BP7 – BP8.

No disturbance (including digging) or predation by foxes was recorded for any Sampled Nests in the GBR during the monitoring season 2011/12.

7.5.3 Environmental impacts on Sampled Nests

The Sampled Nest set in the GBR was monitored for environmental impacts from 10 November 2011 – 28 February 2012, the end of the monitoring period 2011/12. Four types of environmental impacts were recorded on Sampled Nests, namely shifting dune suffocation, shifting dune erosion, tidal flooding, and tidal erosion (refer Glossary).

There was one major cyclone event. On 31 January 2012, Cyclone Iggy passed by the Gnaraloo coastline approximately 500 km offshore. While this event did not result in significant rain or wind at the GBR, high wave energy and unusually high tides were recorded on the beaches of the GBR from 27 January 2012 – 1 February 2012. These high tides caused flooding or erosion to 32 of the 65 (49.23%) Sampled Nests and resulted in dramatic changes in beach profile due to sand erosion. Large escarpments were created on the dunes in the northern sub-sections of the GBR (BP7 – BP8 and BP8 – BP9), while reef rocks were exposed, creating a narrow beach profile in certain areas of the southern section (GBN – BP7).

Out of the 65 Sampled Nests, 40 (61.54%) were affected by one or more environmental impacts (refer Figure 15). 5 nests were eroded by shifting dunes; however, the loss of sand was not sufficient to uncover the egg chambers.

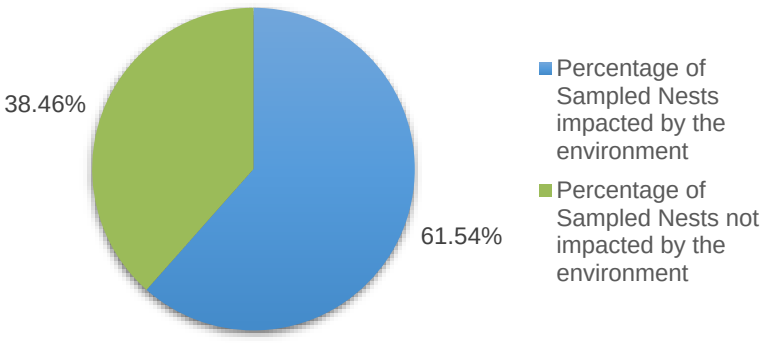

Figure 15: Percentage of Sampled Nests impacted by environmental conditions in GBR, 10/11/2011 – 28/02/2012.

Of the 65 Sampled Nests, 17 (26.15%) experienced impacts from shifting sand dunes because of strong prevalent winds in the GBR (refer Figure 16):

- 14 (21.54%) were suffocated by shifting dunes; and
- 5 (7.69%) were eroded by shifting dunes.

48 (73.85%) of the 65 Sampled Nests were not affected by shifting dunes.

Percentages do not add to 100% because a nest could be both suffocated and eroded by shifting dunes at different periods during the season. During the season 2011/12, 2 of the 65 Sampled Nests experienced suffocation and erosion, both in sub-section GBN – BP7 in the H zone.

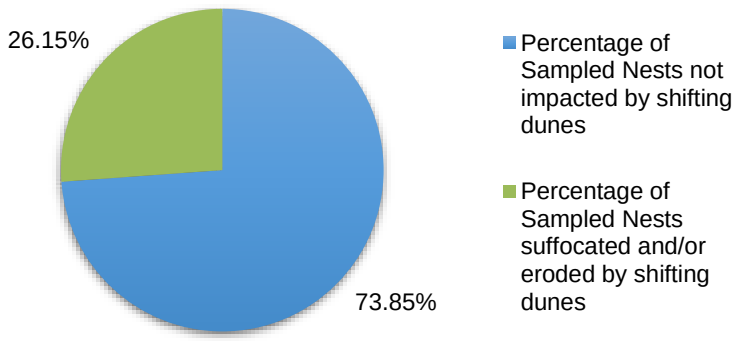

Figure 16: Percentage of Sampled Nests impacted by shifting dunes in GBR, 10/11/2011 – 28/02/2012.

Tidal fluctuations impacted 32 (49.23%) of the 65 Sampled Nests (refer Figure 17):

- 32 (49.23%) were flooded by tides; and
- 10 (15.38%) were eroded by tides.

Of the 65 Sampled Nests, 26 (40%) were not impacted by tides. 10 nests were eroded by tides; however, the loss of sand was not necessarily sufficient to uncover the egg chambers. Sand escarpments through nest areas were counted as tidal erosion as was the loss of sampled nest stakes due to tides.

Flooding includes erosion, therefore percentages do not add to 100% due to the fact that nests that were eroded by tides must also have been flooded by tides.

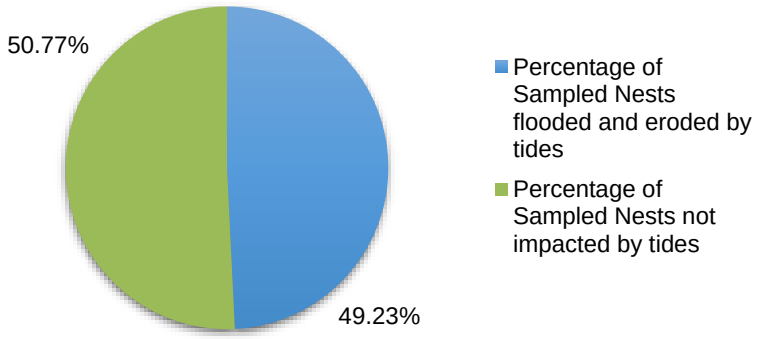

Figure 17: Percentage of Sampled Nests impacted by tides in GBR, 10/11/2011 – 28/02/2012.

The following section provides data on environmental impacts on Sampled Nests in particular sub-sections of the GBR.

The Sampled Nests in the three sub-sections in the GBR experienced different rates of impacts by the environment (refer Figure 18):

- In the sub-section GBN – BP7, 14 of the 20 (70%) Sampled Nests were impacted by environmental factors. The beach profile in this sub-section is mostly flat and wave energy is low compared to other areas of the GBR;
- In the sub-section BP7 – BP8, 4 of the 6 (66.67%) Sampled Nests were impacted by environmental factors. This sub-section contains dynamic beaches and high wave energy in some areas; and
- In the sub-section BP8 – BP9, 21 of the 39 (53.85%) Sampled Nests were impacted by environmental factors. This sub-section predominantly contains dynamic beaches and locations with high wave energy.

Environmental impacts include all shifting dune and tide impacts.

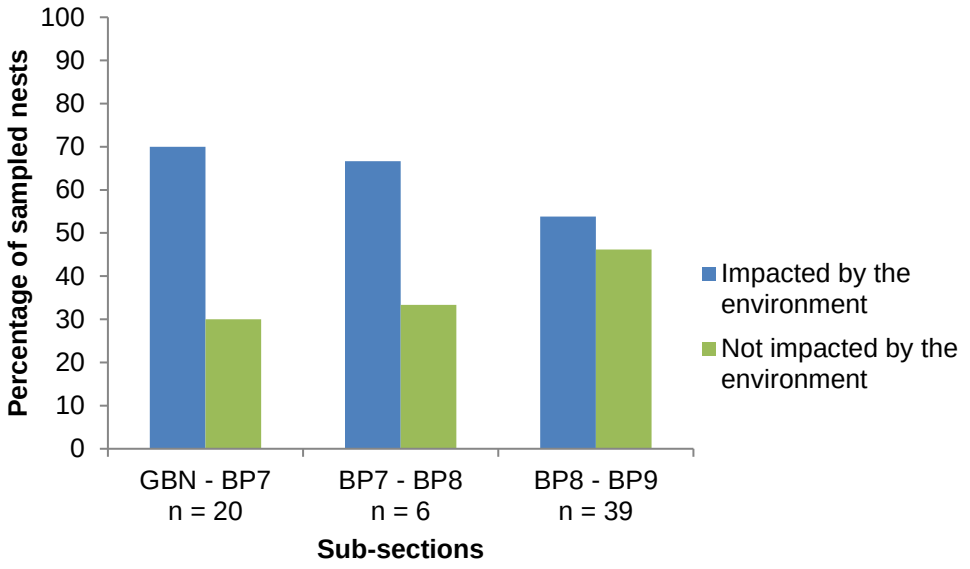

Figure 18: Percentage of Sampled Nests per sub-section impacted by environmental conditions in GBR, 10/11/2011 – 28/02/2012.

In the sub-section GBN – BP7, 7 of the 20 (35%) Sampled Nests were impacted by shifting dunes (refer Figure 19):

- 6 (30%) were suffocated by shifting dunes; and
- 3 (15%) were eroded by shifting dunes.

In the sub-section BP7 – BP8, 4 of the 6 (66.67%) Sampled Nests were impacted by shifting dunes:

- 3 (50%) were suffocated by shifting dunes; and
- 1 (16.67%) was eroded by shifting dunes.

In the sub-section BP8 – BP9, 6 of the 39 (15.38%) Sampled Nests were impacted by shifting dunes:

- 5 (12.82%) were suffocated by shifting dunes; and
- 1 (2.56%) was eroded by shifting dunes.

Percentages do not add to 100% per sub-section as a particular nest could be both suffocated and eroded by shifting dunes at different periods during the season.

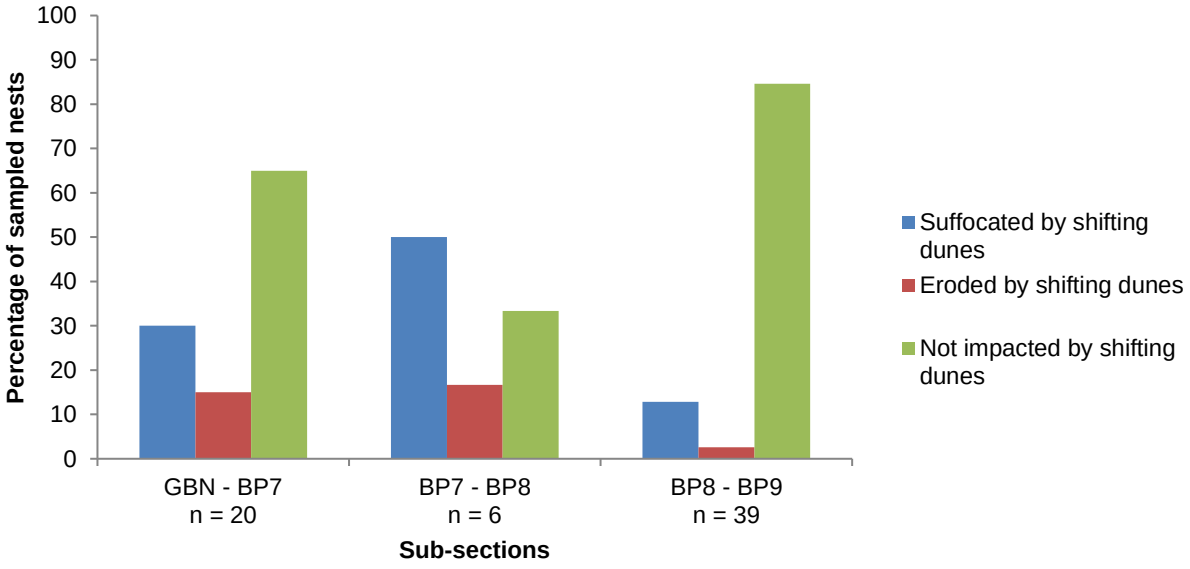

Figure 19: Percentage of Sampled Nests impacted by shifting dunes in each GBR sub-section, 10/11/2011 – 28/02/2012.

In GBN – BP7, 13 of the 20 (65%) Sampled Nests were impacted by tides (refer Figure 20):

- 13 (65%) were flooded by tides; and
- 6 (30%) were eroded by tides.

In BP7 – BP8, 2 of the 6 (33.33%) Sampled Nests were impacted by tides:

- 2 (33.33%) were flooded by tides; and
- 2 (33.33%) were eroded by tides.

In BP8 – BP9, 17 of the 39 (43.49%) Sampled Nests were impacted by tides:

- 17 (43.59%) were flooded by tides; and
- 2 (5.13%) were eroded by tides.

Percentages do not add to 100% per sub-section because nests that were eroded by tides must also have been flooded by tides.

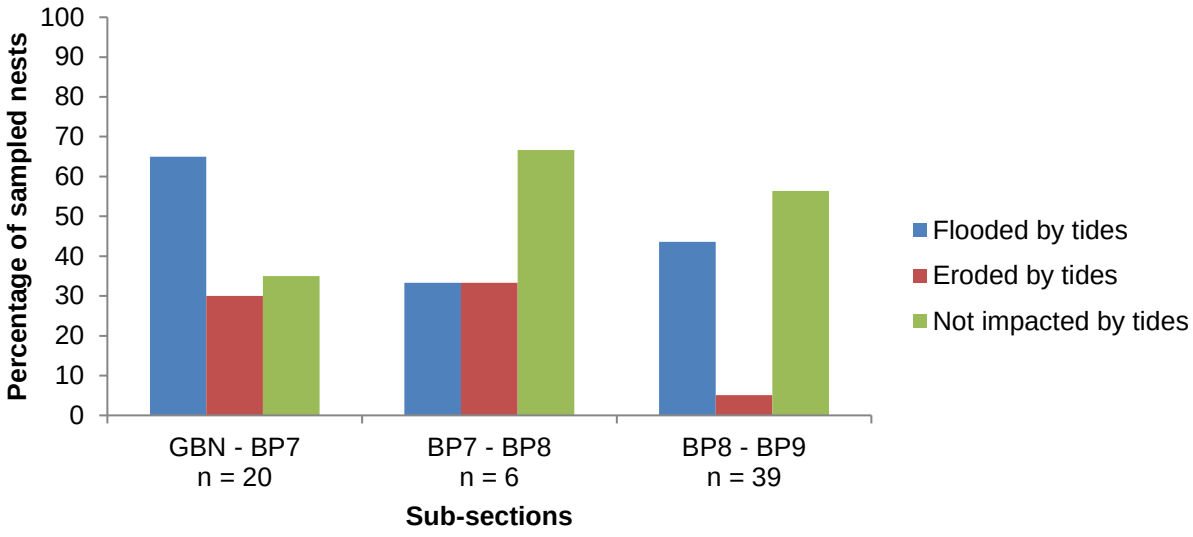

Figure 20: Percentage of Sampled Nests impacted by tides in each GBR sub-section, 10/11/2011 – 28/02/2012.

The following section provides data on environmental impacts on Sampled Nests in the different horizontal beach zones.

In the I zone, 2 of the 2 (100%) Sampled Nests were impacted by shifting dunes (refer Figure 21):

- 1 (50%) was suffocated by shifting dunes; and
- 1 (50%) was eroded by shifting dunes.

In the H zone, 8 of the 30 (26.67%) Sampled Nests were impacted by shifting dunes:

- 7 (23.33%) were suffocated by shifting dunes; and
- 3 (10%) were eroded by shifting dunes.

In the E zone, 4 of the 21 (19.05%) Sampled Nests were impacted by shifting dunes:

- 3 (14.29%) were suffocated by shifting dunes; and
- 1 (4.76%) was eroded by shifting dunes.

In the D zone, 3 of the 12 (25%) Sampled Nests were impacted by shifting dunes:

- 3 (25%) were suffocated by shifting dunes; and

- 0 (0%) were eroded by shifting dunes.

Percentages do not add to 100% per horizontal zone because a nest could be both suffocated and eroded by shifting dunes at different periods during the season.

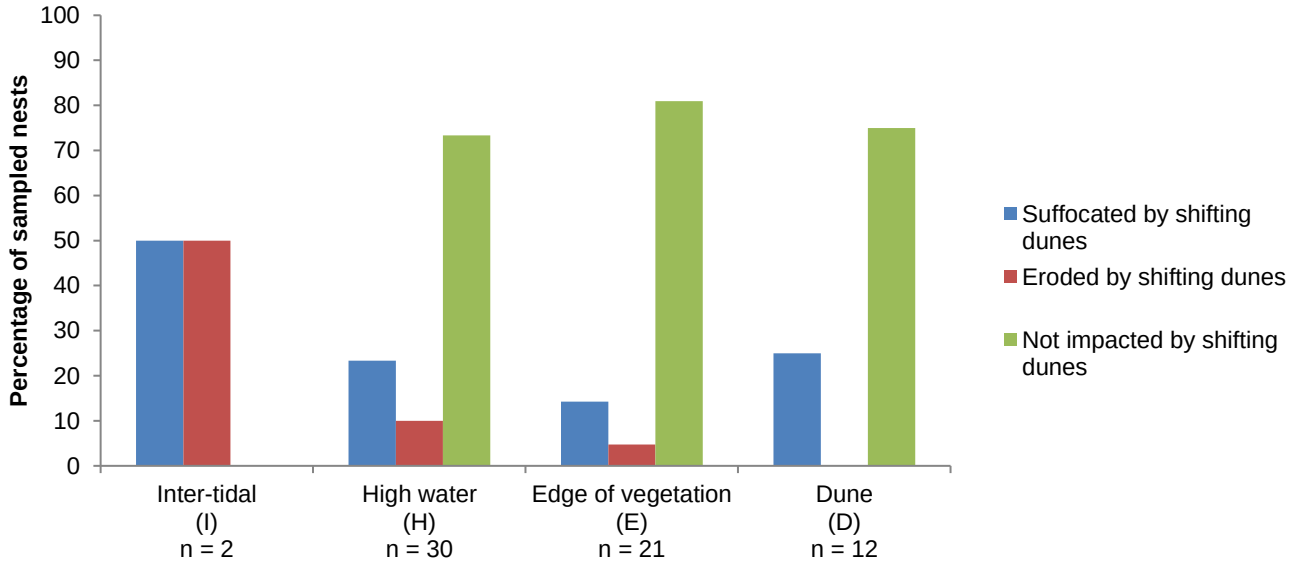

Figure 21: Percentage of Sampled Nests impacted by shifting dunes in each horizontal beach zone of the GBR, 10/11/2011 – 28/02/2012.

In the I zone, 2 of the 2 (100%) Sampled Nests were impacted by tides (refer figure 22):

- 2 (100%) were flooded by tides; and
- 2 (100%) were eroded by tides.

In the H zone, 23 of the 30 (76.67%) Sampled Nests were impacted by tides:

- 23 (76.67%) were flooded by tides; and
- 8 (26.67%) were eroded by tides.

In the E zone, 5 of the 21 (23.81%) Sampled Nests were impacted by tides:

- 5 (23.81%) were flooded by tides; and
- 0 (0%) were eroded by tides.

In the D zone, 3 of the 12 (25%) Sampled Nests were impacted by tides:

- 3 (25%) were flooded by tides; and
- 0 (0%) were eroded by tides.

Flooding includes erosion, therefore percentages do not add to 100% per horizontal beach zone due to the fact that nests that were eroded by tides must also have been flooded by tides.

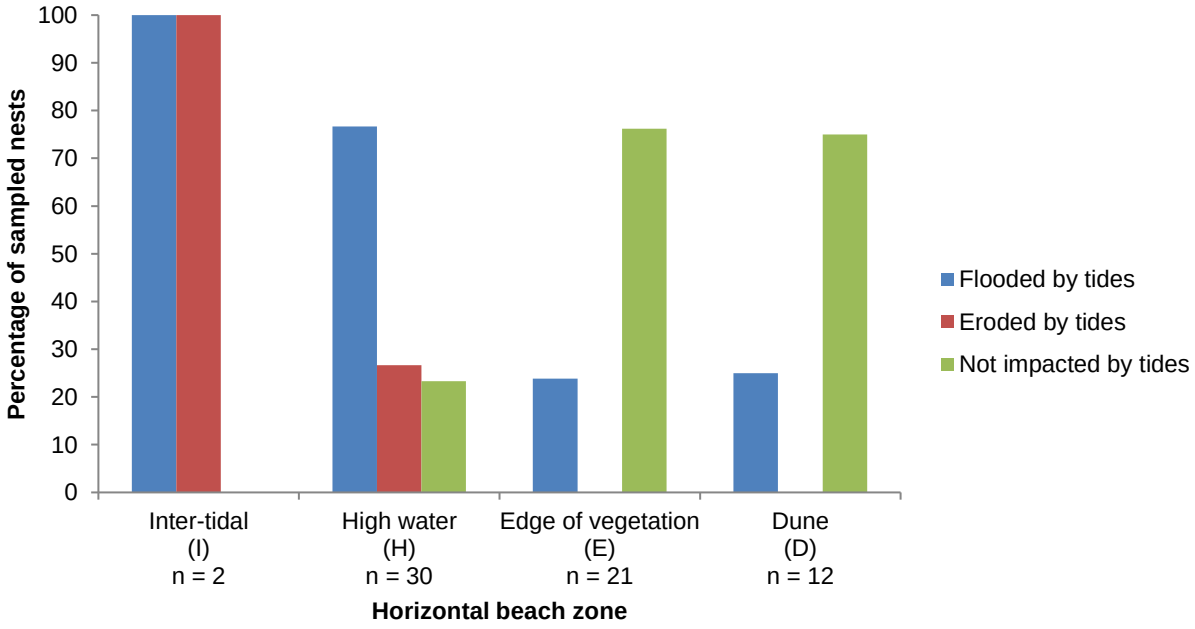

Figure 22: Percentage of Sampled Nests impacted by tides in each horizontal beach zone of the GBR, 10/11/2011 – 28/02/2012.

7.5.4 Hatching events of Sampled Nests

The Sampled Nest set in the GBR was monitored for hatching events from 10 November 2011 – 28 February 2012, the end of the monitoring period 2011/12.

Hatching events included live emerged hatchlings, hatchling tracks out of nests and dead emerged hatchlings nests. Out of 65 Sampled Nests (refer Figure 23):

- 5 (7.69%) were observed to have hatched; and
- 60 (92.31%) were not observed to hatch.

A depression was observed on 8 (12.31%) nests, but were not witnessed to have hatched (refer Glossary).

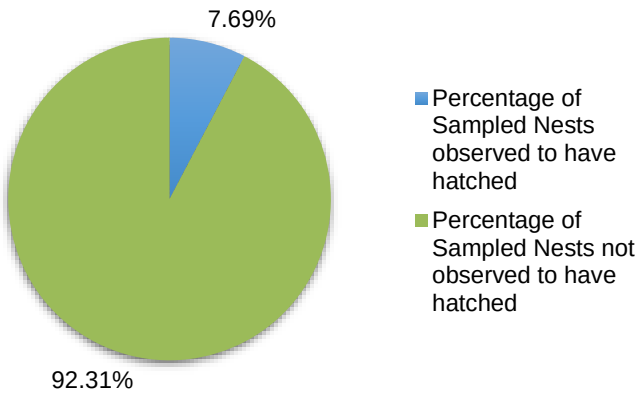

Figure 23: Percentage of Sampled Nests with evidence of hatching observed in GBR during monitoring period, 10/11/2011 – 28/02/2012.

Out of the 5 nests that were observed to have hatched, 2 (40%) experienced some predator and/or environmental impact throughout the incubation period (refer Figure 24):

- 2 (40%) were impacted by crabs;
- 0 (0%) were impacted by shifting dunes; and
- 1 (20%) was impacted by tides.

Of the 60 nests that were not observed to have hatched, 60 (100%) experienced some predator and/or environmental impact during the monitoring period:

- 60 (100%) were impacted by crabs;
- 14 (23.33%) were impacted by shifting dunes; and
- 31 (51.67%) were impacted by tides.

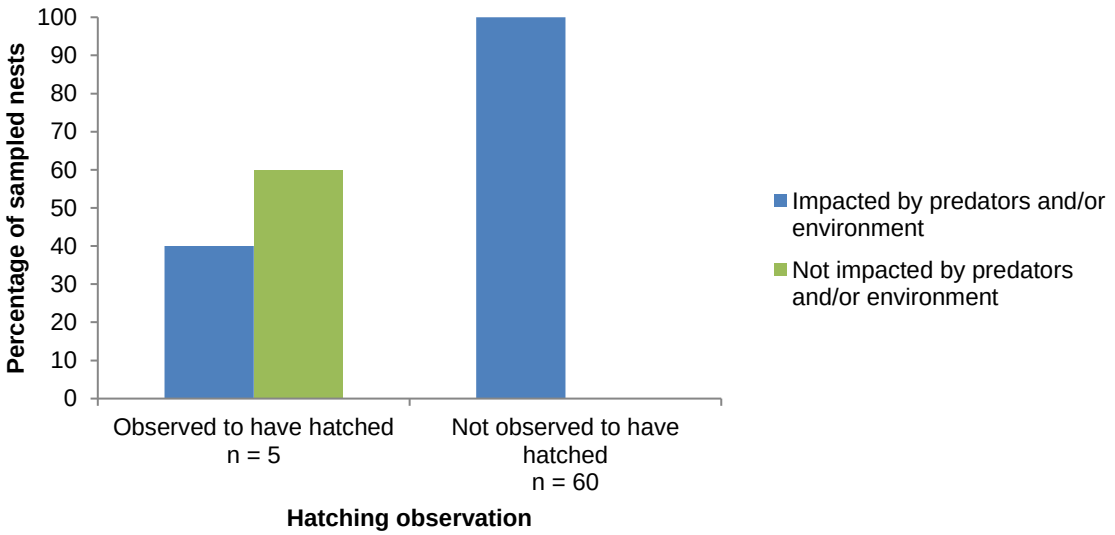

Figure 24: Percentage of Sampled Nests impacted by predators and/or environmental conditions per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

Note: *Predator and environmental impacts include all impacts by crabs, shifting dunes and tides. Nests could be both impacted by predators and impacted by the environment at different periods during the season.*

2 of the 5 (40%) Sampled Nests that were observed to have hatched were impacted by crabs throughout the incubation period (refer Figure 25):

- 2 (40%) were disturbed by crabs; and
- 0 (0%) were predated by crabs.

60 of the 60 (100%) Sampled Nests that were not observed to have hatched during the monitoring period were impacted by crabs:

- 60 (100%) were disturbed by crabs; and
- 33 (55%) were predated by crabs.

Percentages do not add to 100% per hatching observation as nests predated by crabs must also have been disturbed by crabs.

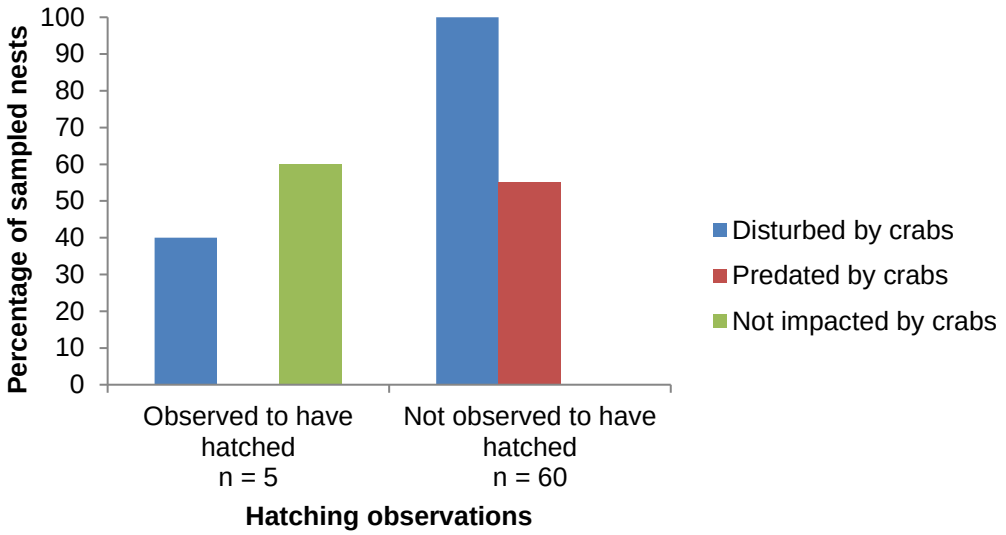

Figure 25: Percentage of Sampled Nests impacted by crabs per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

1 of the 5 (20%) Sampled Nests that were observed to have hatched experienced environmental impacts (refer Figure 26).

38 of the 60 (63.33%) Sampled Nests that were not observed to have hatched experienced environmental impacts.

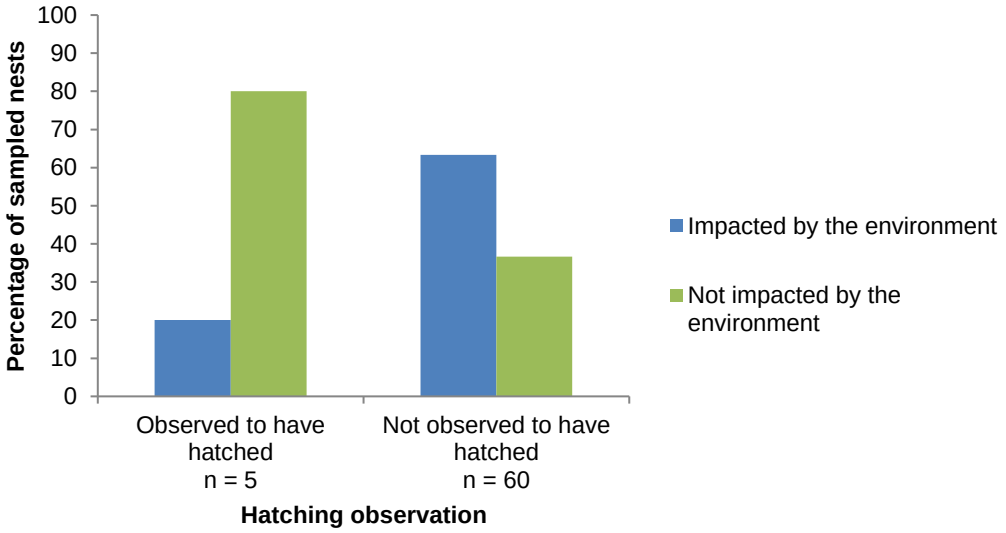

Figure 26: Percentage of Sampled Nests impacted by environmental conditions per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

0 of the 5 (0%) Sampled Nests that were observed to have hatched experienced impacts by shifting dunes.

14 of the 60 (23.33%) Sampled Nests that were not observed to have hatched during the monitoring period were impacted by shifting dunes (refer Figure 27):

- 14 (23.33%) were suffocated by shifting dunes; and
- 5 (8.33%) were eroded by shifting dunes.

Percentages do not add to 100% per hatching event as a particular nest could be both suffocated and eroded by shifting dunes at different periods during the season.

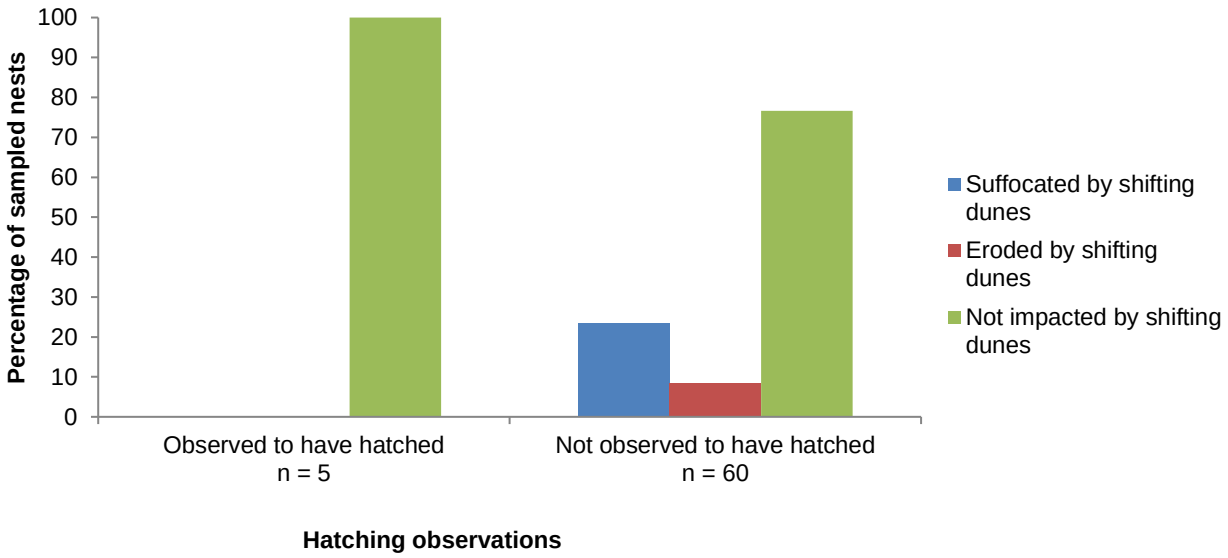

Figure 27: Percentage of Sampled Nests impacted by shifting dunes per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

1 of the 5 (20%) Sampled Nests that were observed to have hatched experienced impacts by tides (refer Figure 28):

- 1 (20%) was flooded by tides; and
- 0 (0%) were eroded by tides.

31 of the 60 (51.67%) Sampled Nests that were not observed to have hatched during the monitoring period were impacted by tides:

- 31 (51.67%) were flooded by tides; and
- 10 (16.67%) were eroded by tides.

Flooding includes erosion, therefore percentages do not add to 100% per hatching observation due to the fact that nests that were eroded by tides must also have been flooded by tides.

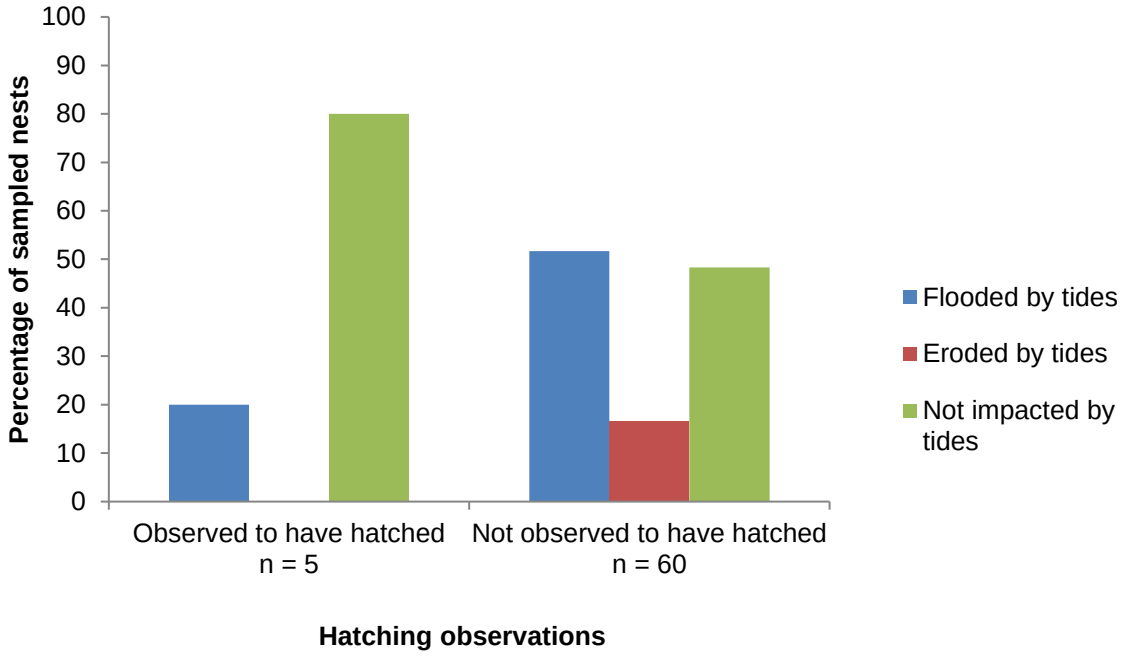

Figure 28: Percentage of Sampled Nests impacted by tides per hatching observation in GBR during monitoring period, 10/11/2011 – 28/02/2012.

7.6 Discussion

7.6.1 Crab impacts on Sampled Nests

Throughout the monitoring season 2011/12, different crab species were observed in the GBR. Of these observed species, golden ghost crabs were observed to predate turtle eggs and hatchlings and running ghost crabs were observed to predate turtle hatchlings.

Both golden ghost crabs and running ghost crabs were observed actively burrowing into turtle nests; however, golden ghost crabs were more frequently observed burrowing into turtle nests. Running ghost crabs were not observed predating turtle eggs. More observation is necessary to determine if this species does in fact predate turtle nests during incubation. Further investigation is also required concerning the relationship, if

any, between the other identified crab species and turtle nests and/or hatchlings in the GBR.

Disturbance of nests by crabs was recorded when at least one crab burrow was observed within a 1 m radius of the nest area. Oftentimes, a dense cluster of crab burrows was observed, indicating that the crabs were most likely burrowing in the location of the egg chamber. When predated eggs or egg fragments were not observed near the burrow opening, it was unknown if the burrows indicated predation. For this reason, disturbance and predation were recorded as two separate events.

The high incidence of disturbance and predation of Sampled Nests in the GBR by crabs is higher than data recorded during the season 2010/11 (cumulatively 73% of nests). **Overall, 95.38% of Sampled Nests were either disturbed or predated in the Study Area 2011/12. Using the Sampled Nest set as a representative sample of all the nests along the entire length of the GBR, it is likely that 333 of the 349 nests dug in the GBR were either disturbed or predated by crabs**.

The proportion of Sampled Nests that were impacted by crabs was 100% in GBN – BP7, 83.33% in BP7 – BP8 and 97.44% in BP8 – BP9. Although crab burrow densities were highest in the middle and northern sub-sections of the GBR (i.e. from 1.2 km south of BP7 to BP9, refer Chapter 'GBR Crab surveys'), this does not correlate with the levels of crab disturbance and predation of Sampled Nests recorded throughout the Study Area.

It also does not appear that crabs disturb or predate nests at different rates in different horizontal zones (100 % in I, 96.67% in H, 90.48% in E and 100% in D) on the beach, even though crab burrow densities were highest in the I zone (refer Chapter 'GBR Crab surveys').

The proportion of green turtle nests disturbed or predated by crabs was similar to those of loggerhead turtles (100% and 95.31% respectively). Because the number of green turtle nests sampled in the survey was very low (6/65, 9.23%), it was impossible to determine if crabs preferentially burrow into green or loggerhead nests.

7.6.2 Fox impacts on Sampled Nests

Tracks of the European red fox (*Vulpes vulpes*) were only observed in the GBR on 4 occasions during the season 2011/12. Despite the presence of fox tracks, no Sampled Nests were disturbed or predated by foxes in the GBR during the monitoring season 2011/12. These results are primarily due to the success of the continued specialised Gnaraloo Feral Animal Control Program 2011/12.

7.6.3 Environmental impacts on Sampled Nests

Environmental factors impacted the majority of Sampled Nests (61.54%). If these results were extrapolated for the total number of nests recorded in the GBR during the monitoring

period 2011/12, 215 of the 349 nests were impacted by environmental conditions in some way.

Among the environmental impacts, tidal flooding was the most common impact recorded for Sampled Nests (49.23%). This equates to approximately 172 out of 349 nests impacted by tides in the entire GBR. Most often, nests located in the Inter-tidal and Supra-tidal zones of the beach experienced frequent tidal flooding and erosion (100% and 76.67% respectively). Shifting dunes resulting in erosion and suffocation did not affect the majority of nests (26.15%). It is estimated that shifting dunes impacted approximately 91 out of the 349 nests in the entire GBR.

While there was not a great difference in the percentage of Sampled Nests that were impacted by environmental conditions in the most southern and middle sub-section of the GBR (70% in GBN – BP7 and 66.67% in BP7 – BP8), fewer Sampled Nests (53.85%) were impacted by environmental conditions in the northern most sub-section, BP8 – BP9.

Interestingly, the Sampled Nests in sub-section GBN-BP7 were the most affected by environmental impacts. This is the calmest and most static section in the GBR, with low wave energy and a relatively stable beach profile. The frequency of tidal flooding and erosion observed here may be explained by the high percentage of Sampled Nests located in the H zone. Nests in this zone are more vulnerable to flooding and erosion by tides due to their close proximity to the water relative to nests in the E or D zones. In BP7 – BP8, the highest percentages of Sampled Nests were in the I and H zones, which would also explain the high number of environmental impacts. In contrast a smaller percentage of nests in the sub-section BP8 – BP9 were in either the I or H zones which might explain the lower percentage of nests that were impacted by environmental conditions.

During the season 2011/12, only one cyclonic event (Cyclone Iggy) was recorded. Whilst this event did not bring heavy rain or high winds to the Gnaraloo coastline, it did produce high wave energy and unusually high tides. These high tides subsequently washed over and eroded 49.23% of the Sampled Nests and created large sand escarpments on dunes in some areas of the GBR (namely sub-sections BP7 – BP8 and BP8 – BP9) which might have made it difficult for female sea turtles to climb the steep dune profile. Using the data collected on Sampled Nests, it is estimated that this event impacted about 172 out of the 349 of the nests in the entire GBR.

7.6.4 Hatching events of Sampled Nests

GTCP field researchers only observed evidence of hatching on 5 of the 65 (7.69%) Sampled Nests during the monitoring period 2011/12 (10/11/2011 – 28/02/2012). Although some nests were observed to have a depression, indicating imminent emergence, live hatchlings or tracks were never observed.

There are a variety of possible reasons for the low percentage of observed hatching events of Sampled Nests. Due to the fact that Sampled Nests were selected until 10

January 2012, some nests could not be monitored for an entire incubation period before the season concluded on 28 February 2012. It was determined during the season 2009/10 that loggerhead nests in the GBR took an average of 69 days to hatch over a 4-month period (November 2009, December 2009, January 2010 and February 2010), as reported in detail in the GTCP Report 2009/10. When applying this average to Sampled Nests chosen during the season 2011/12, only 47 of the 65 (72.31%) Sampled Nests would have incubated for 69 days before the cessation of monitoring activities on 28 February 2012. This leaves a potential 18 (27.69%) nests that did not have enough time to be observed to hatch. This would cause under-representation of the number of nests observed to hatch.

Another possible reason for the low observed hatch rate could be due to the high winds in the GBR. While a hatching event is usually detectable by a large hole in the nest area and emerging hatchling tracks, it is possible that these holes and tracks were covered by sand. Shifting sands could also cause a hatch hole to resemble a depression or a large crab burrow. This factor would also cause under-representation of the number of nests observed to have hatched.

Predator and environmental impacts could have prevented many Sampled Nests from hatching successfully. Crab predation, shifting dune suffocation, shifting dune erosion, tidal flooding and tidal erosion could damage an entire clutch of eggs by disturbing the egg chamber and its micro-climate. However, without performing nest excavations, it is not possible to know whether these predator and environmental impacts are solely responsible for the low hatching rate. Of the 5 nests observed to have hatched, 2 (40%) experienced some impact by crabs or the environment, indicating that these impacts do not always cause total loss of the clutch. 3 of the 5 (60%) nests that were observed to have hatched did not have any predator or environmental impact.

7.7 Conclusion

Crabs had a substantial impact on Sampled Nests in the GBR. Both golden ghost crabs (*Ocypode convexa*) and running ghost crabs (*Ocypode ceratophthalma*) were observed burrowing into turtle nests, however, only golden ghost crabs were observed to predate turtle eggs and hatchlings, while running ghost crabs were only observed to predate hatchlings. The majority of Sampled Nests (95.38%) were observed to be either disturbed or predated by crabs. Crabs did not seem to target nests in any particular sub-section of the Study Area or zone of the beach. Studies in the future should include nest excavations to better understand crab disturbance and predation of the turtle nests in the GBR.

Fox presence in the GBR was only recorded on 4 occasions during the monitoring season 2011/12. Despite the presence of fox tracks, no Sampled Nests were disturbed or predated by foxes. These results are due to the success of the continued Gnaraloo Feral Animal Control Program 2011/12. It is critical that this program be continued as a part of

the GTCP in future seasons to minimize the threat of fox disturbance and predation of turtle nests.

Environmental factors impacted 61.54% of the Sampled Nests in the GBR during the season 2011/12. The most common of these impacts were due to high tides causing flooding of nests. This was in part due to Cyclone Iggy, which was offshore of the Gnaraloo coast on 31 January 2012. While the cyclonic event did not produce heavy rain or high winds in the Gnaraloo coastline, it did cause unusually high tides from 27 January 2012 – 1 February 2012, which inundated and eroded 49.23% of the Sampled Nests.

Environmental conditions impacted the highest proportion of Sampled Nests in the southern most sub-section (GBN – BP7) (70%) and middle sub-section (BP7 – BP8) (66.67%) of the GBR. This was unexpected, considering that these sub-sections are calmer with more stable beach profiles than the northern most sub-section (BP8 – BP9), where only 53.85% of Sampled Nests were impacted by environmental conditions.

Very few of the Sampled Nests (7.69%) were observed to have hatched throughout the monitoring period. Some of the nests had not finished incubating before the cessation of monitoring activities. However, many of the nests that had sufficient time to hatch were still not observed to do so. This observed low hatch rate could be attributed to a combination of high winds, crab disturbance and predation, and environmental impacts such as flooding and suffocation. Excavations should take place during future seasons of the GTCP to investigate the extent to which these factors affect hatching success.

8. GBR CRAB SURVEYS

8.1 Objectives

The objectives of the crab surveys in the GBR during the monitoring period 2011/12 were as follows:

- Investigate the density and spatial distribution of crab burrows;
- Report on the vertical distribution and horizontal zonation of crab burrows;
- Investigate and identify the different crab species present;
- Add to the existing data from the inaugural GTCP crab surveys 2010/11.

Refer to the section titled 'Background' for more detailed information about the overall objectives of the GTCP.

8.2 Study Area

The crab surveys were carried out in the entire GBR (approximately 6.7 km; refer Maps), which is located between -23.76708°/113.54585° (**GBN**) and -23.72195°/113.57750° (**BP9**) and includes the sub-sections GBN – BP7 (approximately 2.35 km), BP7 – BP8 (1.63 km) and BP8 – BP9 (1.72 km).

8.3 Materials and methods

The GBR Crab surveys during 2011/12 followed the same protocol as the previous GTCP season 2010/11, namely 30 m^2 transects were surveyed every 200m along the entire GBR (i.e. from GBN – BP9).

Equipment and methodology used during the crab surveys are detailed in the *GTCP Monitoring Procedure 2011/12* (Hattingh *et al*., 2012).

The GBR Crab surveys were undertaken for part periods during 19 December 2011 – 19 February 2012. A total of 5 crab burrow surveys were undertaken on:

- 19 December 2011*;
- 5 January 2012;
- 20 January 2012;
- 4 February 2012; and

- 19 February 2012.

As occurred during the GTCP 2010/11, these dates are 15 calendar days apart except for the second which occurred 17 days after the first survey. The exact dates are different from the 5 crab burrow survey dates during 2010/11, but provide an insight into crab burrow density and distribution from early January to mid February.

* Due to inconsistencies in methodology (32 transects only) and issues with field data collection during the first survey, results from the crab survey undertaken on 19 December 2011 were not included in the results analysis provided below.

The final 4 crab burrow surveys consisted of 33 ($30m^2$) transects along the GBR. For these surveys:

- GBN – BP7 includes Transects 1 – 17;
- BP7 – BP8 includes Transects 18 – 25; and
- BP8 – BP9 includes Transects 26 – 33.

As done during the GTCP season 2010/11, the beach was divided into the following 3 horizontal zones for the crab surveys:

- Inter-tidal zone (**I**), which includes the area between the water's edge to below the high water mark;
- Supra-tidal zone (**S**), which includes the area between the high water mark to the base of the foredune; and
- Dune zone (**D**), which includes the area from the base of foredune and beyond.

Note that the other research for the GTCP season 2011/12 divided the beach into 4 horizontal zones: I, H, E (Edge of vegetation zone which includes the area between the edge of the vegetation to the base of the foredune) and D (refer Chapter 'GBR Sampled nest surveys').

The GBR Crab surveys 2011/12 were based on the GTCP Crab surveys from 2010/11, and the use of the 3 horizontal beach zones remained the same. However, the Supra-tidal (**S**) zone was incorrectly abbreviated 'H' during the GTCP Crab surveys 2010/11. According to the Ningaloo Turtle Program's (**NTP**) *Turtle Monitoring Field Guide* (ed. 6, 2007) (which the GTCP bases its horizontal beach zones on – refer Glossary), the H zone is defined as the area between the high water mark and the edge of vegetation. However, the GTCP Crab surveys 2010/11 used the abbreviation 'H' to describe the S zone which is the area between the high water mark and the base of the foredune. To avoid discrepancies in the use of the abbreviation 'H', the GBR Crab surveys 2011/12 defined the S zone as the area between the high water mark and the base of the foredune. This horizontal zone encompasses the High water ('H') zone and the Edge of vegetation ('**E**') zone as defined by the NTP. The H and E zones were combined to

create the S zone because the E zone was often very narrow or not present at all between the H and D zones.

All horizontal beach zones were not present in each transect, depending on beach profile and the changing position of the high water mark. Occasionally, the high water mark was at the base of the foredune, thus eliminating the S zone from the transect. In addition, the length of some transects did not always extend into the D zone depending on the width of the beach. If one of the three horizontal zones used for the GBR Crab surveys 2011/12 were not present in a particular transect, a dash mark was noted on the GTCP Crab surveys data sheet 2011/12 in lieu of a zero. Had zeros been recorded in beach zones not actually present in a particular transect, the average number of crab burrows over the 4 surveys for these sections would have been under-represented. Notes were taken if there were special conditions in a particular transect (i.e. rocky sections, turtle tracks from the previous night or staked Sampled Nests) which might result in a higher or lower number of crab burrows than expected.

It was not possible to make repeat transects in identical horizontal beach locations along the GBR during each of the 5 crab burrow surveys during 2011/12 due to the changing position of the high water mark. However, strict adherence to the crab survey protocols ensured that transect spacing vertically along the GBR was consistent at 200m intervals beginning at GBN during each survey.

8.4 Results

8.4.1 Density and vertical distribution of crab burrows in GBR

Crab burrows were found to be present all along the GBR, from GBN – BP9 during the 4 surveys (refer Figure 29 and Maps).

The number of crab burrows recorded per transect during each of the 4 surveys was averaged. Averages were obtained for corresponding transects (e.g. Transect 1 in each of the 4 surveys) even though the corresponding transects of each of the surveys may not have been in the exact same location.

Low crab burrow density was observed from GBN to approximately 1.4 km south of BP7, with an average range of 4 – 30 crab burrows per transect (refer Figure 29). The lowest density of crab burrows per transect in the GBR was observed in Transect 11 (approximately 1.4 km south of BP7) in sub-section GBN – BP7, with an average of 4 crab burrows.

The majority of crab burrows were observed from approximately 1.2 km south of BP7 to BP9, with an average range of 23 – 52 crab burrows per transect. The area from Transect 12 (approximately 1.2 km south of BP7) – Transect 18 (approximately 200 m north of BP7) respectively in sub-sections GBN – BP7 and BP7 – BP8 had the highest density of crab burrows per transect in the GBR with an average range of 30 – 52 crab burrows per

transect. The transect with the highest density of crab burrows per transect in the GBR was Transect 18, with an average of 52 crab burrows.

Numbers rounded for ease of use.

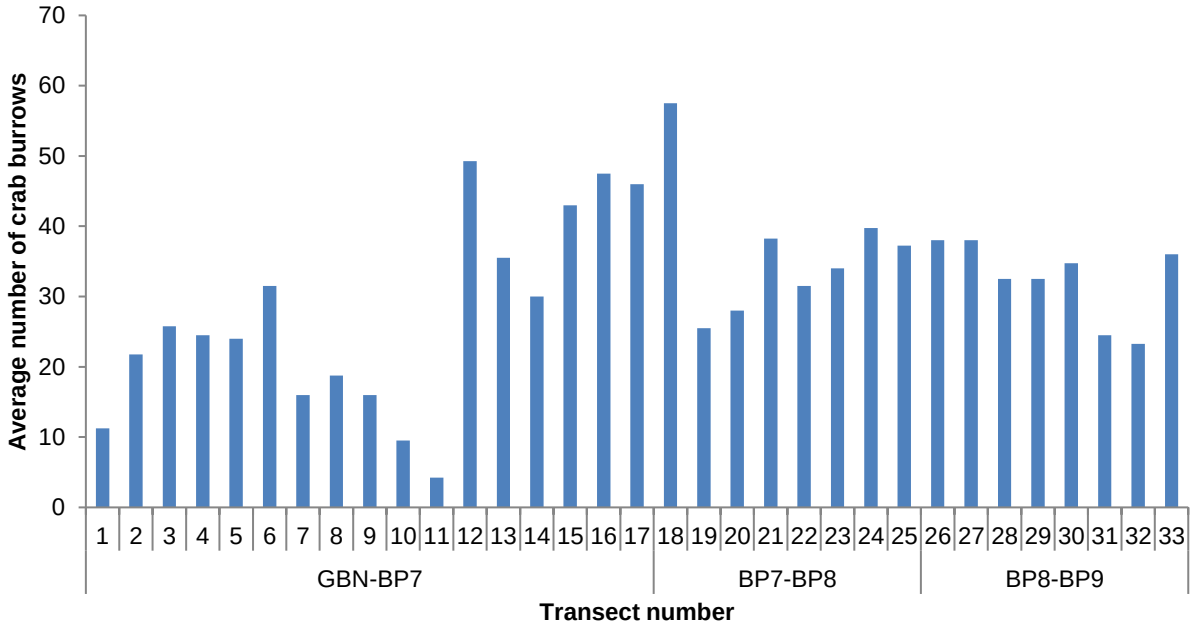

Figure 29: Average number of crab burrows per transect in GBR, 05/01/2011 – 19/02/2012.

Note: *The number of transects per sub-section differs due to the length of each sub-section.*

8.4.2 Horizontal zonation of crab burrows in GBR

During the 4 surveys, crab burrows were found in all horizontal beach zones, including I, S and D (refer Maps).

Of the total 3,794 crab burrows recorded during the 4 surveys:

- 2,229 (58.75%) were located in the I zone;
- 1,398 (36.85%) were located in the S zone; and
- 167 (4.4%) were located in the D zone.

The average number of crab burrows per transect over the 4 surveys was 32.

The average number of crab burrows per transect in each horizontal zone were as follows (refer Figure 30):

- 17 crab burrows per transect in the I zone;
- 12 crab burrows per transect in the S zone; and
- 3 crab burrows per transect in the D zone.

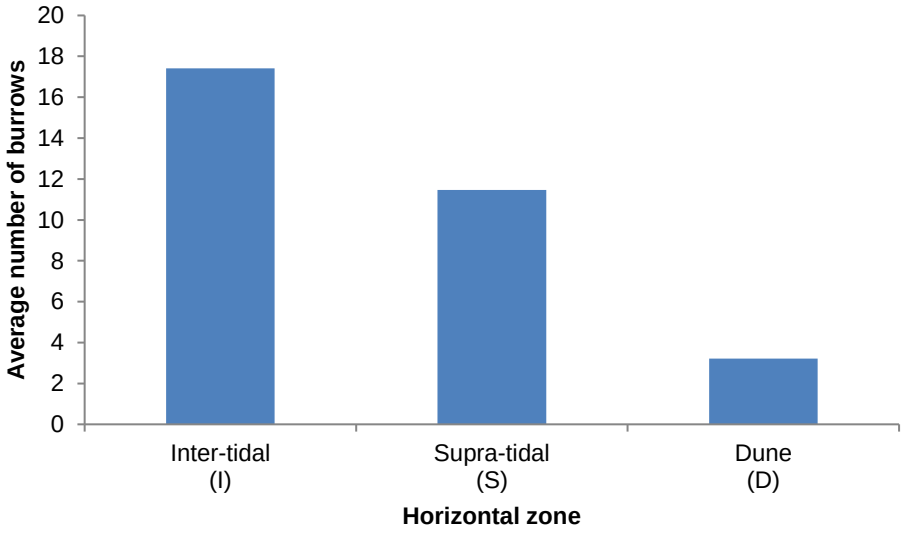

Figure 30: Average number of crab burrows per horizontal beach zone in GBR, 05/01/2012 – 19/02/2012.

Note: *S zone includes the H and E zones (refer Section 'Materials and methods').*

8.4.3 Crab species at the GBR

5 species of crabs were observed in the GBR during the GBR Crab surveys and on monitoring patrols throughout the season (refer Photo plates). These included:

- golden ghost crabs (*Ocypode convexa*);
- running ghost crabs (*Ocypode ceratophthalma*);
- tropical shore crabs (*Grapsus albolineatus*) found in the rocky inter-tidal area approximately 1.4 km south of BP7;
- a yet to be identified, white coloured species with stripes approximately 5cm long, found throughout the study area; and
- another yet to be identified, white coloured species approximately 5 cm long.

Only the golden ghost crab and running ghost crab were observed to disturb and prey on turtles: golden ghost crabs were recorded to burrow into turtle nests, predate eggs and hatchlings. Running ghost crabs also burrowed into turtle nests (although less frequently than golden ghost crabs) and preyed on hatchlings, but were not physically observed during 2011/12 to predate turtle eggs.

8.5 Discussion

8.5.1 Density and vertical distribution of crab burrows in GBR

The GBR Crab surveys conducted during the season 2011/12 add to the crab burrow data collected during the GTCP 2010/11.

Crab burrows were recorded in all sub-sections of the GBR (i.e. GBN – BP9) however, there were differences in crab burrow density and vertical distribution across the GBR.

The majority of crab burrows were recorded in the mid to northern section of the rookery (i.e. from approximately 1.2 km south of BP7 - BP9), with the highest density of burrows occurring in the area approximately 1.2 km south of BP7 to approximately 200 m north of BP7. The beach profile of this area includes a mobile dune system and moderate to high wave energy.

In contrast, lower crab burrow densities were found in the southern section of the GBR (i.e. from GBN to approximately 1.4 km south of BP7). The beach profile of this area includes an adjacent flat hinterland (without the mobile dune systems of the mid to northern section of the rookery) and low to moderate wave energy. The lowest density of crab burrows observed in Transect 11 (approximately 1.4 km south of BP7) is attributable to large exposed rocks along this area of beach. The availability of sand in the area between these exposed rocks and the D zone was minimal and may not have provided an adequate opportunity for burrowing.

Results from the GBR Crab surveys 2010/11 showed the highest crab burrow density in the northern section of the GBR, beginning roughly halfway between sub-section BP7 – BP8 extending to BP9. The GBR Crab surveys 2011/12 found the area with the highest crab burrow density to extend from approximately 1.2 km south of BP7 to BP9, which commences further south than found during the previous year.

The GTCP field team 2010/11 found the highest density of crab burrows occurred around BP8, while the season 2011/12 recorded the highest density of crab burrows in the area approximately 1.2 km south of BP7 to approximately 200 m north of BP7. The beach profile is relatively similar at BP7 and BP8, and the reason for the difference in findings between the two study years is not known.

During both the GTCP 2010/11 and 2011/12, sub-section BP8 – BP9 has been observed to record the highest number of turtle nests. Results 2011/12 did not show a clear correlation between the highest density of crab burrows and the highest density of turtle nests in the GBR.

8.5.2 Horizontal zonation of crab burrows in GBR

The GBR Crab surveys 2011/12 recorded the majority (59%) of crab burrows in the I zone with fewer crab burrows in the S (37%) and D (4%) zones (percentages were rounded for ease of use). Possible reasons for this include:

- proximity to the water in order to hide or escape from predators;
- proximity to the water in order to keep gills moist and extract oxygen from the air;
- sand moisture in the I zone allowing an easier burrowing process; and/or
- higher presence of plants such as seaweed or micro-organisms in the I zone used as a source of food.

The D zone was only present in 39% of the transects due to the reasons stated in Section 'Materials and methods'. This may have caused a misrepresentation of the percentage of crab burrows observed in the D zone. Future crab surveys should extend through all horizontal beach zones for each transect.

Although the majority of crab burrows were located in the I zone, there was evidence of crabs disturbing or predating turtle nests located higher on the beach (refer Chapter 'GBR Sampled nest surveys 2011/12'). These preferences were also apparent during the GTCP season 2010/11 when the majority of crab burrows were recorded in the I (71%) zone. Whilst crab burrows during both study years were predominantly located in the I zone, the reason for the lower finding during 2011/12 is not known. The average number of crab burrows per transect in the I zone (17) was higher than in the S zone (12) and D zones (3). Crab survey results during 2010/11 were not analyzed per transect per zone, therefore comparisons cannot be made on this aspect between the two study years.

Very few crab burrows were found in the D zone during both the GTCP 2010/11 and 2011/12, although crab tracks were frequently observed on the steep dunes of the mid to northern section of the GBR, including the secondary dune system. The steep profile, comparatively dry sand and prevalent winds may make burrowing more difficult in the D zone.

8.5.3 Crab species at the GBR

During the GBR Crab surveys 2011/12, all crab burrows were counted in each transect along GBR, regardless of burrow size. The majority of crab burrows are believed to

belong to golden ghost crabs and the running ghost crabs, which are the most common crab species observed in the GBR.

Very small crab burrows belonging to two small, white, unidentified crab species were also counted. However, it is very unlikely that these species of crab disturb or predate turtle nests due to their substantially smaller size.

The tropical shore crab was not observed to burrow on the beach and was only seen among the rocky inter-tidal area approximately 1.4 km south of BP7. Though this species is comparable in size to the golden and running ghost crabs, its observed preference for rocky, inter-tidal habitat may suggest that the species does not impact turtle nests.

Only the golden ghost crab and running ghost crab were observed to disturb and prey on nests: golden ghost crabs burrows were recorded in nests and evidence of egg and hatchling predation was observed. Running ghost crabs also burrowed into turtle nests, though less frequently than golden ghost crabs, and preyed on hatchlings. However, they were not physically observed predating turtle eggs during 2011/12.

8.6 Conclusion

Crab burrows were recorded in all sub-sections of the GBR. A vertical distribution pattern of crab burrows was observed, with a preference for the mid to northern section of the rookery (i.e. from approximately 1.2 km south of BP7 - BP9). The highest density of crab burrows in the GBR occurred in the area approximately 1.2 km south of BP7 to approximately 200 m north of BP7. This did not show a clear correlation between the highest density of crab burrows and turtle nests (in sub-section BP8 – BP9) in the GBR.

The preferential horizontal distribution of crab burrows was found to be similar during 2011/12 to the results obtained during 2010/11. The majority of crab burrows were located in the I zone. Protection from predators, proximity to the water, sand moisture content and the presence of food sources could explain the higher presence of crab burrows in the I zone. Although average crab burrow numbers were highest near the water, this did not appear to impede or deter the crabs from disturbing or predating turtle nests in higher areas of the beach.

Throughout 2011/12, 5 different crab species were observed at the GBR. These included the golden ghost crab, the running ghost crab, the tropical shore crab and two currently unidentified species. Only the golden ghost crab and running ghost crab were observed to disturb and prey on turtle nests.

9. EDUCATION AND COMMUNITY ENGAGEMENT

Prior to the season 2010/11, community engagement with the GTCP was informal and lacked procedures for involvement of community volunteers. A formal community engagement program was initiated prior to the start of the season 2010/11 and a GTCP Community Volunteer Co-ordinator position was created to expand the scope of community engagement with the GTCP. During the season 2010/11, with help from the GTCP's Project Manager, the Community Volunteer Co-ordinator created and managed a structured community engagement program for the GTCP. This work was continued during the season 2011/12 to expand the community engagement component and increase involvement of school groups and community members with the program.

9.1 Objectives

Objectives during the season 2011/12 were as follows:

- Host community volunteers onsite to participate with the program;
- Host a school group onsite at Gnaraloo to participate with the program;
- Give offsite presentations to schools in Western Australia; and
-
- Expand the program in various ways to increase awareness about sea turtle conservation at Gnaraloo.

Refer to the section titled 'Background' for detailed information about the overall objectives of the GTCP.

9.2 Results

9.2.1 Onsite participation by community volunteers

During the season 2011/12, action was taken to increase the involvement of the general public with the GTCP's research at Gnaraloo. During the period 7 November 2011 to 1 February 2012, 29 community volunteers participated with the GTCP. Participants varied in age from 8 - 56 and represented several nationalities including Australian, Austrian, English, French, German, Irish, Scottish, Spanish, and Swiss. The GTCP hosted participants from single persons to small groups of four. Many people only participated in the program for one patrol; however, a few participated in multiple morning and night patrols.

The community volunteer PowerPoint presentation 2010/11 was updated for the season 2011/12. This presentation was given to all volunteers participating with the GTCP prior to their first excursion with the field research team. This presentation described how the volunteers would assist in turtle track identification and data collection by the GTCP and explained the behaviour expected whilst participating with GTCP researcher patrols.

21 out of the 29 community volunteers participated in morning turtle track patrols with the GTCP researchers. During patrol, GTCP researchers described data that are recorded while monitoring the beach and how to interpret turtle tracks for species identification and Nesting Activity Determination. After working with the researchers on the first few tracks encountered, the volunteers were sometimes left to decipher any additional tracks on the beach on their own before discussing the tracks with GTCP researchers. Patrols also offered additional time for the GTCP team to talk to community volunteers about sea turtle biology and behaviour, the scope of objectives of the GTCP and management action such as feral animal control to protect the GBR.

During the season 2011/12, community volunteers were offered the chance to participate in data collection during night patrols (at the discretion of GTCP researchers) as well as morning patrols for the first time since the commencement of the GTCP in 2008.

As the GTCP had never conducted night patrols with community volunteers in past seasons, new protocols and restrictions had to be created in order to provide a positive and enjoyable experience to the volunteers whilst ensuring that turtles were not disrupted during their activities and the research program not compromised. These protocols included the participation in a morning patrol prior to the night patrol. This allowed researchers to determine if volunteers would follow GTCP protocols to minimize disturbance to turtles in addition to practices in data collection. If volunteers were offered the chance to participate in night patrols, GTCP researchers explained the codes of conduct for participation

School groups were not permitted to participate in night patrols during the season 2011/12 due to group size restrictions (maximum of 4 people). Small groups on night surveys are essential in order to minimise disturbance to turtles while on the beach.

During the season 2011/12, 18 community volunteers participated in night patrols with GTCP researchers. The majority of night patrols with community members occurred during the first half of the season while the GTCP team was performing nightly patrols of the beach for accuracy checks the next morning.

Based on feedback given during the patrols, and afterward on the feedback forms, all volunteers who participated in night patrols had a positive experience. This is likely because most volunteers had the opportunity to witness sea turtles on the beach and

occasionally were able to view turtles laying eggs. It is encouraged that night patrols with community volunteers continue in future seasons.

9.2.2 A field excursion by a school group

One of the objectives of the GTCP program 2011/12 was to host school groups onsite at Gnaraloo to participate in research patrols. These school excursions offer the opportunity for students to participate in hands-on data collection with a scientific program and is especially valuable for students interested in becoming scientists.

The GTCP Community Volunteer Coordinator invited 19 schools to organize a trip to Gnaraloo and participate with the GTCP. Two documents, a flyer announcing the offer and a detailed information package including a tentative schedule and advice to school officials, were emailed out to either principals or heads of the science departments at each school.

A number of schools indicated that they were interested in the offer, but that it was too short notice to organize a trip, often citing issues of approval from the school board as well as acquiring appropriate funds. For these reasons, schools need to be made aware of the opportunity at least one season prior to when the organized trip would occur and possibly contacted by the GTCP's Project Manager during the GTCP off-season. All schools were contacted again at the end of the season in February 2012 to remind them of the opportunity on offer for the GTCP season 2012/13.

One school in the local town of Carnarvon (Western Australia) planned to bring a small group of students to Gnaraloo to participate with the GTCP. St. Mary Star of the Sea Catholic School planned this trip after GTCP researchers gave two presentations at the school. The trip to Gnaraloo was planned to take place on 12-13 December 2011, however due to the unavailability of transportation, the school had to cancel one week prior to the planned arrival date.

In January 2012, for the first time since the commencement of the program in 2008, the GTCP hosted a school group for an onsite visit to Gnaraloo and participation with the GTCP. 11 Year Twelve students (ages 16 - 17) and 3 adults from Nagle Catholic College in Geraldton, WA visited Gnaraloo from 23 January 2012 – 26 January 2012.

After the arrival of Nagle Catholic College at Gnaraloo, the GTCP research team gave the students an educational presentation. GTCP researchers explained the role of the students in assisting researchers with data collection as well as what they would learn during their morning patrols.

The school group participated in 3 morning patrols with the GTCP researchers during their stay. All 14 members participated and were separated into 2 groups of 7. On the first day, one group was taken north from BP7-BP9 while the other group was taken south

from BP7-GBN. The groups then alternated on the following days so that each student had the opportunity to patrol the entire rookery over their 3-day stay period.

During the first patrol, students were instructed on how to identify turtle tracks, species of turtles based on tracks, direction of tracks, and whether the activity was a nest, UNA, or U-track. After learning these features, students were then given the opportunity to collaborate with each other for data collection on remaining tracks. All data collected by the students were double checked for accuracy by the GTCP field researchers. Students continued to collect data during the following 2 patrols.

After the conclusion of each of the 3 morning patrols, students and teachers participated in various activities around Gnaraloo Station including snorkelling at 3Mile Lagoon and Gnaraloo Bay, visiting Tombstones surf break and fishing at 6Mile.

While the school group originally intended to stay from 23 – 27 January 2012, they departed early on the evening of 26 January 2012. This was due to a fire that had broken out on Quobba Station (immediately adjacent to the south of Gnaraloo Station) and the impending Cyclone Iggy that had formed off the coast of Western Australia.

The majority of the students indicated on their feedback forms that they enjoyed the hands-on experience of working with the researchers. Like the community volunteer feedback, some of the students wrote they wished there were more viewing of live turtles, with one student suggesting night patrols for school groups.

Verbal feedback as well as written feedback was also posted on the GTCP Facebook page and emailed to GTCP researchers. All of these responses indicated a positive, enjoyable experience by the students and teachers of Nagle Catholic College while working with the GTCP. Interest in future excursions to Gnaraloo Station to participate with the GTCP was also expressed. The teachers who attended the trip to Gnaraloo discussed their desire to try to make participation in the GTCP an annual school trip for their Year Twelve science students. Based on these responses, it is highly recommended that the GTCP continue to host more schools during the season2012/13.

9.2.3 Volunteer participation records

Volunteer participation logs were kept to record the participants with the GTCP. The use of the indemnity form created during the season 2010/11 was continued. All volunteers were required to sign this form (or have legal guardians sign if they were under 18 years of age) before their first patrol on the beach with the GTCP researchers.

During the season 2010/11, the GTCP received positive feedback from volunteer participants in the program. While some of this feedback was in writing, most was verbal communication to GTCP researchers. To document the success of the GTCP Community Engagement Program 2011/12, a feedback form was created during the season 2011/12 and distributed to volunteers.

The goal of this form was to allow GTCP researchers to understand what volunteers enjoyed or did not enjoy during their participation with the GTCP. The feedback provided was then used to fix any problems encountered by any volunteers. On the form, volunteers were asked to rate their experience with the program, the researchers, what they learned about sea turtles and the conservation work being done at Gnaraloo, and whether they would recommend the program to friends.

Although volunteers were not required to fill out this form after completing their patrol, they were encouraged to return it to the GTCP researchers before leaving Gnaraloo. Of the 13 feedback forms distributed, 9 were filled out and returned. From the comments on the forms returned, all volunteers had a positive experience and enjoyed learning about sea turtles and conservation in addition to participating with the formal patrols by the GTCP field researchers.

The most common positive or negative comment expressed by volunteers through feedback forms or verbal communication with GTCP researchers dealt with the experience of observing a turtle on the beach. Some volunteers who participated in morning patrols were disappointed that they did not see a turtle even though this was explained to them prior to their patrol. They were advised that the morning patrols conducted by GTCP researchers predominately dealt with turtle track interpretation. In contrast, volunteers who did see a turtle either during morning or night patrols rated this experience very highly.

9.2.4 Presentations at regional and metropolitan schools

In addition to contacting schools about onsite excursions to Gnaraloo during the season 2011/12, 8 schools in Western Australia were contacted with an offer of offsite presentations to their students. Presentations at the beginning of the season were given to schools in Carnarvon, WA, due to the proximity to Gnaraloo Station (150 km south of Gnaraloo). Presentations at the end of the season were given in Perth, Walpole, and Denmark, WA, after the GTCP field researchers' departure from Gnaraloo Station.

The season 2011/12 saw a great expansion in the school presentation segment of the GTCP. This was the first season that educational presentations were given to such an extent to local schools. This was also the first year that a presentation was created and tailored for primary school students.

Both the primary school and high school presentations included information about sea turtle biology and conservation and the GTCP research. The primary school presentation included a stronger conservation message aimed at exciting the younger students about sea turtles. The high school presentation provided more technical information about sea turtles and the data collected by the GTCP, including the results at the end of the field season. The initial designs of these presentations were for science classes, although all types of classes were invited to attend. Attendance logs were distributed at all

presentations to get a count of all students and teachers present. **In total, 432 students attended the 8 presentations.**

The majority of presentations (5) were given to schools in the town of Carnarvon. These presentations offered a chance for local students to learn about conservation issues in their area. Presentations in Carnarvon were given to the following schools on the following dates:

- St. Mary Star of the Sea Catholic School (high school group) – 25 October 2011;
- St. Mary Star of the Sea Catholic School (primary school group) – 25 October 2011;
- Carnarvon Primary School – 25 October 2011;
- Carnarvon High School – 10 November 2011; and
- East Carnarvon Primary School – 11 November 2011.

4 presentations were given in Perth, Walpole, and Denmark at the end of the season at the following schools and dates:

- South Freemantle High School– 2 March 2012;
- Walpole Primary School– 8 March 2012;
- Denmark High School– 9 March 2012; and
- Aquinas College– 21 March 2012.

Prior to the presentations, the GTCP team met with the Principal or Deputy Principal of the school for introductions and to explain the scope of the work by the GTCP. This rapport is important to establish a long-term relationship with the schools. It is the goal of the GTCP to make these presentations an annual event, especially to schools in Carnarvon. It is also hoped that in future years some of these schools will organize a school group excursion onsite to Gnaraloo to participate with the GTCP.

A question-and-answer period followed the presentations at all schools. Although all questions asked were valuable, the GTCP researchers were extremely impressed by the quality of the questions asked by primary school groups. As the primary school presentations were a new element in 2011/12, it was unsure how these presentations would be received. After the success of these presentations, it is highly recommended that this be continued and expanded in the GTCP season 2012/13.

The school presentation segment of the GTCP 2011/12 was very successful. All of the teachers and administrators were pleased with the message that was presented and

many expressed their desire to continue their relationship with the GTCP and try to make the presentations an annual event. The GTCP Community Volunteer Co-ordinator 2012/13 should contact all of the schools listed above again to give presentations at these schools. Additional schools should also be contacted about this opportunity during the season 2012/13.

9.2.5 Social media and other information sharing

During the season 2011/12, a number of other outlets were also used to promote community involvement with the program and spread the word about the Gnaraloo sea turtles. The objective of using different media was to reach as many people as possible at the state, national and international level to make them aware and engaged with the research taking place at Gnaraloo.

A Facebook page was created during the season 2010/11 for the GTCP to reach the wider public. The GTCP Facebook page provides updates on program activities and events in the form of notes, field diaries, weekly nest tallies, interesting site events, research activities, opportunities for volunteer participation as well as information on marine and terrestrial biodiversity at Gnaraloo. A large collection of photos was amassed throughout the season and posted on the page.

The Facebook page was maintained throughout the season 2011/12 with regular research updates. A new photo album was also created for photos and videos from throughout the season. The pictures and videos often receive the most views on the Facebook page and should be the focus of future Facebook postings.

During the season 2011/12, two new weekly updates were created and posted on the GTCP Facebook page. The first was a ‘Turtle Thermometer’ posted every Monday, which displayed the total number of nests that were recorded in the GBR each week. The second was ‘Turtle Trivia Tuesday’ in which a trivia question about sea turtles was posted every Tuesday. Anyone was able to answer the question by commenting on the ‘Turtle Trivia Tuesday’ post and answers to the questions were posted on the following Friday. Both of these weekly updates were created to make the GTCP Facebook page more interactive for those who ‘like’ the page. Based on comments left on the webpage, and the significant increase in the number of followers, the GTCP Facebook page continued to be a successful element of the program during the season 2011/12.

A Twitter page was also created during the season 2011/12.

The purpose of the GTCP Twitter page was to provide a more informal place for followers to receive information on the GTCP. Posts allow the GTCP research team to report any special findings or updates. These posts are also sent to mobile phones of followers who have access to Twitter on their phones. Since all posts on Twitter are limited to 140 characters, these short updates provided basic information on the research the GTCP conducted throughout the season.

During the season 2011/12, GTCP researchers also wrote 2 articles for different newsletters. Both articles detailed the work of the GTCP through its first four seasons of operation (2008 – 2012). The first article was sent to the Indian Ocean Turtle Newsletter (**IOTN**). The articles in the newsletter are available online (refer www.seaturtle.org/iotn). While the first draft of this article had been written during the GTCP season 2009/10, the article was updated and arranged for publication during the season 2011/12.The article appears in issue 15 of the IOTN.

The second article was written for publication in Coastlines, a newsletter produced by the then Department of Planning of the West Australian Government. The GTCP article was published in the Autumn edition of Coastlines in 2012.

9.2.6 Radio interviews

The GTCP hosted a journalist, Ms. Fleur Bainger, onsite for 3 days from 17 - 19 January 2012. During this period, Ms. Bainger participated in both morning and night patrols in GBR. During her time at Gnaraloo, Ms. Bainger interviewed all the field researchers and these interviews were used in radio airings and for written articles about the Gnaraloo turtles. The first airing was on 20 January 2012 on 720 ABC Perth's Breakfast program with Eoin Cameron, and the second aired on 26 January 2012 on Radio National's Bush Telegraph program.

Both pieces detailed the experience of participating in a night patrol with GTCP researchers and highlighted the importance of monitoring efforts in both the GBR and the newly monitored GCFR. The audio clip was posted on ABC Online's web page along with a short article written by Ms. Bainger as an accompaniment to the radio piece.

9.3 Conclusion

During the GTCP season 2011/12, the scope of the Education and Community Engagement component of the program was greatly expanded. For the first time since the commencement of the program in 2008, it was able to offer a school group participation with the research efforts at Gnaraloo. The GTCP's reach also extended offsite to more regional schools in Western Australia. Positive feedback was received from all participants with the program who enjoyed learning about the Gnaraloo turtles and appreciated the opportunity to be included with the GTCP's research. Continued interaction with schools is an important aspect of the program and should continue during future seasons.

The GTCP Facebook page saw a large expansion of followers during the season 2011/12 and new content was shared to make it more informative and interactive for the community. Other outlets were also used to increase the public's awareness of the conservation efforts at Gnaraloo, including the creation of a Twitter page, newsletter articles, and radio pieces. It is highly recommended that the Education and Community Engagement component of the program continue to expand in future.

10. GLOSSARY

BP6	The historical Beach Point 6 Permanent Marker, being the vertical white PVC pipe with white PVC cladding at the 6Mile public parking area (-23.76436° / 113.55854°).
BP7	The Beach Point 7 Permanent Marker, being the vertical white PVC pipe affixed atop a fore dune (-23.75001° / 113.56871°), after the Gnaraloo Weather Station.
BP8	The Beach Point 8 Permanent Marker, being a vertical white PVC pipe affixed atop a fore dune (-23.73631° / 113.57448°).
BP9	The Beach Point 9 Permanent Marker, being a vertical metal star picket on the fore dune (-23.72195° / 113.57750°) (delineates the northernmost boundary of the Study Area 2011/12).
CCG	Cape Conservation Group, Exmouth.
Clutch	All of the eggs deposited in a single nest.
Crab burrow	Near vertical hole in the sand with an opening. The excavated sand is carried away from the burrow by the crab and dispersed.
DEC	Department of Environment and Conservation, Western Australia.
DEM	Digital Elevation Model
DD	Decimal Degrees used in GPS data collection
Dune zone (**D**)	Area from the base of the foredune and beyond.

Edge of vegetation zone (**E**)	Area between the edge of vegetation and the base of the foredune.
Egg chamber	Location in which eggs are deposited; a deep hole dug into the primary body pit using the turtle's back flippers.
Emerging track	The track made by a turtle as it comes from the sea up the beach.
Fox presence	Evidence of fox tracks or scat and/or visual of an individual fox.
GIS	Geographic Information System.
GBN	The GBN permanent marker, being the vertical yellow *Gnaraloo Bay North Marine Sanctuary Zone* marker (-23.76708° / 113.54584°) (delineates the southernmost boundary of the Study Area 2010/11).
GBR	Gnaraloo Bay Rookery
GCFR	Gnaraloo Cape Farquhar Rookery
GFACP	Gnaraloo Feral Animal Control Program
GFCP	Gnaraloo Fox Control Program
GTCP	Gnaraloo Turtle Conservation Program.
Hatching event	Emergence of live hatchlings from the egg chamber. Can be determined by actual sighting of hatchlings or presence of hatchling tracks leading to the ocean.
Hatching season	The period that includes hatching of all nests recorded in the Study Area.

Hatching success	The ratio of hatched eggs to the total number of eggs deposited in a clutch, as determined by post-hatching excavation.
Hatchling	A newly hatched turtle.
Hatchling **predation**	Sighting of a predator consuming/preying on a hatchling, or sighting of a dead hatchling having injuries consistent with predation.
High water zone (**H**)	Area between the high water mark and the edge of vegetation.
Intertidal zone (**I**)	Area between the water's edge and below the high water mark.
IOSEA	Indian Ocean – South East Asian Marine Turtle Memorandum of Understanding); an inter-governmental agreement that aims to protect, replenish and recover sea turtles and their habitats in the Indian Ocean and South-East Asian region, working in partnership with other relevant organisations (www.ioseaturtles.org).
Monitoring season	The entire time period during which GTCP team members monitor sea turtle nesting activities at Gnaraloo.
Nest	A successful Nesting Activity that results in the laying of eggs.
Nesting Activity	Any track or nesting attempt (i.e. nest, Unsuccessful Nesting Attempt, U-Track or Unidentified nesting activity) created by a sea turtle.

Nesting Activity Determination	The process of using physical clues to classify a beach Nesting Activity as a Nest, Unsuccessful Nesting Attempt, U-Track or Unidentified nesting activity, **with or without** the turtle present.
Nest depression	Area of caved-in sand over the egg chamber indicating that eggs have begun to hatch. Emergence typically follows between 1 – 3 days after appearance of nest depression.
Nest **disturbance** by crabs	Sightings of a crab burrow(s) into a nest, **without** presence of turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.
Nest **disturbance** by environmental conditions	Inundation, erosion and/or suffocation of nests by tides, storm surges or shifting dunes.
Nest **disturbance** by foxes	Sightings of fox digging(s) into a turtle nest, **without** presence of turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface.
Nest **predation** by crabs	Sightings of a crab burrow(s) into a nest **with** evidence of mortality (e.g. turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells visible within the crab burrows, or an exposed egg chamber) or observation of a crab actively taking a hatchling.
Nest **predation** by foxes	Sightings of fox digging(s) into a turtle nest **with** evidence of mortality (e.g. turtle eggshell fragments, whole turtle eggs or yolky turtle eggshells present at the surface or an exposed egg chamber) or observation of a fox actively taking a hatchling.

Nesting season	The period that includes all turtle beach activities in the Study Area.
Night survey sub-section 2010/11	Area monitored at night for part periods during 2010/11: from the Beach Point 8 (**BP8**) marker to Beach Point 9 (**BP9**) marker.
NTP	Ningaloo Turtle Program, Exmouth.
RAM	Random Access Memory
Returning track	The track made by a turtle as it returns from the land to the sea.
Rookery	A breeding area for a large number of animals.
Study Area	Area monitored daily: from Gnaraloo Bay North (**GBN**) to Beach Point 9 (**BP9**).
Successful nesting attempt or Nest	Turtle beach activity that results in a clutch being deposited.
Supra-tidal zone (**S**)	The area between the high water mark and the base of the foredune, (only used in crab survey) and is inclusive of the High water zone (**H**) and Edge of Vegetation zone (**E**).
SWOT	State of the World's Sea Turtles; works directly with field-based sea turtle researchers across the globe, compiling the most current data available in order to provide an up-to-date global picture of sea turtle status (www.seaturtlestatus.org).
Turtle beach activity	All activities observed but track or turtle sighting on the beach, including nests, unsuccessful nesting attempts (**UNAs**), U-tracks and Unidentified.

Turtle breeding season	The period that includes both nesting and hatching seasons, as evidenced by beach activities and hatching events of all nests in the Study Area.
Unidentified (U) activity	Turtle activity that cannot positively be classified during patrols due to environmental conditions such as winds, tides, rainfall, crab disturbance and shifting sand dunes. During night surveys, a 'U' was recorded if nesting phase could not be determined from the behaviour of the turtle or if nesting activity was not observed.
Unidentified (U) turtle species	Classification assigned when the turtle species could not be determined from the tracks during morning patrols due to environmental conditions such as winds, tides, rainfall, and shifting sand dunes.
Unsuccessful Nesting Attempt or UNA	The emergence of a female from the sea that does not result in the depositing of eggs but results in nesting behaviour such as body pitting. For example, a turtle is witnessed either clearing a body pit or digging an egg chamber, but subsequently abandons the nesting attempt and returns to sea without depositing eggs.
U-track	The female is said to have carried out a U-track when no attempt of body pitting has been witnessed and the tracks on the beach simply appears as a 'U'.

11. REFERENCES

Australian Government – Great Barrier Reef Marine Park Authority. (n.d.) *Marine turtle species descriptions*. Retrieved 21 February 2012 from http://www.gbrmpa.gov.au/corp_site/key_issues/conservation/natural_values/marine_turtles/marine_turtle_species_descriptions

Baldwin, R., Hughes, G.R., and Prince, R.I.T. (2003). Loggerhead turtles in the Indian Ocean. In A. B. Bolten and B. E. Witherington, editors. Loggerhead sea turtles. Smithsonian Books, Washington, D.C., USA. p218–232

Butcher, M. (2010). *Fox control program for Gnaraloo Station, Turtle predation minimisation project.* February 2010. Perth: Animal Pest Management Services

Butcher, M. (2009). *Fox Management Project: Technical Report for Gnaraloo.* November 2009. Perth: Animal Pest Management Services

Butcher, M. (2009). *Fox Control Program for Gnaraloo Station, Turtle Predation Minimisation Project.* January 2009. Perth: Animal Pest Management Services

Butcher, M. (2008). *Fox Control Program for Gnaraloo Station, Turtle Predation Minimisation Project.* December 2008. Perth: Animal Pest Management Services

Casale, P., Riskas, K., Tucker, A.D. and Hamann, M. (2015). *Caretta caretta* (South East Indian Ocean subpopulation). The IUCN Red List of Threatened Species 2015: e.T84189617A84189662. http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T84189617A84189662.en

Conant, T.A., P.H. Dutton, P.H., Eguchi, T., Epperly, S.P., Fahy, C.C., Godfrey, M.H., MacPherson, S.L., Possardt, E.E., Schroeder, B.A., Seminoff, J.A., Snover, M.L., Upite, C.M., and Witherington, B.E. (2009). Loggerhead sea turtle *(Caretta caretta)* 2009 status review under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service

Dodd, C. K. (1988). Synopsis of the Biological Data On the Loggerhead Sea Turtle: Caretta Caretta (Linnaeus, 1758). Washington, DC: Fish and Wildlife Service, U.S. Dept. of the Interior

Ehrhart, L.M., Bagley, D.A., and Redfoot, W.E. (2003). Loggerhead turtles in the Atlantic Ocean: Geographic distribution, abundance, and population status. In A. B. Bolten and B. E. Witherington, editors. Loggerhead sea turtles. Smithsonian Institution Press,Washington, D.C., USA. p157–174

Ehrhart, L., Redfoot, W., Bagley, D. and Mansfield, K., 2014. Long-term trends in loggerhead (*Caretta caretta*) nesting and reproductive success at an important western Atlantic rookery. *Chelonian Conservation and Biology*, *13*(2), pp.173-181.

Godfrey, M.H. and Godley, B.J. (2008). Seeing past the red: flawed IUCN global listings for sea turtles. Endangered Species Research, Vol. 6, p155–159

Hamann M., Kamrowski, R. L., and Bodine, T. (2013). Assessment of the conservation status of the loggerhead turtle in the Indian Ocean and South-East Asia. IOSEA Marine Turtle MoU Secretariat, Bangkok.

Hattingh, K., Boureau, M., Duffy, M. and Wall, M. (2011). Gnaraloo Turtle Conservation Program. *Gnaraloo Bay Rookery, Final Report, Program 2010/11*. Day monitoring program with Night checks and Crab burrow surveys. 20 July 2011. Gnaraloo Station Trust, Western Australia

Hattingh, K., Boelling, P., Jacomy, S., James, A., Leonard, J., Stuart, J-M. and Williamson, M. (2010), *Gnaraloo Day and Night Monitoring Final Report 2009/2010*. Gnaraloo Station, Western Australia: Gnaraloo Turtle Conservation Program

Hattingh, K., Becker, P. and Paterson, G. (2009). Gnaraloo *Day Monitoring Final Report 2008/09*. Gnaraloo Station, Western Australia: Gnaraloo Turtle Conservation Program

Hattingh, K., Edman, R., Morgan, F., Riskas, K. (2012). *GTCP Monitoring Procedure 2011/12*. Gnaraloo Station, Western Australia: Gnaraloo Turtle Conservation Program

International Union for Conservation of Nature and Natural Resources. (n.d.). *The IUCN Red List of Threatened Species*. Retrieved 21 February 2012 from http://www.iucnredlist.org/

Kamezaki, N., Matsuzawa, Y., Abe, O., Asakawa, H., Fujii, T., Goto, K., Hagino, S., Hayami, M., Ishii, M., Iwamoto, T., Kamata, T., Kato, H., Kodama, J., Kondo, Y., Miyawaki, I., Mizobuchi, K., Nakamura, Y., Nakashima, Y., Naruse, H., Omuta, K., Samejima, M., Suganuma, H., Takeshita, H., Tanaka, T., Toji, T., Uematsu, M., Yamamoto, A., Yamato, T., and Wakabayashi, I.. (2003). Loggerhead turtles nesting in Japan. In Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C. p210-217

Lewis, A., Whiting, S., Samson C., Bedford S. and Mau, R. (2008). *A Guide to Turtle Track Beach Monitoring in Australia*. Department of Environment and Conservation, Western Australia

Limpus, C.J., Carter, D. and Hamann, M., 2001. The green turtle, *Chelonia mydas* in Queensland, Australia: The Bramble Cay Rookery in the 1979-1980 breeding season. *Chelonian Conservation and Biology: International Journal of Turtle and Tortoise Research*, *4*(1), pp.34-36.

Limpus, C.J. and Limpus, D.J. (2003). *Biology and the Loggerhead Turtle in Western South Turtles*. U.S.A.: Smithsonian Institute. p93-113

Limpus, C.J., and D.J. Limpus. (2003). Loggerhead turtles in the Equatorial and southern Pacific Ocean: a species in decline. In A. B. Bolten and B. E. Witherington, editors. Loggerhead sea turtles. Smithsonian Institution Press, Washington, D.C., USA. p199–209

Limpus, C.J., Limpus, D. J., Arthur, K., Bell, I. and Draper, R. (2006). *Queensland Turtle Conservation Project: Monitoring marine turtle population dynamics in Moreton Bay Marine Park, 2005-2006*. Queensland: Queensland Environmental Protection Agency

Limpus, C.J. (2009). *A Biological Review Of Australian Marine Turtles*. Pages 15-40. Queensland: Environmental Protection Agency

Marco, A., Abella Pérez, E., Monzón Argüello, C., Martins, S., Araujo, S. and López Jurado, L.F. (2011) The international importance of the archipelago of Cape Verde for marine turtles, in particular the loggerhead turtle Caretta caretta. Zoologia Caboverdiana 2, 2(1): 1–11

Margaritoulis, D., et al. (2003). Loggerhead turtles in the Mediterranean: present knowledge and conservation perspectives. In A. B. Bolten and B. E. Witherington, editors. Loggerhead sea turtles. Smithsonian Institution Press, Washington, D.C., USA. p175–198

Monzón-Arguëllo, C., López, P., López-Jurado, L.F., Marco, A., Naro-Maciel, E., Rico, C. and Varo-Cruz, N. (2010). Population structure and conservation implications for the loggerhead sea turtle of the Cape Verde Islands. Conservation Genetics, 11:1871–1884

National Marine Fisheries Service (http://nmfs.noaa.gov) accessed 26 February 2012

Ningaloo Turtle Program. (2007). *Turtle Monitoring Field Guide.* Exmouth, Western Australia: Cape Conservation Group, Inc

Rees, A.F., Al Saady, S., Broderick, A.C., Coyne, M.S., Papathanasopoulou, N., and Godley, B.J. 2010. Behavioural polymorphism in one of the world's largest populations of loggerhead sea turtles *Caretta caretta*. Marine Ecology Progress Series 418:201–212.Rob, D., Barnes, P,, Whiting, S., Fossette, S., Tucker, T., and Mongan, T (2019) Turtle activity and nesting on the Muiron Islands and Ningaloo Coast: Final Report 2018, Ningaloo Turtle Program. Report prepared for Woodside Energy Limited. Department of Biodiversity, Conservation and Attractions, Exmouth, pp.51.

Salm, R.V. 1991. Turtles in Oman: Status, threats, and management options. Report of the Scientific Results of the IUCN Coastal Zone Management Project CZMP4:F11

Scott, J.A. 2006. Use of satellite telemetry to determine ecology and management of loggerhead turtle (*Caretta caretta*) during the nesting season in Georgia. Master's Thesis, University of Georgia, Athens.

Taylor, R., Chatto, R., Woinarski, J. (2006). Threatened species of the Northern Territory: Loggerhead turtle (*Caretta caretta*). Northern Territory Government, Department of Natural Resources, Environment and the Arts

Tucker, A.D., Baldwin, R., Willson, A., Al Kiyumi, A., Harthi, S.A., Schroeder, B., Possardt, E. and Witherington, B. 2018. Revised clutch frequency estimates for Masirah Island loggerhead turtles (Caretta caretta). *Herpetological Conservation and Biology*, *13*(1), pp.158-166.

Wallace, B.P., DiMatteo, A.D., Bolten, A.B., Chaloupka, M.Y., Hutchinson, B.J., Abreu-Grobois, F.A., Mortimer, J.A., Seminoff, J.A., Amorocho, D., BjorndaL, K.A., Bourjea, J., Bowen, B.W., Briseño Dueñas, R., Casale, P., Choudhury, B.C., Costa, A, Dutton, P.H., Fallabrino, A., Finkbeiner, E.M., Girard, A., Girondot, M., Hamann, M., Hurley, B.J., López-Mendilaharsu, M., Marcovaldi, M.A., Musick, J.A., Nel, R., Pilcher, N.J., Troëng, S., Witherington, B., Mast, R.B. (2011). Global Conservation Priorities for Marine Turtles. PLoS ONE 6(9):e24510. doi:10.1371/journal.pone.0024510

Whiting, A.U. (2016) Estimating abundance and detecting trends for green, loggerhead and hawksbill turtles nesting within the Ningaloo region: 2013-14 to 2015-16 seasons. Report to the Ningaloo Turtle Program.

APPENDIX A:

MAPS

1 Gnaraloo Bay Rookery: Digital Elevation Model (**DEM**)

2 Sea turtle rookeries and marine sanctuary zones on Gnaraloo Station

3 Gnaraloo Bay Rookery

4 Sea turtle nest density and distribution 2011/12, Gnaraloo Bay Rookery

5 Sampled nests impacted by crabs 2011/12, Gnaraloo Bay Rookery

6 Sampled nests impacted by dunes 2011/12, Gnaraloo Bay Rookery

7 Sampled nests impacted by tides 2011/12, Gnaraloo Bay Rookery

8 Crab burrow density and vertical distribution 2011/12, Gnaraloo Bay Rookery

9 Horizontal distribution of crab burrows 2011/12, Gnaraloo Bay Rookery

10 Gnaraloo Cape Farquhar Rookery

APPENDIX B:

GNARALOO WEATHER STATION DATA

At the bottom of each month's weather 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 Rain: ON [Date]	The maximum daily rainfall during the month.
Days of Rain: (>0.2mm), (>2mm), (>20mm)	The number of days on which rainfall exceeded 0.2mm, 2mm, or 20mm is displayed.
Average Wind Speed (kph)	
Max Wind Speed (kph): ON [Date]	
Average Wind Direction	

gnaraloo wilderness foundation

gnaraloo SEA TURTLE CONSERVATION

MONTHLY CLIMATOLOGICAL SUMMARY FOR 1 – 30 NOVEMBER 2011

DAY	TEMPERATURE °C					RAIN (mm)	WIND (kph)			
	MEAN	HIGH	TIME	LOW	TIME		AVERAGE SPEED	HIGH	TIME	DOMINANT DIRECTION
1*	-	-	-	-	-	-	-	-	-	-
2*	-	-	-	-	-	-	-	-	-	-
3	23.1	24.3	5:00p	21.8	12:00m	0	17.2	29	7:00p	WSW
4	22.3	24.3	3:00p	19.7	4:00a	2.6	11.4	33.8	6:00p	W
5	21.4	25.4	12:00p	18.1	6:00a	0	12.4	37	5:00p	WSW
6	21.5	23.9	3:00p	17.2	6:00a	0	14	38.6	6:00p	WSW
7	21.3	25.3	11:00a	18.2	6:00a	0	15.8	41.8	2:00p	S
8	21.2	24.9	5:00p	17.1	6:00a	0	17.7	46.7	4:00p	SW
9	21.7	29.6	2:00p	16.1	5:00a	0	16.9	48.3	3:00p	SSE
10	22.1	29.4	12:00p	17.1	3:00a	0	18.2	48.3	2:00p	S
11	22.3	26.8	10:00a	16.9	6:00a	0	17.7	45.1	4:00p	SW
12	23	30.9	2:00p	18.8	5:00a	0	20	48.3	3:00p	S
13	24.4	36	2:00p	18.1	6:00a	0	19	43.5	8:00a	S
14	24.3	34.3	1:00p	19.2	6:00a	0	20.1	46.7	3:00p	S
15	26.1	36.8	2:00p	19.6	6:00a	0	19.3	48.3	8:00a	S
16	25.2	35.5	1:00p	20.3	6:00a	0	18.5	43.5	4:00p	S
17	23.1	28.3	10:00a	18.8	6:00a	0	18.7	46.7	2:00p	S
18	22.9	30.7	1:00p	18.7	2:00a	0	20.9	53.1	3:00p	SSW
19	23.1	31.8	1:00p	18.2	6:00a	0	20.4	49.9	4:00p	S
20	26.5	36.9	12:00p	18.1	5:00a	0	20.6	51.5	5:00p	SSW
21	28.1	36.9	4:00p	22.2	6:00a	0	17.5	43.5	10:00a	SE
22	27.1	37.1	1:00p	20.3	6:00a	0	17.7	46.7	5:00p	SE
23	26.2	34.6	11:00a	22.6	12:00m	0	13.7	49.9	9:00a	ENE
24	24.7	30.4	10:00a	21.1	3:00a	0	11.3	37	10:00a	ESE
25	25.3	33	12:00p	20.7	5:00a	0	14.6	43.5	3:00p	SE
26	25.4	32.9	12:00p	21.5	12:00m	0	19	49.9	2:00p	S
27	22.8	28.3	12:00p	18.7	6:00a	0	18.7	51.5	12:00p	S
28	21.7	26.1	11:00a	18.5	5:00a	0	20	51.5	3:00p	SSW
29	21.9	28.4	2:00p	17.3	6:00a	0	19.8	53.1	4:00p	SSE
30	23.6	30.4	11:00a	18.7	6:00a	0	17.4	41.8	2:00p	S

* Weather station not erected until 3 November 2011.

Average Temperature: 23.7°C
Max>=32.0°C: 10
Max Temperature: 37.1°C ON 22 November 2011
Min Temperature: 16.1°C ON 9 November 2011
Max Rain: 2.59mm ON 4 November 2011
Total Rain: 2.59mm
Days of Rain: 1 (>0.2mm), 1(>2mm), 0 (>20mm)
Average Wind Speed: 17.4 kph
Max Wind Speed: 53.1 kph ON 18 November 2011, 29 November 2011
Average Wind Direction: S

gnaraloo wilderness foundation

gnaraloo SEA TURTLE CONSERVATION

MONTHLY CLIMATOLOGICL SUMMARY FOR 1 – 31 DECEMBER 2011

DAY	TEMPERATURE °C					RAIN (mm)	WIND (kph)			
	MEAN	HIGH	TIME	LOW	TIME		AVERAGE SPEED	HIGH	TIME	DOMINANT DIRECTION
1	22.6	25.1	3:00p	19.6	1:00a	0	16.3	38.6	12:00p	WSW
2	22.8	25.2	3:00p	18.1	5:00a	0	7.6	27.4	5:00p	W
3	23.9	25.8	2:00p	22.3	12:00m	0	6.6	30.6	6:00p	W
4*	-	-	-	-	-	0	7.2	32.2	5:00p	SW
5*	-	-	-	-	-	0	11.1	43.5	1:00p	WSW
6	22.8	25.1	3:00p	19.9	12:00m	0	11.7	40.2	3:00p	WSW
7	23.1	25.2	2:00p	19.9	2:00a	0	14.2	37	6:00p	W
8	23.2	25.5	5:00p	20.6	6:00a	0	12.2	38.6	3:00p	SW
9	23.4	25.3	2:00p	20.9	5:00a	0	9.7	35.4	3:00p	WSW
10	23.8	26.9	3:00p	19.6	6:00a	0	8	35.4	3:00p	WSW
11	24	26.1	1:00p	21.4	4:00a	0	5.3	30.6	4:00p	S
12	24.9	28.9	10:00a	21.4	6:00a	0	8.9	37	4:00p	SSW
13	24.8	29.7	11:00a	21.3	12:00m	0	12.4	48.3	2:00p	SSW
14	23.7	28	3:00p	20	6:00a	0	13.4	51.5	3:00p	SSW
15	23.8	26.8	2:00p	20.1	6:00a	0	13.2	51.5	5:00p	SW
16	24	26.8	9:00a	21.3	3:00a	0	11.4	45.1	12:00p	SW
17	25.3	32.5	11:00a	21.6	6:00a	0	10.5	46.7	5:00p	SW
18	25.1	30.9	10:00a	20.9	6:00a	0	15.1	51.5	1:00p	SW
19	25.2	34.6	3:00p	20.5	6:00a	0	13.5	51.5	5:00p	S
20	25.7	32.7	12:00p	20.4	6:00a	0	12.6	38.6	3:00p	S
21	26.8	38.5	1:00p	21.4	6:00a	0	11.3	38.6	3:00p	SSE
22	27.9	41.4	1:00p	23.2	1:00a	0	16.3	48.3	7:00p	S
23	29	39.9	2:00p	23.6	6:00a	0	20.6	46.7	5:00a	S
24	27.5	35.5	11:00a	23.8	5:00a	0	21.4	45.1	3:00p	S
25	28.2	39	1:00p	23.7	6:00a	0	20.6	46.7	4:00p	S
26	27.4	38.1	12:00p	23.4	6:00a	0	17.2	43.5	12:00p	SSW
27	25.2	27.3	3:00p	22.2	6:00a	0	6.3	27.4	5:00p	SSW
28	25.1	26.8	3:00p	23.2	12:00m	0	1.6	27.4	4:00p	W
29	23.6	25.7	12:00p	20.8	12:00m	0	9.5	35.4	4:00p	WSW
30	22.8	25.1	2:00p	19.7	6:00a	0	13.4	38.6	12:00p	WSW
31	23.3	26.3	2:00p	20.3	4:00a	0	14.5	48.3	5:00p	SW

* Temperature data omitted due to temperature recorder malfunction.

Average Temperature: 24.8°C
Max>=32.0°C: 9
Max Temperature: 41.1°C ON 22 December 2011
Min Temperature: 18.1°C ON 2 December 2011
Max Rain: 0.00mm
Total Rain: 0.00mm
Days of Rain: 0 (>0.2mm), 0 (>2mm), 0 (>20mm)
Average Wind Speed: 12.0 kph
Max Wind Speed: 51.5 kph ON 14 December 2011, 15 December 2011, 18 December 2011, 19 December 2011
Average Wind Direction: SW

gnaraloo wilderness foundation

gnaraloo SEA TURTLE CONSERVATION

MONTHLY CLIMATOLOGICAL SUMMARY FOR 1 – 31 JANUARY 2012

DAY	TEMPERATURE °C					RAIN (mm)	WIND (kph)			
	MEAN	HIGH	TIME	LOW	TIME		AVERAGE SPEED	HIGH	TIME	DOMINANT DIRECTION
1	23.1	26.8	11:00a	19.6	6:00a	0	11.9	40.2	1:00p	SW
2	23.5	26.9	2:00p	20.1	5:00a	0	7.7	37	5:00p	SW
3	23.7	26.5	10:00a	20.1	6:00a	0	9.2	33.8	1:00p	WSW
4	23.9	26.5	5:00p	20.9	6:00a	0	6.3	38.6	3:00p	WSW
5	23.8	26	2:00p	21.2	6:00a	0	7.9	33.8	2:00p	WSW
6	24.2	28.2	3:00p	20.8	6:00a	0	9.8	40.2	1:00p	SW
7	25.1	32.9	2:00p	21.3	6:00a	0	14.2	56.3	4:00p	S
8	29.3	40.7	3:00p	21.9	6:00a	0	16.6	51.5	5:00p	SE
9	29.5	35.4	1:00p	26.7	3:00p	0	16.6	51.5	5:00a	E
10	28.9	35.7	2:00p	23.8	5:00a	0	10.9	37	9:00a	ENE
11	28.3	32.3	11:00a	25.2	6:00a	0	11.6	37	6:00p	E
12	28.7	35.2	12:00p	25.6	6:00a	0	6.6	35.4	3:00p	E
13	29	33.9	10:00a	27	12:00m	0	5.3	30.6	8:00a	SE
14	26.9	28.6	3:00p	25.3	12:00m	0	0.5	16.1	11:00a	W
15	25.9	27.9	4:00p	23.8	6:00a	0	0	0	---	---
16	26.4	32.8	12:00p	22.6	7:00a	0	12.9	48.3	3:00p	SW
17	25.6	30.2	11:00a	22.6	6:00a	0	8.9	37	5:00p	WSW
18	25.4	28.1	5:00p	22.9	1:00a	0	4	32.2	6:00p	WSW
19	25.8	27.8	3:00p	23.8	7:00a	0	9.7	45.1	7:00p	SW
20	26.1	29.2	1:00p	23.6	6:00a	0	8.7	43.5	4:00p	SW
21	26.7	28.9	2:00p	23.9	2:00a	0	11.3	41.8	4:00p	SW
22	28.6	35.9	12:00p	24.9	11:00p	0	11.3	46.7	4:00p	SSE
23	27.9	36.9	1:00p	25.2	1:00a	4.4	4.5	41.8	5:00p	SW
24	30.1	37.6	12:00p	26.8	1:00a	0	8.5	37	5:00p	SE
25	31.2	38.9	6:00p	24.3	10:00p	17.4	11.3	56.3	7:00p	E
26	29.7	39.2	4:00p	25.3	1:00a	5.2	9.2	41.8	10:00p	ENE
27	30.7	37.8	5:00p	24.7	5:00a	3.2	14.3	56.3	5:00p	ENE
28	31.3	37.1	2:00p	26	7:00a	0	12.7	54.7	12:00p	ENE
29	30.7	40.1	4:00p	26.7	10:00p	0.6	9.3	53.1	3:00p	WSW
30	28.4	35.1	2:00p	25.2	8:00p	7.4	8.9	54.7	2:00p	ENE
31	27.6	31.4	12:00p	24.9	5:00a	11.6	18.5	53.1	12:00p	N

Average Temperature: 27.3°C
Max>=32.0°C: 17
Max Temperature: 40.7°C ON 8 January 2012
Min Temperature: 19.6°C ON 1 January 2012
Max Rain: 17.4mm ON 25 January 2012
Total Rain: 49.8mm
Days of Rain: 7 (0.2mm), 6 (>2mm), 0 (>20mm)
Average Wind Speed: 9.6 kph
Max Wind Speed: 56.3 kph ON 7 January 2012, 25 January 2012, 27 January 2012
Average Wind Direction: WSW

gnaraloo wilderness foundation

gnaraloo SEA TURTLE CONSERVATION

MONTHLY CLIMATOLOGICAL SUMMARY FOR 1 – 28 FEBRUARY 2012

DAY	TEMPERATURE °C					RAIN (mm)	WIND (kph)			
	MEAN	HIGH	TIME	LOW	TIME		AVERAGE SPEED	HIGH	TIME	DOMINANT DIRECTION
1	27.9	29.3	3:00p	26.2	3:00a	0.6	20.9	38.6	6:00a	NNW
2	27.6	29	12:00p	26.7	10:00p	0	18.7	37	3:00a	NW
3	27.1	29.1	4:00p	25.6	12:00m	0	18.5	45.1	5:00p	SW
4	27.7	33.7	4:00p	23.6	7:00a	0	14.6	41.8	6:00p	S
5	29.1	37.9	3:00p	23.2	5:00a	0	17.7	45.1	9:00a	SE
6	28	33.3	10:00a	25.4	2:00a	0	16.1	33.8	5:00p	NW
7	27.2	29.1	1:00p	25.1	12:00m	0	8.5	29	7:00p	NNW
8	25.8	28.2	1:00p	22.8	7:00a	0	8	30.6	5:00p	WSW
9	26.5	29.6	3:00p	22.7	6:00a	0	10.1	43.5	6:00p	WSW
10	27.7	32.1	6:00p	23.8	7:00a	0	10	40.2	4:00p	SW
11	27.8	33.2	11:00a	23.7	7:00a	0	10.3	38.6	3:00p	SW
12	27.1	34.3	1:00p	23.1	7:00a	0	9.7	38.6	4:00p	S
13	27.4	35.6	2:00p	22.9	6:00a	0	10.5	38.6	8:00a	SSE
14	27.1	35.2	2:00p	22.7	7:00a	0	13.5	41.8	5:00p	S
15	25.8	31.2	12:00p	21.9	6:00a	0	11.1	45.1	4:00p	SW
16	25.5	29.3	11:00a	21.9	7:00a	0	10.3	40.2	4:00p	SW
17	26.2	32.8	1:00p	22.6	7:00a	0	11.7	51.5	5:00p	SW
18	27.1	34.2	1:00p	23.1	7:00a	0	12.1	45.1	1:00p	SSW
19	26.8	33.7	12:00p	22.8	6:00a	0	7.7	40.2	5:00p	SW
20	27.2	29.6	12:00p	24.8	6:00a	0	4.8	29	6:00p	WSW
21	27.9	33.3	11:00a	24.5	3:00a	0	8.2	46.7	8:00p	WSW
22	28.9	37	1:00p	25.3	7:00a	0	8.4	43.5	4:00p	S
23	27.5	33.1	1:00p	23.4	3:00a	1.8	8.9	45.1	4:00p	SW
24	27	36.1	3:00p	22.8	7:00a	0	10.1	41.8	9:00a	SW
25	25.9	32.8	2:00p	22.4	6:00a	0	13.7	45.1	5:00p	SSW
26	24.7	30.8	1:00p	20.7	6:00a	0	14.6	48.3	3:00p	S
27	25.9	33.6	12:00p	21.7	3:00a	0	13.7	45.1	6:00p	S
28*	22.6	24.1	1:00a	22	5:00a	0	0	0	-	-

*Weather station disassembled after 7:00am on 28 February 2012.

Average Temperature: 26.9°C
Max >= 32°C: 17

Max Temperature: 37.9°C ON 5 February 2012
Min Temperature: 20.7°C ON 26 February 2012
Max Rain: 1.8mm ON 23 February 2012
Total Rain: 2.4mm
Days of Rain: 2 (>0.2mm), 0 (>2mm), 0 (>20mm)
Average Wind Speed: 11.5 kph
Max Wind Speed: 51.5 kph ON 17 February 2012
Average Wind Direction: SW

APPENDIX C:

PHOTO PLATES

1 GBN looking north, 2011/12

2 BP7 looking south, 2011/12

3 BP7 looking north, 2011/12

4 BP8 looking south, 2011/12

5 BP8 looking north, 2011/12

6 BP9 looking south, 2011/12

7 Night patrol car park 2011/12

8 Female loggerhead (*Caretta caretta)* at GBR, 2011/12

9 Loggerhead (*Caretta caretta)* track at GBR, 2011/12

10 Loggerhead (*Caretta caretta)* nest at GBR, 2011/12

11 Loggerhead (*Caretta caretta)* hatchling boil at GBR, 2011/12

12 Female green (*Chelonia mydas*) at GBR, 2011/12

13 Green (*Chelonia mydas*) track at GBR, 2011/12

14 Green (*Chelonia mydas*) nest at GBR, 2011/12

15 Example of staked Sampled Nest at GBR, 2011/12

16 Crab disturbance of Sampled Nest at GBR, 2011/12

17 Crab predation of nest at GBR, 2011/12

18 Golden ghost crab (*Ocypode convexa*) with turtle egg at GBR, 2011/12

19 Golden ghost crab (*Ocypode convexa*) with loggerhead hatchling at GBR, 2011/12

20 Running ghost crab (Ocypode ceratophthalma*) at GBR, 2011/12*

21 Tropical shore crab (*Grapsus albolineatus) at GBR, 2011/12*

22 Unidentified crab species at GBR, 2011/12

23 Another unidentified crab species at GBR, 2011/12

24 Feral cat track at GBR, 2011/12

25 Fox (*vulpes vulpes*) track at GBR, 2011/12

26 GTCP presentation to East Carnarvon Primary School, 2011/12

27 GTCP field team with community volunteers at Gnaraloo prior to morning patrol, 2011/12

28 School group with GTCP field team at GBR, 2011/12