gnaraloo wilderness foundation

gnaraloo SEA TURTLE CONSERVATION

Gnaraloo Turtle Conservation Program

Ningaloo Coast World Heritage Area:
Gnaraloo Bay Rookery &
Gnaraloo Cape Farquhar Rookery

Report for Field season 2012/13

www.gnaraloo.org

Gnaraloo Wilderness Foundation & Gnaraloo Turtle Conservation Program

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1 EXECUTIVE SUMMARY

The season 2012/13 saw the completion of a vast scope of research and other work under often protracted demanding and difficult conditions. The entire *Gnaraloo Turtle Conservation Program* (**GTCP**) team (in office and field based) is commended for their work and commitment to season-end, including the release of this report with its further new knowledge and important findings regarding the nesting sea turtles of the Gnaraloo Bay and Gnaraloo Cape Farquhar rookeries.

The GTCP was established in 2008 after 8 previous years of informal surveys by others. The GTCP is dedicated to the protection of endangered marine turtle species and their beach nesting rookeries along a 65 km stretch of coastline on the Ningaloo Reef at Gnaraloo in Western Australia (**See Maps and Photo plates**).

Daily monitoring of turtle tracks in the Gnaraloo Bay Rookery (**GBR**) has been conducted annually from early November to late February since 2008 by scientific GTCP field teams along with a variety of complementary research activities. Surveys of the previously undocumented Gnaraloo Cape Farquhar Rookery (**GCFR**), located approximately 22 km north of the Gnaraloo Homestead, were initiated by the GTCP in 2011/12 to commence gathering data on turtle nesting in this rookery.

The endangered loggerhead turtle (*Caretta caretta*) has been recorded as the primary species nesting in both the GBR and GCFR Survey Areas, along with green turtles (*Chelonia mydas*). This document reports on the activities of the GTCP during the season 2012/13.

Overview

The GTCP was again expanded during 2012/13, closely following the recommendations of the 4 previous years of monitoring (2008/09 – 2011/12). The Sampled Nest surveys first introduced during 2011/12 were continued as well as the monitoring of the GCFR which was also first commenced in 2011/12. Extensive desk top pre-season work to improve and strengthen the program (based on the learning from previous seasons) was undertaken for a month off-site under the supervision and direction of the GTCP Project Manager. The community engagement component of the program was also again successfully expanded during 2012/13. The program won two awards during the season for its work with the Gnaraloo sea turtles.

GBR Day track surveys

Day Surveys were conducted between 2 November 2012 and 28 February 2013. A total of 699 sea turtle nesting activities were recorded in GBR, 312 of which were nests (all species). The first nest was dug on 8 November 2012 and the last on 13 February 2013. Nesting peaked on 23 January 2013. During the week ending on this day, 51 nests were recorded from 92 nesting activities. As with previous seasons, most activities were observed in sub-section BP8 – BP9 (63.8%), followed by GBN – BP7 (25.5%) and BP7 – BP8 (10.7%).h

The season 2012/13 reported the lowest number of turtle nests in the GBR since the program commenced in 2008. The dominant species that utilised the GBR for nesting was the loggerhead which accounted for most nesting activities. It is estimated that one green turtle female utilised the GBR for nesting during the season.

Though feral animal tracks of European Red Fox (*Vulpes vulpes*), feral cats (*Felis catus)* and wild dogs (*Canis lupus familiaris*) were reported for 38 of the 119 survey days in the GBR, no turtle nests in the survey area were predated by feral animals during 2012/13. One cat was sighted within the BGR on several occasions and one digging event (cat) was recorded, but it did not penetrate a nest.

Separate detailed GFACP reports are available at https://gnaraloo.org/our-reports-and-papers/

GBR Night verification surveys

These surveys were conducted periodically from 8 December 2012 until 12 February 2013. The aim was to quantify the margin of error within day track interpretation data for both Species Identification (**SI**) and Nesting Activity Determination (**NAD**), as well as to generate an estimate for Nest detection bias.

Overall, an accuracy of 98.5% was achieved for SI from 68 turtle encounters; and 88.5% for NAD from 52 activity comparisons between night observations and day interpretations the following morning.

Distinguishing between successful and unsuccessful nesting attempts can be challenging given environmental impacts, such as strong winds, on the tracks. Since the GTCP 2010/11, the Nest detection bias in the GBR has been consistently negative, revealing the tendency for the GTCP field researchers to underestimate the number of nests during Day Surveys. The error between night survey verification and the corresponding Day Survey nest count was -15.8 % during 2012/13. Nests were more often identified as Unsuccessful Nesting Attempts (**UNAs**) showing a conservative tendency for the field team.

Night verification surveys will continue in future seasons to verify and improve the accuracy of the GTCP data.

GBR Sampled Nest surveys

A randomised sub-sample of nests (n = 62) across all Sub-sections, referred to as ‘Sample Nests’, were selected within the GBR for daily monitoring of predation (by native and feral animals), environmental impacts and hatching events. Most were loggerhead nests.

No turtle nests in the survey area were predated by feral animals during 2012/13. Most Sampled Nests were disturbed by ghost crabs (90.3%). GBR Sub-section BP8–BP9 had the highest level of predation (as opposed to Disturbance) by crabs, with 47.2% of Sampled Nests being predated at least once by golden ghost crabs (*Ocypode convexa*). All recorded predation events of Sampled Nests were by the golden ghost crab, though the running ghost crab, *Ocypode ceratophthalma*, was also observed burrowing around nests, though no predation events were witnessed. Sub-section GBN–BP7 and the dune zone experienced less crab predation compared to other areas. The reported results were based on the nests which survived the severe Tropical Cyclone Narelle (n=24) and which were monitored for varying, often short (i.e. several weeks), lengths of time depending on when the nests were dug before the cyclone. Thus, the recorded estimates of crab disturbance and predation impacts during 2012/13 are likely low.

Environmental impacts on Sampled Nests were widespread and frequent across the GBR, a large portion of which were associated with severe Tropical Cyclone Narelle. 61.3% of the Sampled Nests were lost due to cyclonic impacts. The beach profile was also altered by the cyclone, with heavy erosion producing steep dune embankments and exposing rocks in previously flat sections of beach. Due to the heavy losses of turtle nests from cyclonic events, the practice of excavating nests found in the high-water zone and relocating them to positions higher up the beach or incubating through artificial means could be considered.

Of the 24 nests that survived the environmental impacts caused by cyclone Narelle, only one had a hatching event witnessed before the end of survey on 28 February 2013. Nests determined to be no longer viable after 82 days of incubation at the GBR should be excavated in future to both check if a clutch was laid, and to determine the relative development stage any eggs had reached.

GCFR Day track surveys

On ground monitoring of the GCFR continued for a second year to monitor turtle use of the rookery and identify species composition and the areas with high nesting activities.

Four surveys, spanning four days each, were conducted throughout the season in December 2012, January 2013 (twice) and February 2013. Overall, 223 activities were recorded over the four survey periods, 57 of which were new. Of the new activities, the majority were identified as loggerhead. Most new Nesting Activities was found within GCFR Sub-section GFR–GLN (3).

A deceased adult male green turtle, and a green and a hawksbill sub-adult of undetermined sex were found at GCFR during the surveys, coupled with the sightings of individuals of breeding size and smaller than breeding size, indicate that the waters surrounding the GCFR may be used as feeding and/or breeding grounds.

Sampling of the GCFR is still in its infancy and with limited data it is not yet possible to definitively comment on the size or importance of this nesting area. Surveys of the GCFR must continue during future seasons.

Comparison of GBR and GCFR

The number of new turtle nesting activities over the four surveys at GCFR was less than half of the activities recorded at GBR during the same time frame. Most nesting activities recorded at GCFR and GBR were attributed to loggerhead turtles.

Green turtles, although making a small percentage of the total new activities, were still found in higher numbers at GCFR than in the entire season at GBR. As most green nesting activities occurred during the first GCFR surveys, it is possible they may nest earlier in the season at GCFR. Continued surveys of greater length and starting earlier in the season are needed to provide a greater understanding of green activity and use of this rookery.

Education and community outreach

Community engagement is an important tool for promoting awareness of turtle conservation. During 2012/13, community engagement occurred again via outlets such as newspaper articles, radio broadcasts, and Facebook posts, as well as school presentations and excursions (at Gnaraloo and elsewhere in Western Australia after the end of the field surveys). Two school groups visited Gnaraloo and participated with the GTCP during the season and another conducted a reconnaissance visit regarding returning the following season in 2013/14. Various school presentations were conducted in Carnarvon and throughout the Perth Metropolitan Area and the program was recognised with two awards.

2 BACKGROUND

2.1 Global and regional perspectives

Effective conservation of long-lived, highly mobile species like sea turtles is limited by the paucity of long-term datasets, especially in remote areas. Consistent, long-term data collection is required to assess nesting patterns and threats to marine turtles in the Indian Ocean (Wallace *et al.*, 2011). Given Gnaraloo's remote geographic location there is limited information available on the sea turtle populations and related environmental and anthropogenic impacts. Monitoring of these rookeries is critical for conservation management of the area.

Since migratory species can cross multiple geo-political boundaries and borders, constructing a single, unified management plan can be difficult. As a result, studies of population size, health, and demographics are often conducted separately. This can affect classification efforts as different studies may have different results depending on local, rather than global populations (Lewison *et al*., 2004, Martin *et al.*, 2007; Nevins *et al.*, 2007). *The Convention on the Conservation of Migratory Species of Wild Animals* (**CMS**), also known as the *Bonn Convention*, acts as a framework with independent instruments evolving to develop models tailored to global conservation needs throughout the migratory range. The *International Union for Conservation of Nature* (**IUCN**) Red List of Threatened species provides conservation status, taxonomic, and distribution information on flora and fauna, often as a global evaluation. The IUCN evaluates each sea turtle species as a single group across their entire range (IUCN, 2012). Australia is also a signatory on *The Convention on International Trade in Endangered Species of Wild Fauna and Flora* (**CITES**) which was designed to ensure international trade in animals and plants doesn't threaten their survival. All sea turtle species are covered by and listed in CITES. Australian marine turtles are also protected at a national level under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (**EPBC Act)** which aims to protect and manage significant flora, fauna, ecological communities, and heritage places, and encompasses *Matters of National Environmental Significance* (**MNES**)**.**

The status of each turtle species known to nest at Gnaraloo are assessed at an international, national and state level. Their conservation status varies between the different Australian states, although in

Western Australia, all three species are considered Rare under the *Wildlife Conservation Act 1950* (Government Gazette, 2012).

The primary threats to sea turtles include predation, environmental factors, and anthropogenic impacts. Predation pressure changes with the life stage of turtles. In Australia, clutches face predation from both native and introduced terrestrial species (Blamires *et al.*, 2003, Limpus 2002). Hatchlings encounter further predation as they head from the nest to the ocean, with birds and marine animals such as sharks (Limpus *et al.*, 2003). Environmental impacts can also have detrimental effects on sea turtle populations. Tropical Cyclones which produce high swells and strong surface currents can disorientate sea turtles from their migratory routes. Strong winds and storm surges are capable of eroding nesting beaches and destroying nests (Pike & Stiner, 2007). Sex is determined by ambient sand temperature during incubation (Woolgar, 2011), so changes in climate could produce a gender bias (Fuentes *et al.*, 2009). Major impacts occur from direct and indirect anthropogenic processes. Commercial harvesting occurred from the early 1930’s until 1973 across Western Australia, including the Ningaloo area (Limpus, 2009).

2.2 Sea turtles of Gnaraloo

Loggerhead turtles (*Caretta caretta*) migrate internationally, foraging in subtropical and temperate regions of the Atlantic, Pacific and Indian Oceans (Dodd, 1988; Witherington *et al.*, 2009). They are known to nest at various locations between 19° and 36° latitudes in both northern and southern hemispheres (Baldwin *et al.,* 2003; Witherington *et al*., 2009). Due to their circum-global distribution, the species has been divided into ten sub-populations or regional management units (**RMUs**) based on the available nesting and genetic data (Wallace *et al.,* 2010). The southeast- Indian Ocean RMU is among the least studied populations, therefore, vital information on loggerhead ecology in the region is lacking. Current census data estimates the annual nesting population for the entire stock to be in the several thousands (Baldwin *et al.,* 2003).

Western Australia is believed to hold all loggerhead nesting in the Southeast Indian Ocean (Dodd, 1988; Conant *et al.,* 2009), with nesting sites spanning from the Shark Bay World Heritage Area (which includes Dirk Hartog Island) through the Ningaloo Coast World Heritage Area (which includes Gnaraloo) to the Muiron Islands north of Exmouth (Conant *et al*., 2009). Western Australia’s population of loggerhead turtles is considered the largest in the country (Conant *et al*., 2009; Limpus, 2009).

Green turtles (*Chelonia mydas*) are an international sea turtle species that forages in subtropical waters. Nesting in Australia occurs from the Ningaloo Coast to the Lacepede Islands (Limpus, 2008). Previous seasons have shown that a small percentage of nests at Gnaraloo belong to green turtles (Hattingh *et al.,* 2011). However, in other rookeries within the Ningaloo region, they are responsible for many of the nests recorded (Markovina, 2008).

Hawksbill turtles (*Eretmochelys imbricata*) have five predominant nesting sites around the world. Two of these nesting sites are in Australia. The main Australian nesting site is on Milman Island within the Great Barrier Reef, though several smaller nesting sites are present within Western Australia. Nesting tends to occur in smaller numbers than other species, with multiple nesting activities across a wide range of sites (Witzell, 1983).

2.3 GTCP overview and context

The *Gnaraloo Turtle Conservation Program* (**GTCP**) is a scientific program that conducts standardized sea turtle surveys during the nesting season. It is based on the Ningaloo Turtle Program (**NTP**) in Exmouth. The overarching goal of the GTCP is to monitor and protect marine turtle rookeries along the southern end of the Ningaloo Reef at Gnaraloo, Western Australia (**Appendix A**). The GTCP currently surveys two sea turtle rookeries – *Gnaraloo Bay Rookery* (**GBR**) and *Gnaraloo Cape Farquhar* (**GCFR**) – where loggerhead turtles are the predominant nesting species, along with green turtles. Hawksbill sea turtles (*Eretmochelys imbricata*) are also found in the region, although nesting has never been confirmed at Gnaraloo. The GTCP conducts daily early morning track surveys to monitor nesting activities, in addition to collecting data on environmental impacts, day vs. night survey data verification, and feral animal predation events. The *Gnaraloo Feral Animal Control Program* (**GFACP**) is linked to and runs in parallel with the GTCP to manage introduced predators such as the European Red Fox (*Vulpes vulpes*), feral cats (*Felis catus*) and wild dogs (*Canis lupus familiaris)* to reduce predation on turtle nests and hatchlings.

Surveys of the GCFR were expanded to include 14km during the season 2012/13 and these nesting beaches were also surveyed more frequently during 2012/13 compared with 2011/12.

The activities of the GTCP and GFACP align with sea turtle conservation goals set at the regional, national, and international levels by legislation and strategic plans. Specifically, the GTCP and GFACP contribute to sea turtle conservation by:

1. supporting the recovery of sea turtle populations and threat abatement for species listed in the EPBC Act as MNES;
2. identifying significant coastal nesting rookeries and critical nesting habitat for loggerhead sea turtles on the Gnaraloo coastline, which were largely unknown or unsurveyed prior to the work by the GTCP in 2008;
3. developing and managing an annual on-ground monitoring program of seasonal sea turtle nesting and feral predator activities at the Gnaraloo rookeries;
4. annually identifying and undertaking management activities to protect the Gnaraloo rookeries from threats that may impact the turtles' reproductive success;
5. implementing an extensive annual training and employment program of graduate scientific professionals as future leaders and decision-makers, including a comprehensive scientific internship program (up to 6 months, fulltime);
6. collaborating with external researchers (e.g., universities and students) to undertake targeted additional turtle research projects to address questions of importance;
7. carrying out an extensive annual educational and community engagement program that includes primary and high schools, post-secondary institutions, community and indigenous groups, non-government organisations, and the public (at the local, national and international scale); and
8. freely sharing information about Gnaraloo's sea turtles with government departments, universities, and sea turtle experts (at the local, national and international level).

2.4 Teams and training

The GTCP's Researcher Recruitment Program was again competitive during 2012/13, with more than 60 qualified and skilled applicants from Australia and overseas. Efforts focused on attracting and appointing capable candidates from the local, national, and international fields.

The final GTCP research team 2012/13 comprised the following persons:

- *Lead Scientific Officer and Project Manager:* **Karen Hattingh** (MPhil in Environmental Science, South Africa): co-founder and lead officer of the GTCP and GFACP since inception, with extensive prior private sector experience.
- *Field Team Leader* (17/11/2012 – 07/04/2013) and *GIS Cartographer* (12/10/2012 – 07/04/2013): **Careena Crossman** (BSc Hons Antarctic Studies, Western Australia); completed NTP training by the Department of Environment and Conservation (**DEC**) in Exmouth and feral animal track training by APMS at Gnaraloo.
- *Field researcher* (14/12/2012 – 07/04/2013) **Andrew Greenley** (BSc Biological Sciences, Conservation and Wildlife Biology, Molecular Biology, Western Australia); completed Turtle track training at Gnaraloo and feral animal track training by APMS at Gnaraloo.
- *Field Community Volunteer Coordinator* (04/12/2012 – 07/04/2013): **Danica Ilich** [BSc Marine Science (Western Australia), Certificate II Outdoor Recreation (Marine Tourism) (Western Australia)]; completed Turtle track training at Gnaraloo and feral animal track training by APMS at Gnaraloo.
- *Field researcher* (26/11/2012 – 13/02/2013): **Justine Arnold** (BSc Marine Science and Environmental Management, in progress, Western Australia); completed Turtle track training at Gnaraloo and feral animal track training by APMS at Gnaraloo.

Assistance was also provided by the following persons for part periods pre-and-during the season: **Colin Valentine, Regina Clery**, **Natalie Connolly, Sheri Gagnon, Wonnita Andrus**, **Nikki Best** and **James Vaughan**.

Prior to travelling to Gnaraloo, some of the GTCP field team members and assistants underwent a period of up to a month of intensive pre-season training and technical work with the GTCP Lead Scientific Officer and Project Manager to further develop and expand the scope of the program during 2012/13.

2.5 Funding and resourcing

Funding for the GTCP 2012/13 was provided entirely by the Gnaraloo Station pastoralist (Paul Richardson) without whom the program would not have been possible. The total program cost of $243,000 included provision of $240,000 (financial and in-kind) by Gnaraloo Station and $3,000 (in-kind) by DEC Exmouth. ESRI Australia, through its Conservation Grant Progra, again provided a full license of ArcGIS software for the season 2012/13.

Funding contributions may be viewed at www.gnaraloo.org/current-past-supporters/

2.6 Approvals

Research by the GTCP was again conducted under a Regulation 17 licence issued by DEC under the *Wildlife Conservation Act 1950* (Western Australia).

3 GNARALOO WEATHER

3.1 GBR Survey Area

This chapter details the weather conditions and storm events experienced at Gnaraloo during 2012/13.

The weather conditions were recorded daily by the GTCP's Davis Pro Vantage 2 weather station. The weather station monitored atmospheric conditions, including temperature, wind speed and direction, and rainfall. Measurements were recorded hourly and downloaded on a weekly basis.

Season 2012/13 was characterized by moderate day-time and mild night-time temperatures. The maximum temperature (44.6°C) was recorded on 6 February 2013, while temperatures fell to as low as 16.5°C on 25 November 2012. Gnaraloo features a prevailing southerly wind which remained relatively consistent during November 2012 – February 2013. Wind speeds reached a maximum of 59.5 km/h (13 January 2013), with a monthly average range of 11.4 – 15.1 km/h. Rainfall was recorded on 17 occasions during 2012/13, totalling 84.4 mm.

Multi-year patterns of temperature, wind speed and rainfall are shown in **Figures 1 – 3**.

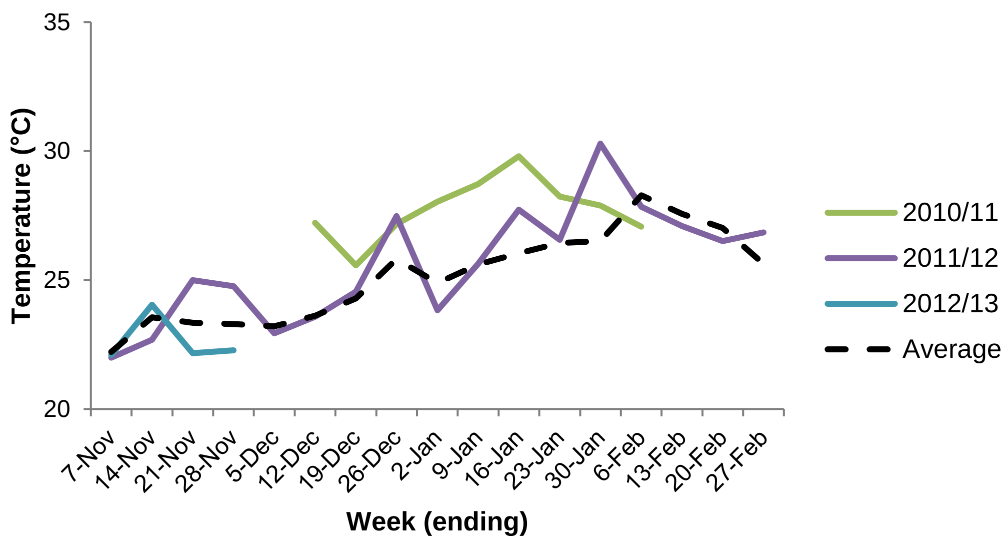

Figure 1: Weekly mean temperature at Gnaraloo Homestead, 2010/11 – 2012/13

Notes: The sensors which measure external temperature and humidity on the Gnaraloo Weather Station malfunctioned during the season for varying periods of time. During these periods, the sensors which measured internal temperature and humidity continued to function normally. Using the data available from both sensors an equation was produced to solve for external temperature.

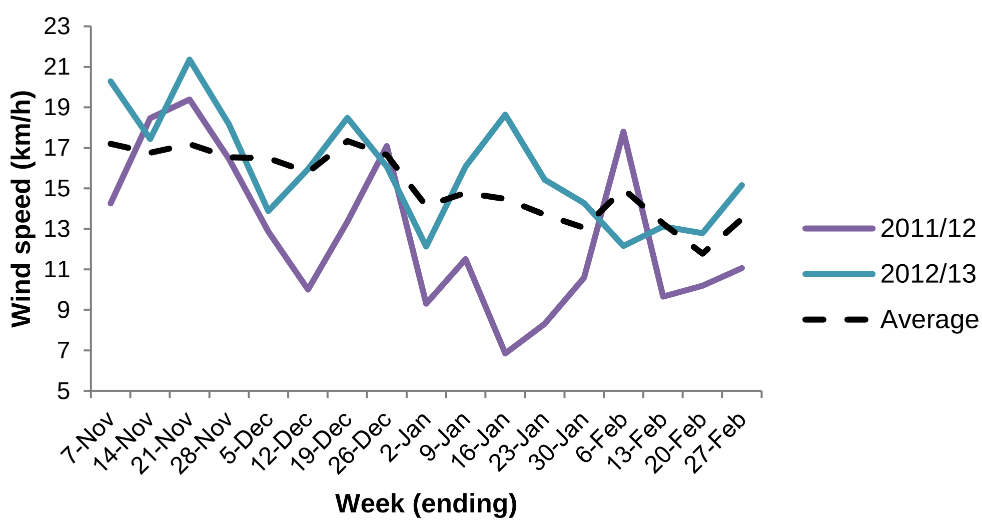

Figure 2: Weekly mean wind speed at Gnaraloo Homestead, 2011/12 – 2012/13

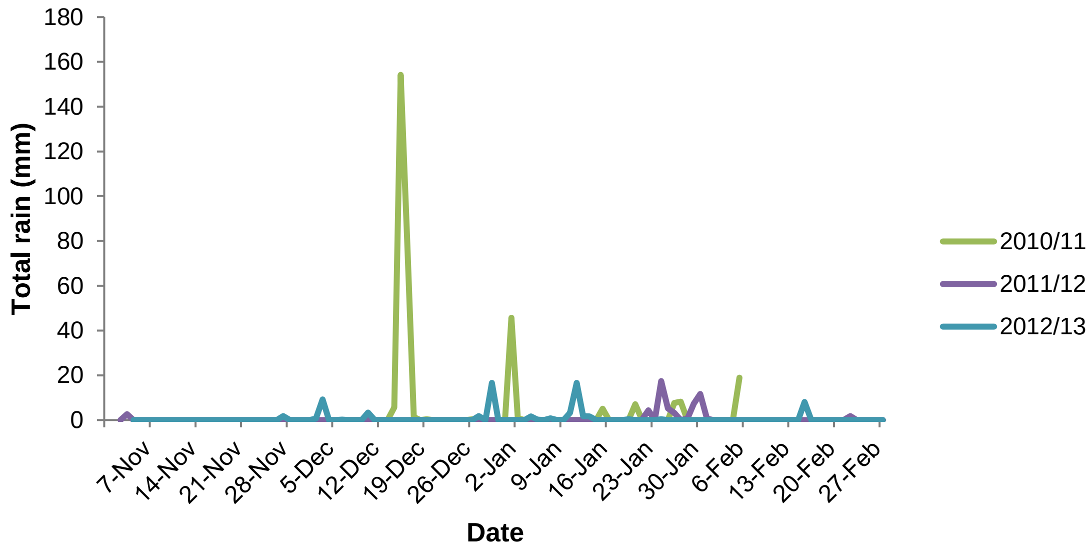

Figure 3: Daily total rain at Gnaraloo Homestead, 2010/11 – 2012/13

3.2 Severe Tropical Cyclone Narelle

On 13 January 2013, severe Tropical Cyclone Narelle was located directly west of Exmouth. Associated rain occurred from 11 January 2013 to 14 January 2013 and the Gnaraloo Weather Station measured 23.2 mm over this 4-day period (**Figure 4**). The lowest barometer reading was 996.2 hPa, recorded at 16h00 on 11 January 2013. Wind speed peaked at 59.5kph at 13h00 on 13 January 2013.

The abnormal tides and wind bought on by the category 3 system caused significant changes to beach morphology in the Gnaraloo Bay Rookery. The consequences of this were many nests being inundated or eroded; several were lost due to exposure or being washed away. It was estimated that due to this event, 61.29% of the season's recorded nests were lost (**Chapter 7**).

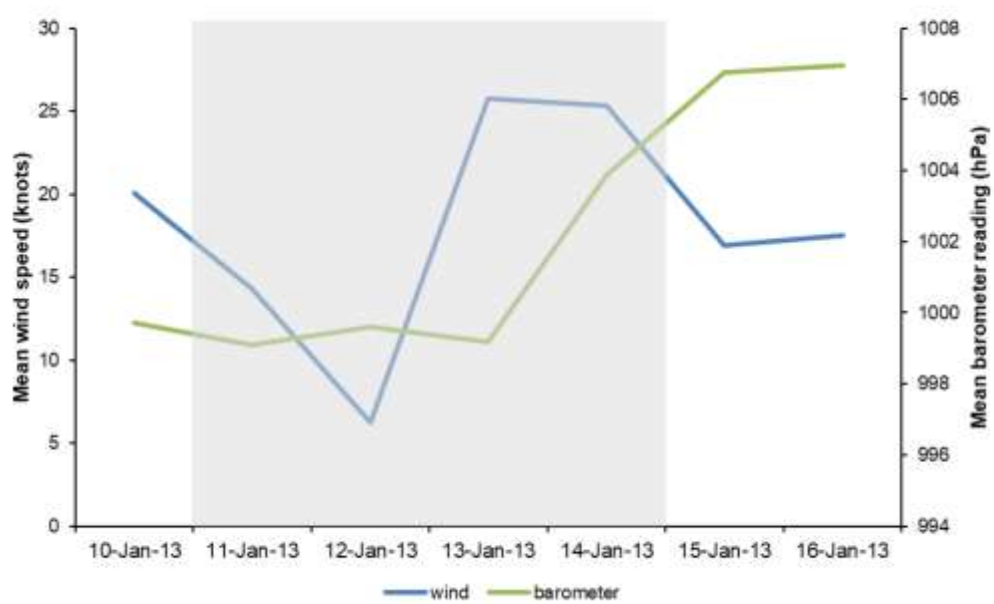

Figure 4: Rain, wind and barometer data from Gnaraloo Weather Station, 10 - 16 January 2013

Notes: Days with rain are shaded in grey, ranging from 0.2 – 7.6 mm of recorded rainfall.

4 FERAL ANIMAL MERI MONITORING

4.1 Introduction

This chapter details the results of feral predator monitoring by the GTCP during Day Surveys in Gnaraloo Bay and Gnaraloo Cape Farquhar in 2012/13.

The *Gnaraloo Feral Animal Control Program* (**GFACP**) has been in operation on Gnaraloo Station since 2008. Under the GFACP, tracking and control efforts at Gnaraloo initially focused primarily on the European Red Fox (*Vulpes vulpes*) given significant previous predation of turtle eggs and hatchlings by foxes before the commencement of the GTCP. The GFACP consequently expanded to also target feral cats (*Felis catus)* and wild dogs (*Canis lupus familiaris*).

The GFACP is a separate but linked complimentary program to the GTCP. Baiting is undertaken with 1080 which is considered to be the most widespread vertebrate pest control method available in Western Australia at the time (Glen and Dickman, 2003, Butcher and Hattingh, 2012).

Separate detailed GFACP reports are available at https://gnaraloo.org/our-reports-and-papers/

At the start of the GFACP in 2008, feral animal control works focused on protecting turtles breeding at the GBR. Each year since then, the baited area has increased and now covers all accessible areas of Gnaraloo. During the season 2011/12, baiting efforts expanded to target wild dogs to further protect the biodiversity of Gnaraloo. As visitors to Gnaraloo are permitted to bring their dogs with them, baiting is not undertaken at or around 3Mile Camp, the Gnaraloo Homestead precinct or the public beach area at Gnaraloo Bay. However, fox baits are laid in and surrounding the Gnaraloo 6Mile area that is used by visitors for shore fishing as this is essential to protect the GBR.

4.2 Objectives

The primary objective of the GTCP in collaboration with GFACP was to achieve 100% protection of incubating turtle eggs and hatchlings from feral animals. Secondary objectives of the GTCP's feral animal control involvement were as follows:

- Provide an immediate link between the GTCP and GFACP to ensure adaptive management of feral animals in real-time;
- Immediately communicate the presence of any feral predators to the appropriate sources, namely the GTCP Project Manager, the Gnaraloo Leaseholder and to the GTCP's contractor Animal Pest Management Services (**APMS**) for action.

For a more detailed account of the work, results and findings of the GFACP, please refer to the separate annual GFACP reports.

4.3 Material and methods

During daily monitoring of the GBR from 2 November 2012 to 28 February 2013 as well as the further reconnaissance surveys of the Gnaraloo Cape Farquhar Rookery (**GCFR**), the GTCP field survey teams recorded the presence or absence of feral predators and/or their tracks.

Under the GTCP's Monitoring, Evaluation, Reporting, Improvement (**MERI**) management strategy, GTCP field researchers walked between the high-water mark (**H**) zone and the edge of vegetation (**E**) zone or the base of dune (**D**) beach zone to observe evidence of feral animals if present in the two rookeries.

The process of defining this designated line was undertaken at the beginning of the season which included testing. GTCP field researchers walked in the different beach zones in each of the three sub-sections in GBR to determine which beach zone allowed the greatest line of sight. The field team also considered which zone of the beach in each sub-section had a greater occurrence of feral animal activities.

The conclusion reached was section dependent. Different regions of the beach were to be patrolled during morning surveys to optimise the chance of seeing feral predator tracks if present. GBN – BP7 (Sub-section 1 in GBR) benefited from two field researchers due to the width of the initial section with one researcher walking at the threshold of the H-and-E-zones, while the other researcher walked a line through the midpoint of the E-zone. As BP7–BP8 (Sub-section 2 in GBR) is a narrow section and lacks an E-zone, the base of the dune was patrolled. BP8–BP9 (Sub-section 3 in GBR) varies in width substantially therefore where present, the E-zone was patrolled, otherwise the base of dune (where the H-zone meets the D-zone) was surveyed.

Tracks and animals were identified in field by the GTCP researchers who had brief fox track training during the DEC Exmouth turtle track training, and they also used *Tracks, Scats and Other Traces: A Field Guide to Australian Mammals, Revised Edition* (Trigg, 2004) as a guide. Photos were then sent to APMS personnel to confirm identifications.

The GTCP Procedure and prior reports contain detailed methods.

4.4 Results

4.4.1 GBR feral predator presence

Feral animal tracks were frequently present during daily monitoring of the GBR. Most of these tracks were identified as feral cats, although tracks of wild dogs and foxes were also reported. Feral animal activity was reported in all sub-sections of GBR (**Figure 5**).

Tracks were recorded for 38 of 119 days of the monitoring period. One cat was sighted within the rookery on several occasions. One digging event on 17 December 2012 (cat) was recorded, but it did not penetrate a nest. It was observed that feral animal activity decreased post baiting events. GBR Sub-section 1 (GBN–BP7) had the highest proportion of days with both feral cat and wild dog tracks. Wild dog tracks were not observed in GBR Sub-sections 2 (BP7-BP8) or 3 (BP8-BP9). GBR had equal fox activity throughout all three sub-sections.

No turtle nests in the survey area were predated by feral animals during the season 2012/13.

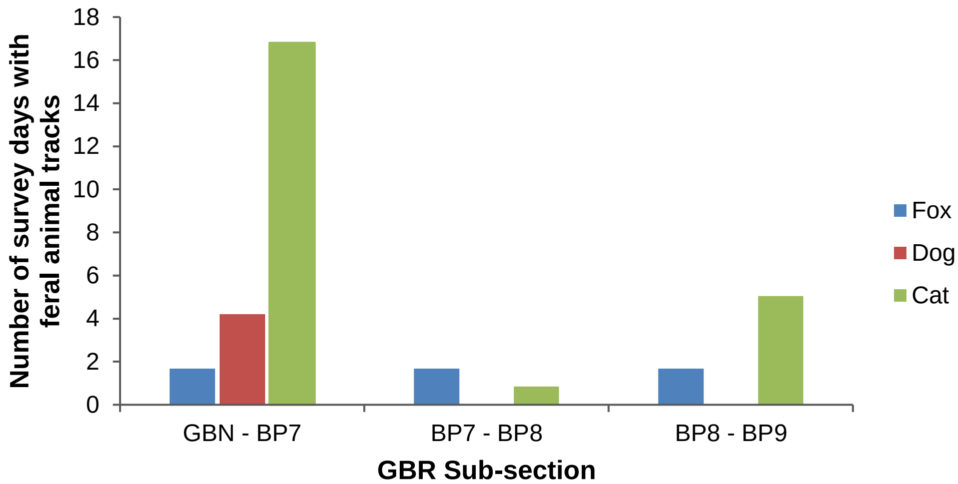

Figure 5: Feral animal presence per GBR Sub-section (01/11/12 - 28/02/13)

4.4.2 Five-year trends of feral predator presence in GBR

Fox presence in the GBR has declined dramatically since the first two years of the GTCP (i.e. from 2008 to 2010). However, there still was some fox presence during the previous GTCP season (2011/12), but still very low levels compared to when the project started (**Figure 6, Figure 7**). In contrast, the number of feral cat tracks has increased, although season 2012/13 recorded less than the previous year. The presence of wild dogs in the GBR has remained at relatively steady levels since 2009/10 with tracks observed on approximately 4% of survey days.

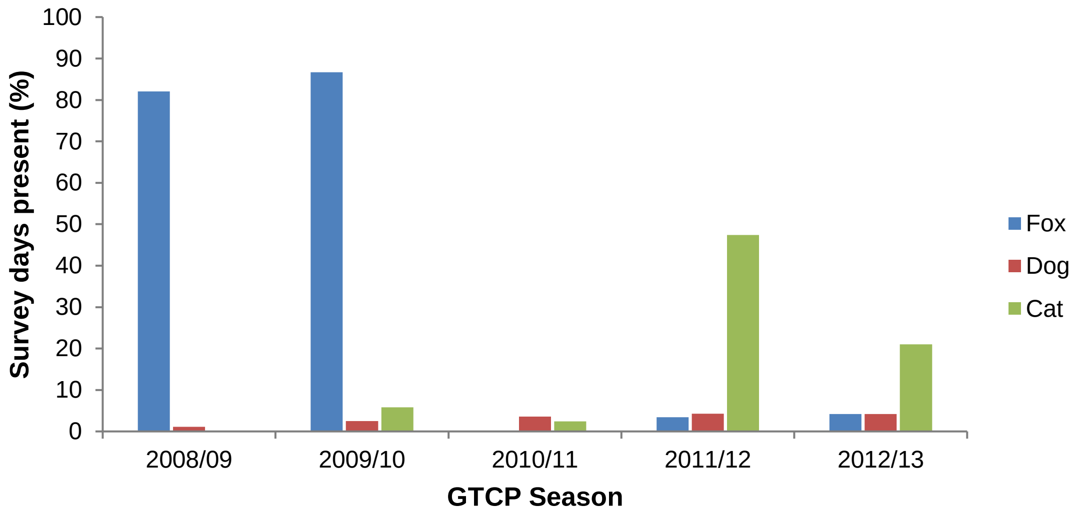

Figure 6: Feral animal presence in GBR, 2008/09 - 2012/13

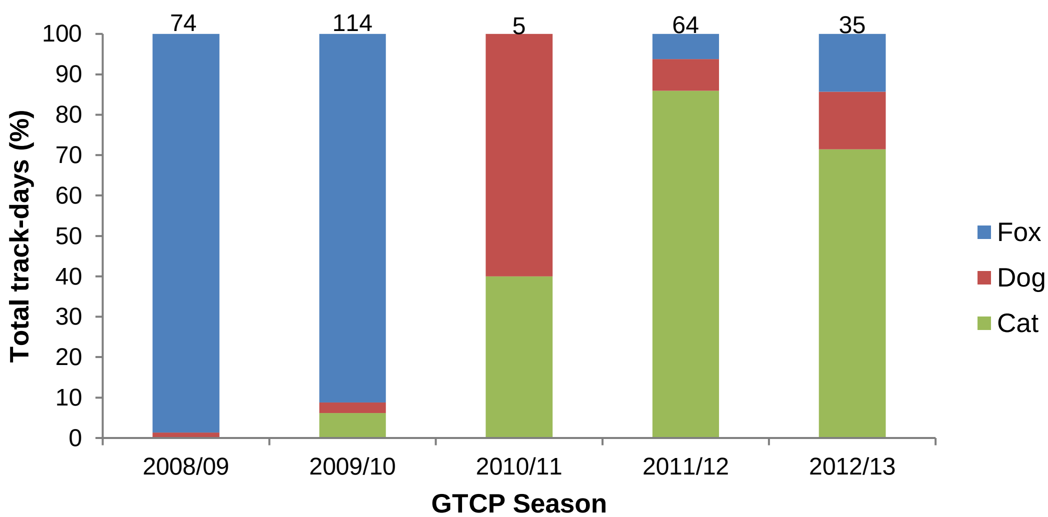

Figure 7: Feral predator composition in GBR, 2008/09 - 2012/13

Notes: The total number of feral animal track-days (i.e. presence) per season is given above each bar. Due to the foraging ranges of different feral animal species, multiple sets of tracks in the GBR on a single day could belong to a single feral animal, and not to multiple animals. This type of scenario was counted as a single track-day for that particular species. This means that a single survey day could yield up to 3 track-days (but only to a maximum of 1 track-day per species).

4.4.3 GCFR feral predator presence

All three species of predator tracks were observed during surveys in the GCFR. These included wild dog (n=1) and cat (n=2) tracks in GCFR Sub-section 1 (GFS–GFH) and fox tracks (n=1) during the December 2012 surveys in GCFR Sub-section 3 (GFS–GFH). Tracks belonging to wild dogs and cats were observed at the Gnaraloo Farquhar Hut by GTCP field researchers.

The impacts on hatchlings or incubating clutches from feral animals in the GCFR still remain mostly unknown due to the minimal surveys of the area, however no evidence of disturbance or predation was observed during the day patrols by the GTCP field teams.

4.5 Discussion

The GTCP's commitment to adaptive and innovative programs has produced a third consecutive season with 100% protection of turtle nests from feral predators. The chain of communication introduced this season was effective in ensuring all involved parties were frequently updated on feral animal activities to allow for immediate adaption and management. The low levels of recorded fox presence and activity during the seasons 2010/11 - 2012/13 indicate that after diminishing the core fox population of Gnaraloo, continued feral animal control by APMS has prevented the population recovering.

Only one digging event was reported on 17 December 2012, the species was confirmed by APMS as a feral cat. This behaviour has not been observed in the GBR before but has been reported elsewhere (Recio *et al.,* 2010). It has been documented that feral cats in other regions often avoid hard baits such as those made with kangaroo meat, yet it has been observed that feral cat activity decreases in GBR after a baiting event (Butcher & Hattingh, 2012). Further investigation is required on the behaviour, eating habits and population of feral cats in Gnaraloo to better tailor the GFACP to be more effective.

It is important to note the continued presence of wild dogs within Gnaraloo property boundaries since 2008/09 to 2012/13. Previous research has suggested that the presence of sheep and goats may prevent wild dogs from taking meat baits despite high quality of baits used (Thomson & Algar, 2000).

It is difficult to interpret results of GCFR with only 16 days surveyed over the nesting season 2012/13. Though there was evidence of tracks, but not predation of turtle nests by feral animals, it would indicate a successful feral animal control program.

4.6 Conclusion

The shift from turtle nests and hatchlings in the GBR predominantly being predated by foxes to 100% protection of turtle nests from all feral predators for a third consecutive season during 2012/13 is a testament to the success of the GTCP and the GFACP. It is a goal that effective feral animal control will continue to yield similar results in future. There remains a pressing need to continue determining where new feral animal threats are infiltrating the Gnaraloo property and developing mitigation strategies to prevent future intrusion in these vulnerable areas. Further investigation on the population of feral animals in GCFR is required to better understand the impact these animals are having on the northern rookery and what is required from a control perspective to protect those turtle nests and hatchlings too.

5 GBR DAY TRACK SURVEYS

5.1 Introduction

This chapter reports on the Day Surveys conducted in the GBR between 2 November 2012 and 28 February 2013.

Formal daily monitoring of turtle tracks at Gnaraloo Bay has been undertaken from early November to late February annually since 2008 by the GTCP. Temporal variation within previous seasons estimates that the nesting period (as opposed to the hatching period) at Gnaraloo begins at approximately 17 November each year, peaks at 10 January and concludes by 22 February (Hattingh et al., 2011). Variation in the number of nesting activities during subsequent nesting seasons can provide important insights into the population health (Limpus 2009). The analyses undertaken by the GTCP provide a greater insight into the nesting habits of the sea turtles frequenting Gnaraloo. Due their slow growth and late maturity, sea turtles are intrinsically vulnerable to anthropogenic activities, therefore continuous monitoring with the goal of building a long-term data set will be critical for the understanding of the nesting trends at Gnaraloo within the Southern Ningaloo Coast World Heritage Area.

5.2 Objectives

The objectives of the day monitoring program in the GBR during the season 2012/13 were:

- Collect and interpret data on sea turtle nesting activities through daily track monitoring;
- Identify the species of nesting sea turtles and the types of nesting activities;
- Collect and interpret data on disturbance and predation of turtle nests (eggs and hatchlings) by introduced and native predators and/or by environmental factors (refer to Sampled Nest Chapter);
- Continue to analyse and interpret trends in turtle nesting activities.

5.3 Material and methods

5.3.1 Survey Area

Daily monitoring during the season 2012/13 was carried out in the GBR (refer to Maps) located between -23.76708°S, 113.54584°E and -23.72195°S, 113.57750°E. This mainland survey area is approximately 6.7 km in length and consists of the calm, relatively static beach of Gnaraloo Bay northward to beaches featuring dynamic beach topography and mobile dune systems. Previous reef surveys undertaken in the Gnaraloo Bay marine sanctuary zone of the Ningaloo Marine Park revealed a diverse benthic habitat (Van Keulen & Langdon, 2011). Due to the differences in beach dynamics throughout the study area, it is separated as follows: GBN – BP7 (3.35 km) (Sub-section 1), BP7 – BP8 (1.63 km) (Sub-section 2) and BP8 – BP9 (1.72 km) (Sub-section 3).

5.3.2 GBR Day Survey protocol

Daily monitoring of GBR was undertaken from 2 November 2012 to 28 February 2013 (n = 119 days). The 1 November 2012 survey was not performed due to technical issues.

Formal monitoring was undertaken at GBR from 2 – 8 November 2012 by GTCP field researchers. From 8 – 13 November 2012, Gnaraloo Station staff assisted with day monitoring while GTCP team members were receiving turtle tracking training by DEC in Exmouth. Gnaraloo Station staff members were required to fill the data sheets to the best of their ability including recording a GPS location. Two UTs were recorded in this period. On 13 November 2012, two activities were identified as nests during the morning survey. When GTCP field researchers returned that afternoon, both recorded activities were checked and confirmed as nests.

The GBR was walked by two researchers and all turtle nesting activities were recorded with their location noted using a handheld Global Positioning System (**GPS**) unit. Nesting activities recorded included: Nest (**N**), Unsuccessful Nesting Attempt (**UNA**), U Track (**UT**) or Unidentified Nesting Activity (**Ua**). The species responsible for each activity was assessed, if track quality allowed, based on track characteristics.

The GTCP Procedure contains detailed methods and equipment used.

5.3.3 Estimating the number of nesting loggerhead females

The number of female loggerhead sea turtles that nested within the GBR during the season 2012/13 was estimated based on a scientific literature review for clutch frequency. We divided the number of loggerhead nests recorded during the season by the mean of the estimated clutch frequency (**ECF**) and the mean ECF ± 1 SD.

5.3.4 Statistical analysis

Variation in the total number of nesting activities, number of nests and nesting success rate was analysed using linear regression in the Data Analysis add-on package in MS Excel.

5.4 Results

5.4.1 Nesting Activities

From the period of 2 November 2012 to 28 February 2013, 699 sea turtle Nesting Activities were recorded (**Table 1**), comprising of 312 N (44.6%), 195 UNA (27.9%) and 165 UT (23.6%). 27 UA (3.8%) could not be identified due to degradation by tide or wind erosion.

Loggerhead turtles accounted for 672 of 699 (96.1%) activities reported in the GBR.

Loggerhead turtles dug the majority of nests (97.1%) in GBR for the 2012/13 season with seven nests allocated to green turtles. Two nests were unable to be identified to species due to degradation by tide or wind erosion.

Table 1: Nesting Activities in GBR (02/11/12 - 28/02/13)

	NESTING ACTIVITY TYPE				
	NEST (N)	**UNSUCCESSFUL NESTING ATTEMPT (UNA)**	**U TRACK (UT)**	**UNIDENTIFIED NESTING ACTIVITY (UA)**	**TOTAL**
LOGGERHEAD	303	184	163	22	672
GREEN	7	2	1	0	10
UNKNOWN	2	9	1	5	17
TOTAL	**312**	**195**	**165**	**27**	**699**

5.4.2 Temporal distribution of Nesting Activities

The sea turtle nesting season 2012/13 at Gnaraloo Bay began on 8 November 2012 and ceased on 13 February 2013 (monitoring continued until 28 February 2013).

Nesting steadily increased from early November to mid December 2012 then plateaued slightly with an average of 27 nests per week until nesting peaked from 17 – 24 January 2013 with 50 nests dug (**Figure 8**). From there, nesting decreased slowly over a three-week period and concluded on 13 February 2013. A sharp decrease in all nesting activities occurred during the week of 10 – 17 January 2013, during a period of unusual tidal conditions caused by severe Tropical Cyclone Narelle.

Although nesting fluctuated greatly throughout the season 2012/13, the peak period occurred mid to late January 2013, as recorded in previous seasons. On 23 January 2013, the seasonal peak of 15 loggerhead nests was reported.

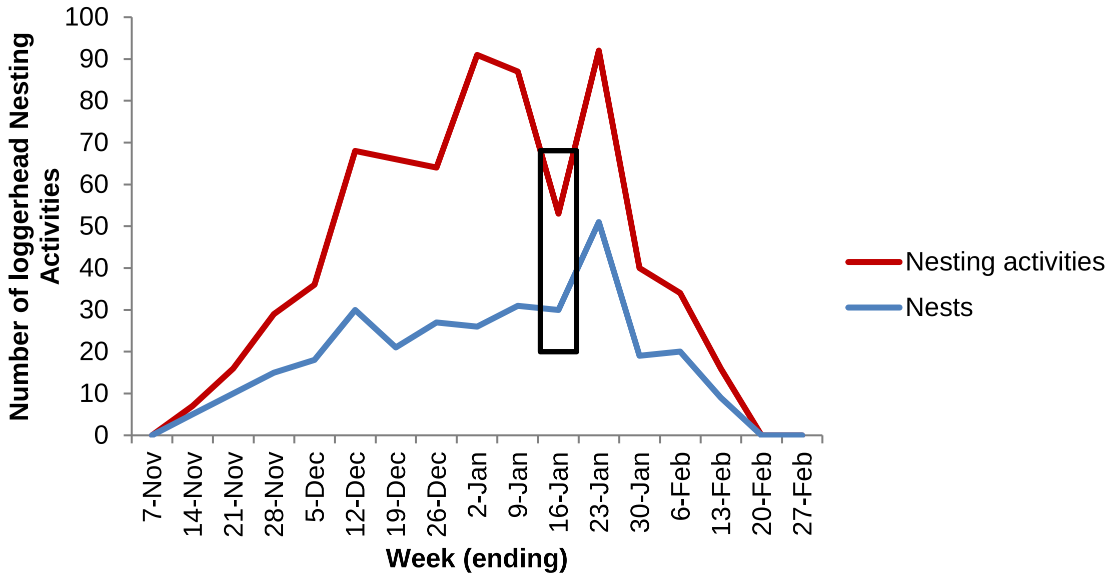

Figure 8: Loggerhead Nesting Activities and nests per week in GBR during 2012/13

Notes: The square highlights the dates of Cyclone Narelle which altered environmental conditions from 11 – 14 January 2013.

5.4.3 Spatial distribution of Nesting Activities

Nesting activities during 2012/13 were concentrated in Sub-section BP8 – BP9 (63.8%) followed by GBN – BP7 (25.5%) and BP7 – BP8 (10.7%). Nests followed the same pattern, with the majority occurring in Sub-section BP8 - BP9 (62.8%) followed by Sub-sections GBN - BP7 (30.4%) and BP7 – BP8 (6.7%) (**Figure 9**).

All Green nests were dug in GBN – BP7 this season. This distribution of Nesting Activities and nests is consistent with previous seasons. Mapping of the nest densities within each Sub-section revealed an intermittent distribution with hotspots in Sub-section BP8 – BP9 and a more uniform distribution throughout Sub-sections GBN – BP7 and BP7 – BP8 (**Appendix A**).

Overall, Nesting Activities were predominantly located within the high-water (**H**) horizontal beach zone (50.2%). The intertidal (**I**) horizontal beach zone recorded the lowest number of nesting activities (2.4%) (**Figure 10**).

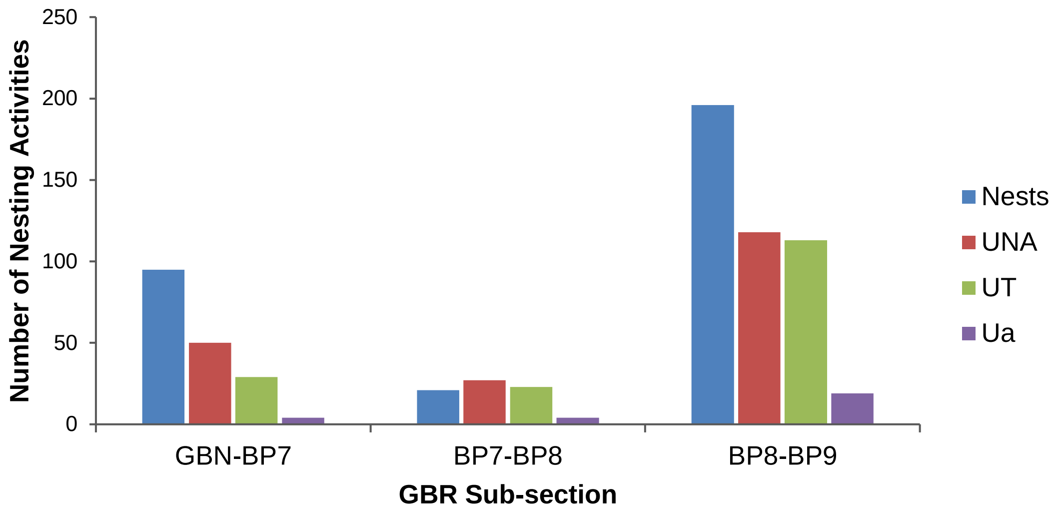

Figure 9: Nesting Activities in GBR Sub-sections, 02/11/2012 – 28/02/2013

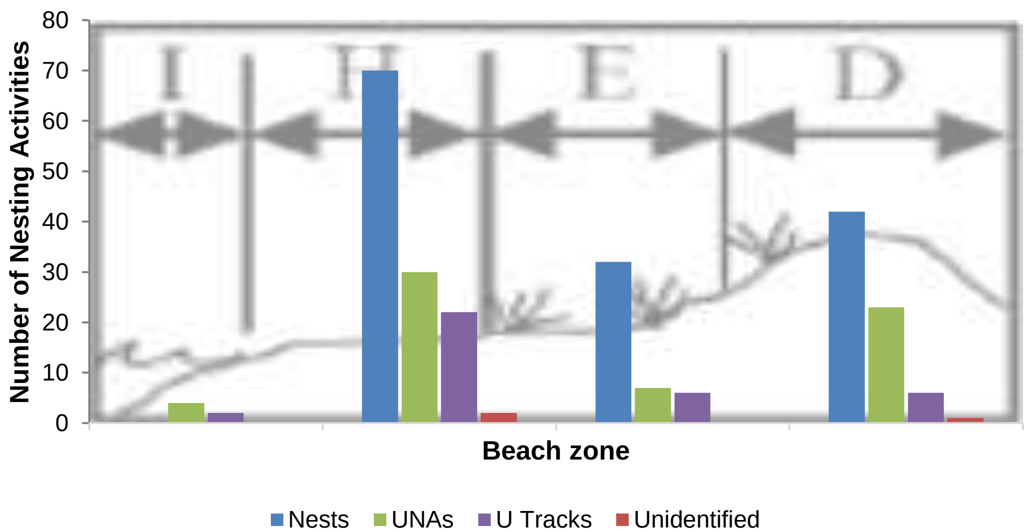

Figure 10: Horizontal distribution of some Nesting Activities in GBR

Notes: Not all Nesting Activities were assigned a beach zone.

5.4.4 Multi-year trends in GBR

5.4.4.1 Species and nesting activities since 2008/09

Loggerheads are the dominant species recorded as nesting in the GBR during 2008/09 – 2012/13 (**Figure 11**). Greens also use the rookery for nesting, albeit in low numbers.

Figure 11: Nests per species in GBR during 2008/09–2012/13

The total number of Nesting Activities (i.e. inclusive of Nests, UNA, UT and Ua) recorded per season during 2009/10 – 2012/13 ranged from 699 (2012/13) to 813 (2009/10), with an average of 770.5 [Standard Error (**SE**) = 25.6].

A non-significant decline in the number of total Nesting Activities per season was observed during seasons 2009/10 – 2012/13 (F1, 2 = 16.32, P = 0.056, r2 = 0.89, **Figure 12**).

The total number of nests per season during 2008/09 – 2012/13 ranged from 312 (2012/13) to 522 (2009/10), with an average of 388.0 (SE = 38.1). A weak negative trend in the number of nests during seasons 2008/09 – 2015/16 was apparent, although this trend was non-significant (F1, 3 = 0.61, P = 0.49, r2 = 0.17, **Figure 13**). Season 2012/13 had the lowest number of total Nesting Activities and nests since the start of monitoring in 2008/09.

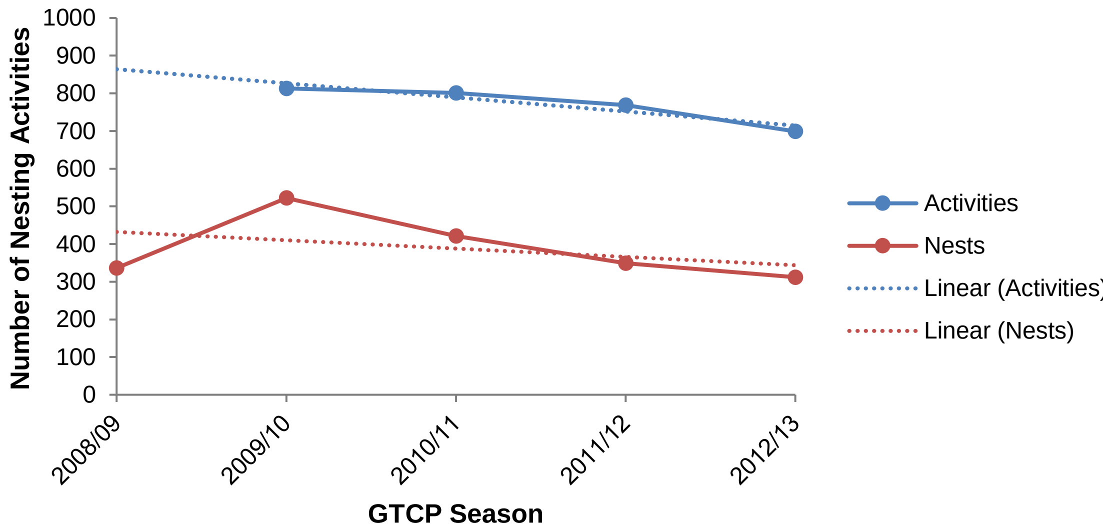

Figure 12: Total Nesting Activities in GBR during 2009/10 – 2012/13

Notes: Season 2008/09 Nesting Activities data are not included as researchers did not record the details of emergences that did not result in a nest (i.e. UNA, UT).

Overall nesting activity progressed with the same pattern as previous seasons (**Figure 13, Figure 14**).

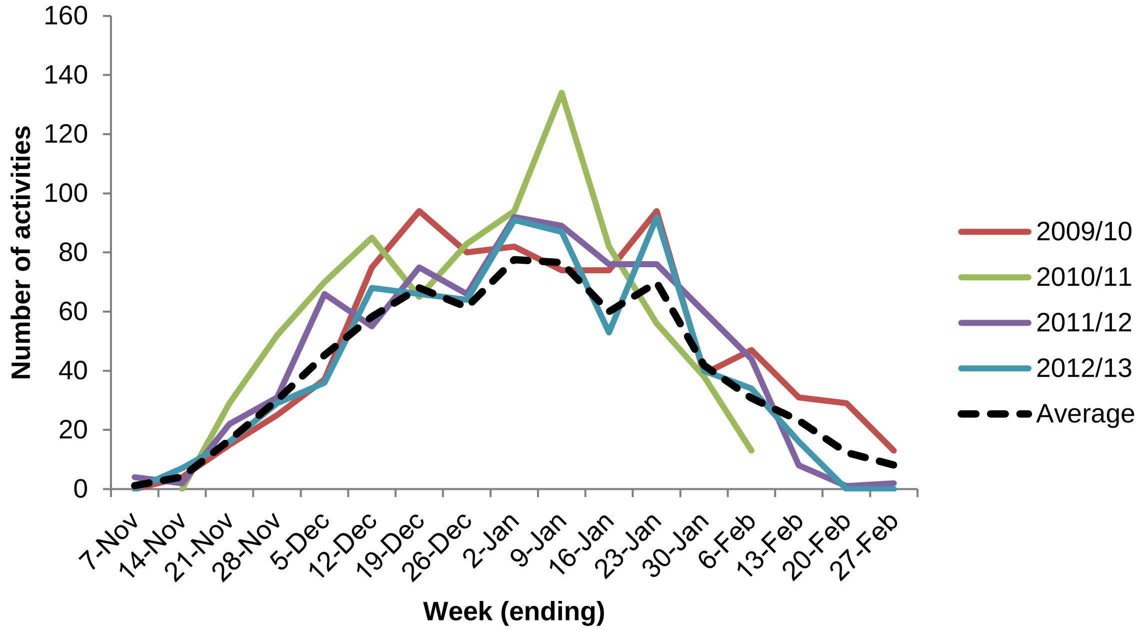

Figure 13: Weekly Nesting Activities in GBR during 2009/10 – 2012/13

Notes: Season 2008/09 Nesting Activity data are not included as researchers did not record the details of emergences that did not result in a nest (i.e., UNA, UT).

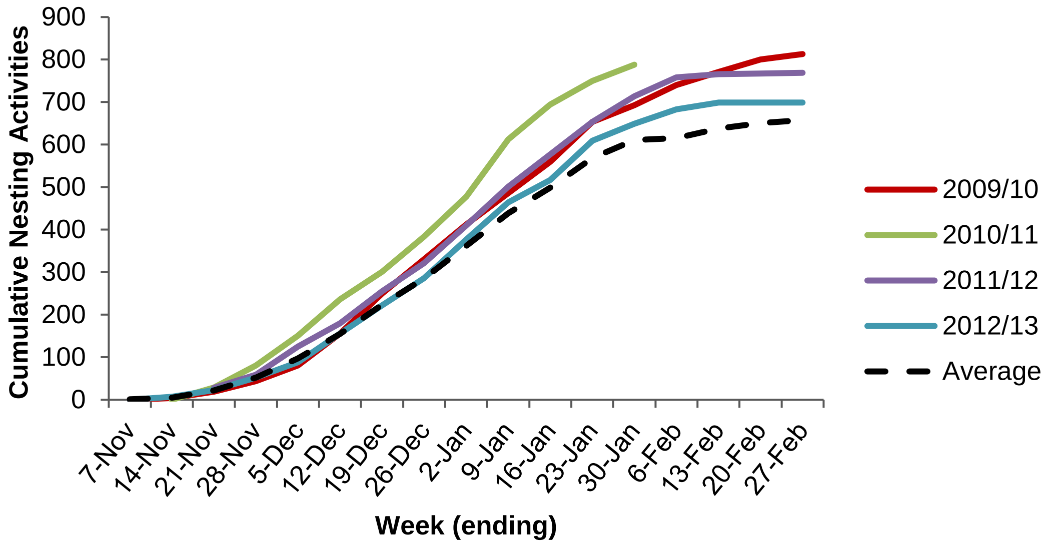

Figure 14: Cumulative weekly Nesting Activities in GBR during 2009/10 - 2012/13

5.4.4.2 Nesting Activities and nests by Sub-section since 2008/09

The number of Nesting Activities and nests recorded per season in the GBR during the monitoring period of 1 November to 28 February are shown in **Figure 15** and **Figure 16**. Very few nests are dug in BP7 – BP8 each season.

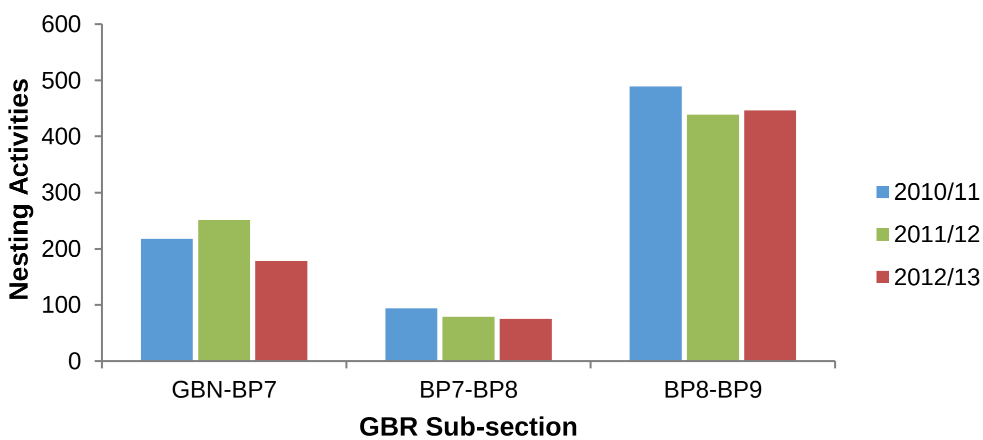

Figure 15: Nesting Activities in GBR Sub-sections during 2010/11 - 2012/13

Notes: Different GBR Sub-section breaks were used during the season 2009/10 (i.e., GBN–BP6, BP6–BP7 and BP7–BP9) and the locations of some UNA and UT were not recorded, so it was not possible to allocate these activities to particular Sub-sections. Therefore, this season is excluded.

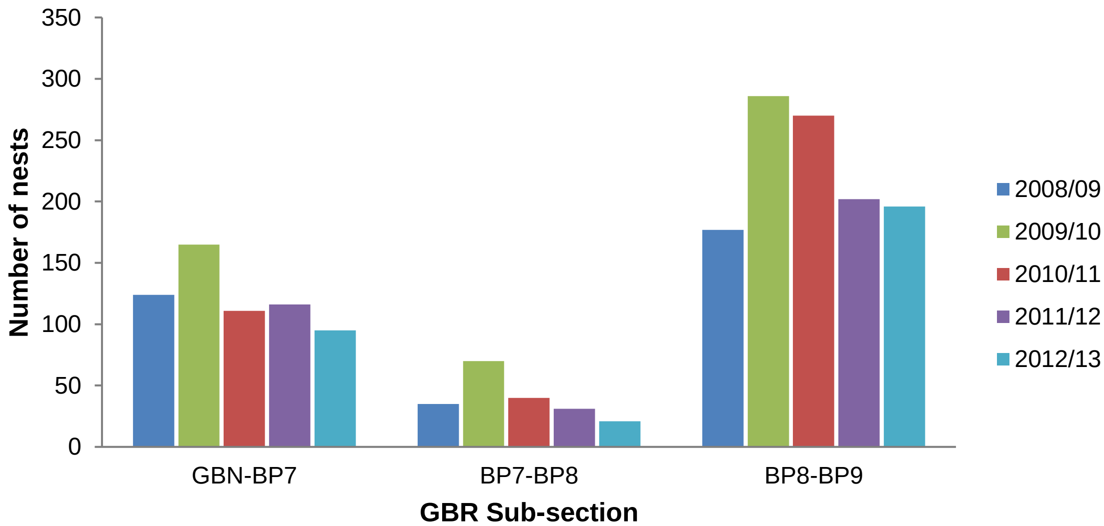

Figure 16: Nests in each GBR Sub-section during 2008/09 - 2012/13

5.4.4.3 Nesting Success since 2009/10

The overall Nesting Success in the GBR based on GTCP Day Survey data during the seasons 2009/10 – 2012/13 ranged from 46.0 % (2011/12) to 64.2% (2009/10), with an average of 52.4% (SE = 4.2). (**Figure 17**).

Season 2012/13 recorded a 46.4% nesting success rate, which was below average.

Green turtles were more successful than loggerhead turtles with 70% of green turtle emergences resulted in a nest compared to 46.7% for loggerhead turtles.

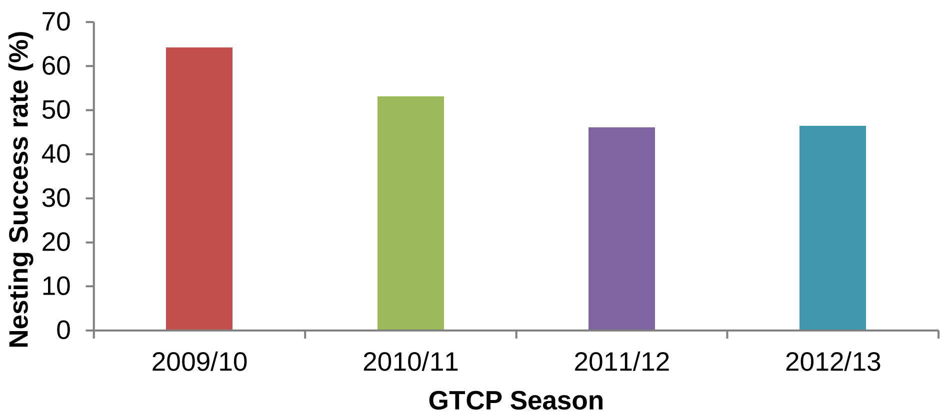

Figure 17: Nesting Success rate in GBR during 2009/10 - 2012/13

5.4.5 Estimated number of nesting female loggerhead turtles

A total of 303 loggerhead turtle nests were observed in the GBR during Day Surveys in 2012/13. The mean of the estimated clutch frequency (**ECF**) per year derived from satellite telemetry available for loggerheads was 4.78 [standard deviation (**SD**) = 0.45] per season per female (Scott, 2006; Rees *et al*., 2008; Rees *et al*., 2010; Tucker, 2010).

Using the mean ECF ± 1 SD, we estimate that 63 female loggerhead turtles nested in the GBR during 2012/13, with lower and upper bounds of 58 and 71.

It is estimated that one green turtle female utilised GBR for nesting during the season 2012/13 based on a scientific literature review for green clutch frequency (Limpus *et al.*, 2001). A green turtle nest was dug in GBN – BP7 on average every 14 (13.86) days throughout the nesting season.

5.4.6 Strandings and mortalities

One stranding occurred during the turtle monitoring period 2012/13. On 3 December 2012, an adult female loggerhead became stuck in between rocks on the exposed reef at low tide after nesting in sub-section BP7 – BP8. A rescue was undertaken successfully by two GTCP field researchers.

During the season 2012/13, six mortalities were recorded in the GBR Survey Area (**Table 2**) All occurred in sub-section GBN – BP7 and all were green turtles. Detailed mortality reports and photographs for these specimens were recorded.

Table 2: Mortality events during the GTCP season 2012/13

SUB-SECTION	DATE	SPECIES	MATURITY	SEX
GBN-BP7	1 November 2012	Green	Immature	Female
GBN-BP7	30 November 2012	Green	Immature	Female
GBN-BP7	4 December 2012	Green	Adult	Male
GBN-BP7	26 December 2012	Green	Immature	Unknown
GBN-BP7	13 January 2013	Green	Immature	Unknown
GBN-BP7	13 February 2013	Green	Immature	Unknown

5.5 Discussion

During the GTCP monitoring season, a total of 699 sea turtle nesting activities were recorded, of those, 312 were determined to be nests. 97.1% of these nests were dug by loggerhead turtles. It is estimated that one green turtle utilised the GBR Survey Area for nesting this season. The GBR had 91 nesting activities and 50 nests per week during its peak period. Though the overall nest total is lower than previous seasons, the estimated population of nesting females, both loggerhead and green, are within the range estimated in previous seasons. Continuing full-season site-specific research into the clutch frequency of sea turtles at their various nesting locations in Western Australia will strengthen the accuracy of female population estimates.

The GTCP field team recorded 48.6% of nests in the GBR Survey Area between the intertidal and the edge of vegetation beach zones during the season 2012/13, making these nests vulnerable to tidal inundation and exposure from sand movement.

The season 2012/13 estimated Nesting Success to be 46.4%. Nesting Success was quantified using data collected during night verification surveys (**Chapter 6**).

There was a higher rate of mortality in comparison to previous seasons with several immature green sea turtles (which have been known to inhabit and use the Ningaloo Lagoon along the Gnaraloo coastline as a pre-adult coastal feeding zone) found dead in or near the GBR Survey Area this season. Known causes of mortality in sea turtles include direct take, fisheries by-catch, disease, boat related mortality, pollution, global warming and decline of food sources (Witherington *et al,* 2009). Of these, it is unlikely that any died as a direct result of boat injury, direct take or fisheries by-catch. Research on the health of Gnaraloo Bay and its inhabitants is limited, therefore, causes of mortality are unknown. Further investigation via necropsy is required in response to the green turtle mortalities this season.

5.6 Conclusion

Day monitoring activities during 2012/13 successfully collected further data on nesting sea turtles along the Gnaraloo coastline to contribute to the baseline data recorded by the GTCP since 2008. The continuance of daily monitoring by the GTCP for at least another 25 years is recommended to understand the sea turtles nesting at Gnaraloo Bay. It is also important to carry on the annual full season monitoring of Gnaraloo Bay as the sea turtle species that frequent Gnaraloo are listed as endangered, vulnerable and/or threatened.

The GTCP season 2012/13 recorded the lowest number of nests and nesting activities since the commencement of the formal monitoring program in 2008. The timing of nesting in the GBR during 2012/13 was similar to previous seasons with activity peaking between mid-December and late January. As the GBR Day Survey data set continues to grow, it will be valuable to conduct an analysis of nesting phenology in relation to broad environmental parameters. Overall, there has been a decline in nesting activity within the GBR since 2009/10. These trends have been driven primarily by decreases in nesting activity in all GBR Sub-sections. The overall Nesting Success rate within the GBR, and within each of the GBR Sub-sections, has not shown any trend over time. Since 2008/09, the total number of nests has declined in sub-section GBN–BP7 and marginally in sub-section BP7–BP8. Due to the very short duration of the GBR Day Survey time series, these results should be interpreted cautiously. A biologically meaningful trend analysis will be possible in future given continued consistent monitoring of the GBR. The decline in nesting activity should be carefully monitored due to the suspected long-standing impact of fox predation at Gnaraloo prior to 2008.

6 GBR NIGHT VERIFICATION SURVEYS

6.1 Introduction

This chapter reports on the night surveys conducted in the GBR. The use of daytime beach surveys to monitor sea turtle nesting activity involves potential for error because it relies on the ability of a researcher to correctly interpret subtle track characteristics to infer the type of nesting activity (e.g., nest versus UNA) and the species responsible (Schroeder & Murphy, 1999). Furthermore, various environmental or ecological conditions (e.g., high winds, tidal wash, presence of vegetation, high nest density) can obscure track characteristics, making reliable interpretation even more challenging (Whiting, 2008). While well-developed guidelines exist to help researchers interpret tracks (Schroeder & Murphy, 1999), the subjective nature of this method and the potential for track degradation or masking means that 100% accuracy is challenging to achieve for nesting activity identification and species assessments. Thus, for programs, such as the GTCP, that rely primarily on daytime beach track surveys as an index of nesting turtle abundance, it is critical to verify track assessments during day surveys via comparison with direct, independent observations of turtle nesting activities during night surveys (Schroeder & Murphy, 1999). In addition to facilitating critical data verification, night surveys also allow researchers to gain an improved understanding of turtle nesting behaviour and the physical characteristics of tracks produced by different nesting activities.

6.2 Objectives

The objectives of the Night Verification Surveys in the GBR during 2012/13 were to:

- Determine the accuracy of Species Identification (**SI**) and Nesting Activity Determination (**NAD**) assessments during morning track monitoring;
- Improve the knowledge and field observational skills of the GTCP field researchers to correctly identify turtle species through tracks (particularly loggerheads vs. hawksbill turtles) and determine nesting activities (particularly the characteristics of nests vs. unsuccessful nesting attempts (**UNAs**), to increase the accuracy of the day monitoring efforts;

- Confirm the possible presence of nesting hawksbill (*Eretmochelys imbricata*) turtles in the GBR by visual identification using morphological features; and
- Determine Nesting Success using the sub sample of turtles witnessed nesting during night monitoring.

6.3 Material and methods

6.3.1 Night survey methodology

The night patrol protocols followed are set out in detail in the *GTCP Monitoring Procedure 2012/13* (Hattingh *et al.,* 2013). The accuracy of track interpretation by the GTCP field researchers for species and activity identification was calculated by comparing direct night observations to monitors' interpretations on the following day.

It was mandatory that two GTCP field researchers were present during each of the scheduled night surveys for safety and to maximise the number of turtles sampled per night. On a given night survey, researchers searched the beach in the GBR after sunset for up to 4 hours. Night surveys were conducted primarily in GBR Sub-section BP8 – BP9, where most of the nesting activity occurs (**Chapter 5**). However, opportunistic night observations were also made in GBR Sub-section BP7 – BP8 on the way to and from Sub-section BP8 – BP9. For an activity to be considered verified, the turtle had to be observed during a nesting phase that would ensure 100% certainty of the activity (i.e. N, UNA or UT). Nests were considered verified if a turtle was seen covering, but not laying eggs. For UNA, the turtle had to be seen at the egg chamber phase at the latest and observed returning to the ocean without laying eggs. For UT, the turtle had to be seen at the emergence phase at the latest and witnessed returning to the ocean without attempting to dig a nest.

6.3.2 Targeted sample sizes and accuracies

The *GTCP Procedure 2012/13* contains the calculations for the targeted sample sizes and accuracies.

A sample size of 96 turtle encounters was calculated to statistically quantify accuracy of species identification (**SI**). The target sample size was calculated (0.95 confidence interval, 0.1 margin of error, and an average accuracy from previous seasons of 97.5%), with a desired accuracy of 95%.

For Nesting Activity Determination (**NAD**) verification, a target sample size of 54 verified nesting activities was calculated (0.95 confidence interval, 0.1 margin of error, and an average accuracy from previous seasons of 84.5%), with a desired accuracy of 80%.

Upon reaching these sample sizes, the seasonal accuracy for SI and NAD was determined. If the desired accuracy (95% for SI and 80% for NAD) was not met, the target sample size would be recalculated using the current season's level of accuracy and additional observations were made until the revised target sample size was achieved.

6.3.3 Nest detection bias

A Nest detection bias was determined by comparing the Day track interpretations with the independent, direct observations during night surveys. The number of nests recorded during night surveys was taken to represent the true value, while the number of nests counted during Day Surveys represented the observed value. The discrepancy between true and observed number of nests was calculated for the season 2012/13 to determine any over-or-underestimation of nest numbers.

6.4 Results

6.4.1 Summary

The GTCP researchers conducted night patrols periodically in the GBR from 8 December 2012 until 12 February 2013. Field Researchers observed turtles for 29 of 37 nights with a total of 68 turtles encountered during surveying hours. The highest number of turtle encounters (6) occurred on 18 January 2013, this night also had the highest number of successful nests.

6.4.2 SI accuracy

Night monitors identified all 68 turtles encountered as loggerheads *(C. caretta*).

On 9 December 2012 (the first day of verification), the day researcher mistakenly identified an activity to be from a green (*C. mydas*) turtle, resulting in the only confirmed inaccurate SI for the team 2012/13. This gave the GTCP field team a SI accuracy of 98.5%

6.4.3 NAD accuracy

Due to the parameters set for activity verification (**Chapter 6.3.1**), and the discrepancies between night and day, only 52 activities were included for verification. The researchers 2012/13 had an overall NAD accuracy of 88.5%.

Misidentification occurred between UNAs and successful nests over the entire survey periods with four nests identified as UNAs and three UNAs recorded as nests. (**Table 3**).

Table 3: NAD discrepancies between day and night surveys in 2012/13

IDENTIFIED ACTIVITY BY DAY MONITOR	OBSERVED ACTIVITY BY NIGHT MONITOR	FREQUENCY OF ERROR
UNA	N	4
N	UNA	3

6.4.4 Nest detection bias

A total of 52 verified nesting activities, including those that were verified during night surveys but whose tracks were missed during Day Surveys, were used to estimate the Nest detection bias. The error between night survey verification and the corresponding Day Survey nest count was -15.8 %.

While the NAD rate in 2012/13 was similar but slightly lower (i.e. more accurate) than the previous GTCP years, there was a downward bias in that nests were more often identified as UNAs showing a conservative tendency for the field team.

6.4.5 Observed nesting activities and phases

Of the 68 turtles observed during night surveys in 2012/13, the nesting activity was verified for 52. Most verified activities were nests (73.1%), while UNA and UT were recorded more rarely (**Table 4**).

Table 4: Types of nesting activities observed during night surveys in GBR

ACTIVITY SEEN	FREQUENCY	PERCENTAGE OF TOTAL (%)
N	38	73.1
UNA	11	21.2
UT	3	5.8

6.5 Discussion

To further increase the chances of turtle encounters, improvements in the GTCP's night survey procedure and protocols were developed during the pre-season. It was expected that a higher number of turtles would be encountered by commencing night surveys later in the season compared to previous years. As there was an increase in turtle encounters compared to previous seasons, it is thought these changes improved the night monitoring techniques. However, other factors such as environmental conditions, unpredictable nesting patterns and turtle behaviour, and population numbers, may have also influenced the number of turtle encounters.

6.5.1 SI accuracy

The GTCP field team achieved an SI success rate of 98.5%. These results are consistent with the previous two seasons of monitoring (2010/11–2012/13), which had SI accuracies exceeding 95%. Thus, current levels of training by the GTCP and experience of the seasonal GTCP field team appear adequate for reliable SI during Day Surveys.

Due to the night monitoring protocols, visual confirmation of turtle species is expected for species correlation, and night monitors are required to 100% identify the presence of a particular turtle species, evenk in low light conditions. This season, all turtles encountered were identified as loggerhead turtles by night monitors. The one SI error was an incorrect green turtle track interpretation. Loggerhead and green turtle tracks can appear similar in relation to the sand inclination as a loggerhead turtle attempts to move forwards up a dune, the tracks appear simultaneous and lose their shape. As this error occurred on the first morning of verification, it was accepted that inexperience in track interpretation was the main cause.

6.5.2 NAD accuracy

The GTCP field team 2012/13 achieved an NAD success rate of 88.5% in 52 verified night survey observations. While all UT activities were correctly correlated between night and morning monitors, throughout the season, there were consistent errors in the Day Survey data set which involved mistaking N and UNA. These activities have similarities with sand composition after a loggerhead turtle has finished digging. Furthermore, environmental impacts such as strong winds can deteriorate or alter the appearance of activities, as sand may be deposited or eroded. It is common for experienced track interpreters to be confused by loggerhead UNAs and successful nests at times: therefore, it is unrealistic to expect inexperienced track interpreters to demonstrate a high accuracy of differentiation between these activities. Compared to previous seasons, the overall accuracy of nesting activity verification appeared to be higher. This may be due to improved training and reference material offered by the GTCP as it has expanded since its commencement in 2008. However, due to field team re-structuring, most of the field team 2012/13 weren't provided with pre-season training or reading material, rather they were guided by the GTCP field Team Leader for a week before independently commencing morning monitoring, prior to the commencement of the night verification surveys.

Several of the NAD discrepancies, occurred around severe weather conditions experienced in the Gnaraloo area from the presence of Tropical Cyclone Narelle, which was off the coast of Western Australia from 10 January 2013 and dissipated on 14 January 2013. Degradation of turtle tracks and activities was caused by increased tides and strong winds. These environmental factors can erase key identifying features of tracks and activities. This prevents researchers during the day from making accurate identifications through track interpretation only.

Overall, current levels of training by the GTCP and experience of the seasonal GTCP field team appear adequate to achieve at least an 80% NAD success rate. Nevertheless, it is extremely important to continue night surveys in the future for accurate and strengthened interpretation skills and to evaluate variation in error rates at the program level.

Track interpretation is prone to error as each nesting activity is unique and has many variables (Whiting, 2010). It is therefore important that night verifications encounter a statistically significant large sample size in order to produce a quantifiable margin of error. Track interpretation is used in several turtle monitoring programs (NTP, 2007; Hattingh *et al.,* 2011). The GTCP has strengthened its track interpretation practices from 2010/11 through the introduction and implementation of additional night verification surveys for part of the season to identify the margin of error in the accuracy of Day track interpretation.

6.5.3 Nest detection bias

Since the GTCP 2010/11, the Nest detection bias in the GBR has been consistently negative, revealing the tendency for the GTCP field researchers to underestimate the number of nests during Day Surveys.

However, the magnitude of this bias has decreased over time and, during 2012/13, the Nest detection bias was -15.8%, meaning that the errors were predominantly in one direction (i.e., consistently mistaking N for UNA).

Overall, this suggests improvement at the program level as more experienced seasonal field teams are hired and each successive field team can learn from the previous teams' experience. By comparing nest counts from night and Day Surveys, we were able to derive a correction factor to estimate the number of nests in the GBR each season after accounting for Nest detection bias. This improves the accuracy of our assessment of the number of nests and the number of reproductive females using the GBR each season. As additional seasons of data become available, a more detailed analysis of year-to-year variation in Nest detection bias will become possible.

6.6 Conclusion

Night verifications are an important aspect of the GTCP as they improve the integrity and reliability of data. Overall, the GTCP field team 2012/13 demonstrated a high level of accuracy and a relatively small margin of error needs to be allocated to day track interpretations. SI was particularly accurate with only one error occurring. Although some confusion between successful nests and UNAs occurred throughout the season, it was still above the necessary accuracy level for NAD of 80%. Continuation of night surveys as it is currently undertaken is essential to continue to monitor SI and NAD errors to ensure overall data quality and to develop season-specific correction factors to account for Nest detection bias.

7 GBR SAMPLED NEST SURVEYS

7.1 Introduction

This chapter reports on a statistically representative sub-sample of nests in the GBR which were monitored daily for signs of predation (feral and native), disturbance, environmental impacts and hatching success to apply these results to all nests in the GBR.

7.2 Objectives

The objectives of monitoring the Sampled Nests in the GBR during the season 2012/13 were to:

- Closely observe a statistically representative subset of nests for the entire GTCP monitoring period to record their fate (i.e. whether they survive to hatching);
- Monitor the extent and impact of feral and native predators on these turtle nests;
- Examine the extent and impact of environmental factors on these turtle nests;
- Where possible, observe hatchling events and record the factors which prevent turtle hatchlings from making a successful ocean entry; and
- Investigate the consequences of selection of nest position and situation by the nesting female adult turtle.

7.3 Material and methods

The GTCP Procedure 2012/13 contains detailed methods. Briefly, a statistically representative subset of nests recorded during GBR Day Surveys in each GBR Sub-section were randomly selected to become Sampled Nests. The Sampled Nest survey began on 13 November 2012 and continued until season end on 28 February 2013. During the daily monitoring of the GBR, each nest observed was allocated a unique identifying code. The codes consisted of the GBR Sub-section the nest was found in, the date and a number allocated in numerical order. If the allocated number pertained to one of the randomised numbers for that sub-section, then a painted wooden stake was used to mark the nest. The unique identifier code was then written on the stake.

Nests which had been identified and staked were monitored daily when encountered by the GTCP Field researchers during their morning surveys. During that period, all new predator and environmental interactions associated with the nest were recorded. If the nest was unchanged from the previous day, that was reported also.

Previous GTCP field research teams identified that loggerhead nests in the GBR have a mean incubation period of 67 days (range 55 – 82 days) (Hattingh *et al.*, 2010). As monitoring of the GBR was planned to conclude on 28 February 2013, a cut-off date of 4 January 2013 was selected for Sampled Nest allocation. Therefore, on average, any clutches laid before the cut-off date was expected to hatch before, or by, the conclusion of the GTCP monitoring period.

By selecting nests based on incubation range (versus the average incubation period), additional nests undergoing quick incubation rates could potentially be studied to hatching. This would simultaneously allow for a broader sample in which a temporal comparison may be made (i.e. seeing what impacts predators and the environment have on nests recorded early in the season versus those recorded in the middle of the season).

7.3.1 Survey Area

Sampled Nests were monitored in all sub-sections of the GBR (23.76708°S / 113.54584° E to 23.72195° S / 113.57750° E) (**Appendix A**).

7.3.2 Calculating sample size

A target sample size of 82 nests was determined by ‘calculating a sample for proportions’ formula then applying the ‘finite population correction for proportions’.

The resulting number was then divided between the three GBR Sub-sections based on the proportion of nests found in each Sub-section during the previous two GTCP seasons. The mean incubation period (67 days) was also considered.

The number of targeted Sampled Nests for each GBR Sub-section was as follows:

- GBN–BP7: 23 nests.
- BP7–BP8: 8 nests.
- BP8–BP9: 51 nests.

Nests to be designated as Sampled Nests were selected using a random number generator[1]. The parameters for the random number generator were set to a minimum of one and a maximum based on the average number of nests for each sub-section in GBR during 15 November to 4 January during GTCP seasons 2010/11 and 2011/12.

7.4 Results

7.4.1 Sample size

Out of the targeted sample size of 82, 62 Sampled Nests were marked across all GBR Sub-sections for the season 2012/13.

In Sub-section GBN–BP7, 20 Sampled Nests were marked, 6 in BP7–BP8 and 36 were established in BP8–BP9 before the 4 January 2013 cut-off date (**Table 5**). Of the 62 Sampled Nests monitored, the nesting species were identified predominantly as loggerheads, accounting for 59 of the total 62. Only one nest was attributed to green turtles whilst no hawksbill nests were identified. Two of the Sampled Nests could not be identified to species and were recorded as Unidentified (**Appendix A**).

[1] http://randomizer.org.form.html

Table 5: Summary of Sampled Nests per GBR Sub-section

	GBN–BP7	BP7–BP8	BP8–BP9	TOTAL
LOGGERHEAD	18	6	35	59
GREEN	1	0	0	1
UNIDENTIFIED SPECIES	1	0	1	2
TOTAL	**20**	**6**	**36**	**62**

Most of the Sampled Nests (43.5%) were located in the high-water zone while a further 33.9% were in the dune zone, all others (22.6%) were located in the edge of vegetation zone. No Sampled Nests were located within the intertidal zone (**Table 6**).

Table 6: Number of Sampled Nests per horizontal zone and GBR sub-section

	GBN–BP7	BP7–BP8	BP8–BP9	TOTAL
INTERTIDAL	0	0	0	0
HIGH-WATER	9	1	17	27
EDGE OF VEGETATION	3	3	8	14
DUNE	8	2	11	21
TOTAL	**20**	**6**	**36**	**62**

Note: Includes all Sampled Nests, including those destroyed by severe Tropical Cyclone Narelle.

7.4.2 Nest disturbance and predation

Note that calculations are only based on nests still surveyed after severe Tropical Cyclone Narelle (n=24) (**Chapter 3 and Section 7.4.3**). These data are included but the nests were monitored for varying, often short (i.e., several weeks), lengths of time depending on when the nests were dug before the cyclone. Thus, estimates of crab disturbance and predation impacts this season are likely low.

During the season 2012/13, there were no recorded predation or disturbance events from feral animals, though fox, wild dog and feral cat tracks were observed throughout the monitoring period (**Chapter 4**).

Disturbance by crabs burrowing into the sand around Sampled Nests was widespread, with almost every Sampled Nest in the GBR being impacted.

Of the Sampled Nests found in the high-water (**H**) zone, 37% were subject to crab predation during incubation, making it the zone with the most crab predation. The edge of vegetation (**E**) zone had the least nest predation by crabs at 21.4%.

GBR Sub-section BP8–BP9 had the highest level of predation by crabs recorded, with 47.2% of Sampled Nests being predated at least once by *Ocypode convexa*, followed by BP7–BP8 at 16.7%. GBN–BP7 was found to have the lowest level of crab predation, at only 10% (**Figure 18**).

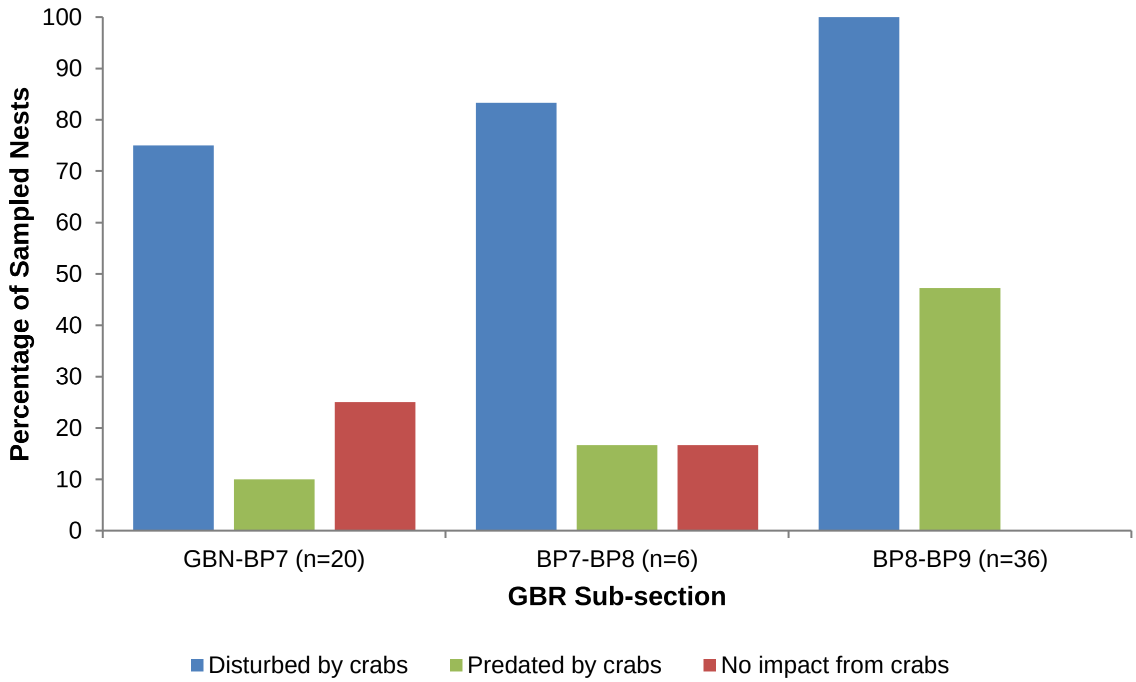

Figure 18: Percentage of Sampled Nests impacted by crab disturbance and/or predation per GBR Sub-section

7.4.3 Environmental impacts

Tropical Cyclone Narelle passed by the GBR. The greatest impact on the rookery was due to increased tides and winds on 14 January 2013. Many nests were lost in each GBR Sub-section, with 70% of Sampled Nests being washed away in GBN–BP7. Overall, the GBR lost 61.3% of the Sampled Nests due to inundation or erosion of entire sections of dunes. The single green turtle Sampled Nest, located in GBN–BP7 was present after the cyclone.

Table 7 shows the number of Sampled Nests remaining after 14 January 2013 and the percentage of nests lost per GBR Sub-section.

Table 7: Impacts of Tropical Cyclone Narelle on Sampled Nests in GBR during 2012/13

GBR SUB-SECTION	TOTAL NO. OF NESTS	NO. OF NESTS POST TROPICAL CYCLONE NARELLE	PERCENTAGE OF NESTS LOST
GBN–BP7	20	6	70%
BP 7–BP8	6	2	66.7%
BP 8–BP9	36	16	55.6%

All 27 Sampled Nests located within the high-water zone were inundated by tides. Between these nests, there were 209 inundation events over the course of the survey, and on average, a nest would be impacted by inundation by tides/storms (**ITS**) 7.74 times (SD = 5.55). The least common environmental impact was nest erosion by shifting sand dunes (**ESD**), which only occurred once in the high-water zone.

ITS impacted 78.6% of the 14 Sampled Nests located within the edge of vegetation zone. Overall, there were 41 ITS events across these nests, with nests being impacted an average of 2.93 times (SD = 2.30). ESD was the least common with only one event recorded.

The most common environmental impact of the 21 Sampled Nests in the dune zone was suffocation by shifting dunes (**SSD**), with 30 SSD events being recorded and an average of 1.43 (SD = 2.04) impacts per nest. However, this only impacted 28.6% of nests, whilst ITS impacted 57.1% of nests across the season. ESD was the least common environmental event, impacting 19.1% of nests.

Across each of the GBR Sub-sections, ITS was the most common environmental impact (**Figure 19**). All Sampled Nests were impacted in BP8–BP9, 80% in GBN–BP7 and 66.7% in BP7–BP8. In GBN – BP7, SSD was the least common impact, only impacting 10% of Sampled Nests. In BP7–BP8 and BP8–BP9, ESD was the least common, as it was never recorded in BP7–BP8 and only occurred in 8.3% of Sampled Nests in BP8–BP9.

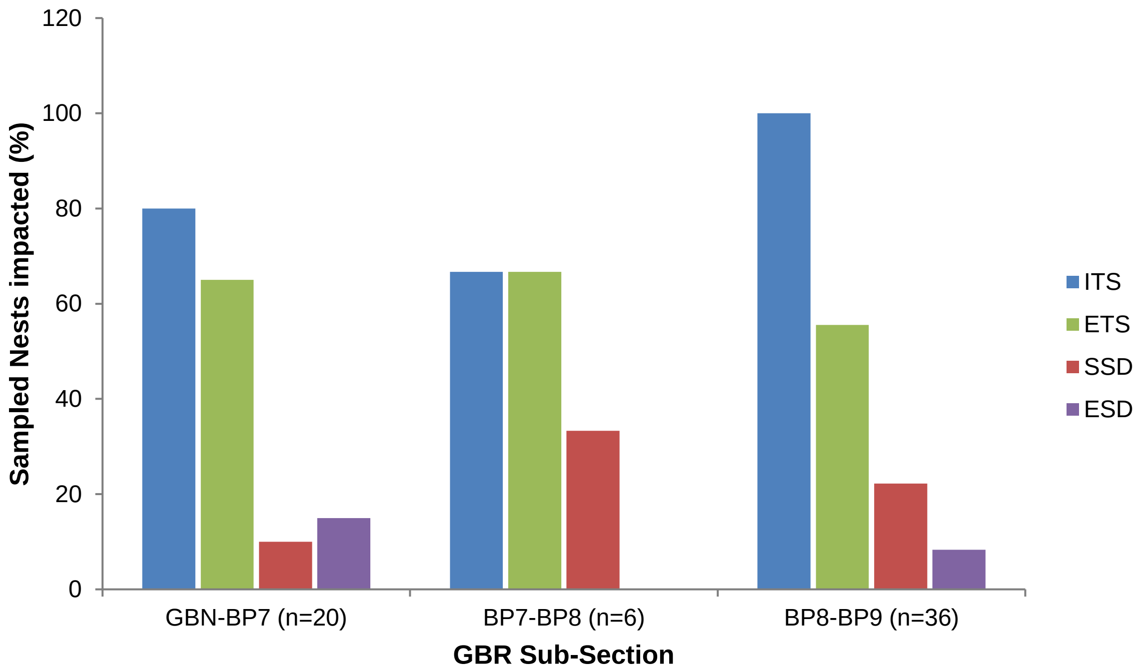

Figure 19: Percentage of Sampled Nests per GBR Sub-section impacted by specific environmental events

Notes: ITS = inundated by tides/storms. ETS = eroded by tides/storms. SSD = suffocated by shifting dunes. ESD = eroded by shifting dunes.

Excluding the intertidal zone, which had no Sampled Nests, each of the horizontal beach zones lost several nests to severe Tropical Cyclone Narelle. The greatest numbers of Sampled Nests in all GBR Sub-sections were lost in the high-water zone (**Figure 20**). The fewest number of nests were lost in the dune zone.

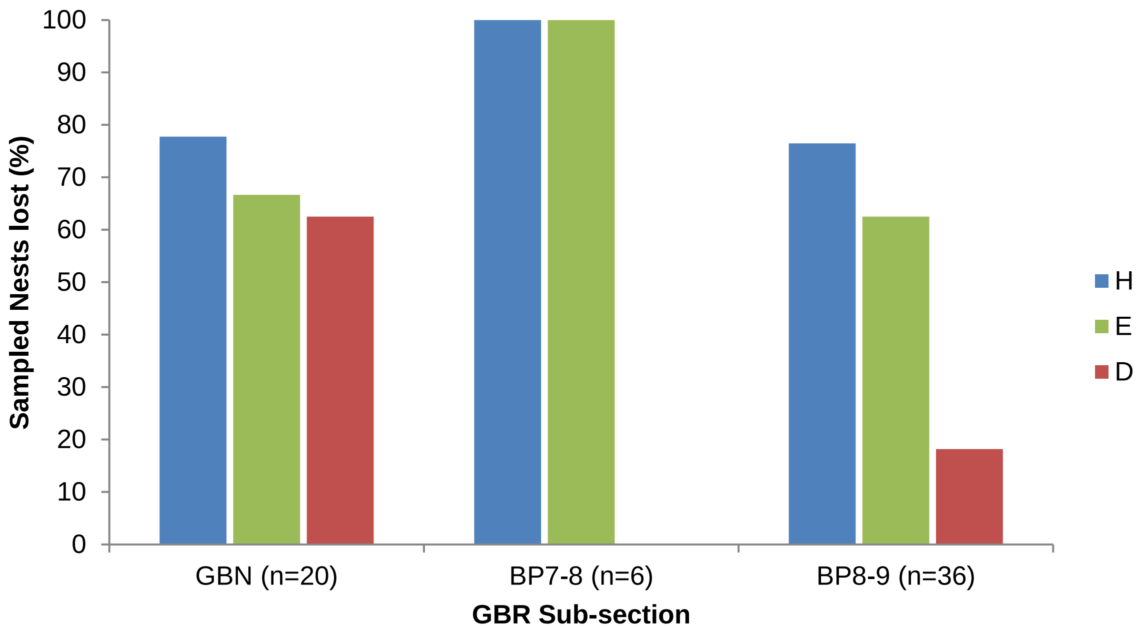

Figure 20: Percentage of Sampled Nests per horizontal zone and GBR Sub-section lost to severe Tropical Cyclone Narelle

Notes: H = high-water zone. E = edge of vegetation zone. D = dune zone. No Sampled Nests were located within the intertidal (I) zone. Total percentages for each sub-section don't add to 100 as percentages are separate for each horizontal zone.

7.4.4 Evidence of hatching

Of the 24 nests that survived the environmental impacts caused by cyclone Narelle, only one, in sub-section GBN–BP7, had a hatching event witnessed before the end of survey on 28 February 2013. It is unclear how many of the hatchlings made it to the ocean, as no live hatchlings were observed. Predation of recently emerged hatchlings was apparent with three deceased hatchlings found nearby, with signs of golden ghost crab predation.

Six Sampled Nests reached 80 days of incubation without a hatching event being witnessed by the GTCP field researchers. Of these, five were found within BP8–BP9. The single nest in GBN–BP7 was the only green turtle Sampled Nest.

There were 17 nests that had no hatching event recorded but were still to reach 80 days of incubation before the end of the surveys on 28 February 2013. Five of these nests had reached 67 - 69 days of incubation at the completion of the surveys but had yet to show signs of hatching. All these nests were impacted by environmental factors and crab disturbance, with three also being predated by crabs.

7.5 Discussion

7.5.1 Nest disturbance and predation

The feral control methods employed by the *Gnaraloo Feral Animal Control Program* during 2012/13 resulted in no evidence of disturbance or predation of sea turtle nests in the GBR by feral animals (fox, wild dog or feral cat) (**Chapter 4**).

On the other hand, disturbance and predation of Sampled Nests was widespread throughout the GBR, predominately due to the presence of the golden ghost crab (*Ocypode convexa*). Other species such as the running ghost crab (*Ocypode ceratophthalma*) were also observed to dig burrows around nests, though no predation events were witnessed.

Most Sampled Nests in the GBR were impacted by disturbance due to ghost crabs (90.3%). The NTP (Kelliher *et al.,* 2011) states that >5% of turtle nests being predated is an acceptable, sustainable level, and a significantly lower percentage than what was recorded at the GBR during the season 2012/13. Crab predation of turtle nests was greatest in BP8–BP9 at 47.2%. The lowest level of predation by crabs occurred in the dune zone, which is consistent with ghost crab habitat-use.

7.5.2 Environmental impacts

Environmental impacts had a substantial effect on the Sampled Nests in the GBR, with all but one nest being impacted in one way or another. The narrow, relatively flat beach that defines portions of the rookery, leads to high risk of inundation of nests located between the high-water and edge of vegetation zones. The high levels of inundation of nests located within BP8–

BP9 can be attributed to the large percentage of Sampled Nests occurring in the H and E zones compared to the other sub-sections.

Inundation of nests for even a relatively short period of time can potentially destroy entire clutches. This is due to the turtle's soft-shelled eggs, which are highly permeable to oxygen and water (Packard *et al*., 1982; Packard & Packard 1988) leading to drowning of developing hatchlings. Several factors have been shown to affect the survivability of inundated nests. Deeper nests can withstand inundation as it takes longer for the seawater to filter through the sand to the clutch (Ernst *et al*., 1994). In general, green turtles tend to dig deeper nests than loggerheads, indicating possible increased survivability of green turtle nests in areas where inundation is present (Ernst *et al.,* 1994).

The relative developmental stage of the eggs within the clutch can also alter the length of time a nest can be inundated without negative effects. As eggs develop, they require increasing levels of oxygen to be present (Packard, 1999). Inundation therefore can cause greater damage to eggs further along development by restricting available oxygen levels.

Due to the high levels of inundation that are likely to occur in the H zone, loggerhead nests located further up the beach have a greater chance of survival (Mrosovsky, 1983; Hays & Speakman, 1993). This is reflected by the high level of loss of nests located within the H zone of GBR, especially after the impact of STC Narelle, during the GTCP 2012/13. In contrast, the Sampled Nests located further up the beach in the dunes were more commonly impacted by shifting dunes causing erosion or suffocation of nests.

7.5.2.1 Tropical Cyclone Narelle

Tropical Cyclone Narelle caused significant damage to the GBR and radical changes in the beachscape were observed by the GTCP field researchers. Increased tides caused widespread inundation and erosion of dunes, leading to the loss of many turtle nests. Across GBR, 61.3% of Sampled Nests, were lost due to the environmental impacts associated with the cyclone.

The highest losses of Sampled Nests occurred in the H zone. This area is composed of wide, flat areas of beach with sparse vegetation offering little protection against the increased tide. Subsequently, sub-sections BP8–BP9 and GBN–BP7, which had large percentages of Sampled Nests located in the H zone, had a large portion of nests lost.

GBN–BP7 is historically the calmest, least dynamic section of the GBR. The beach is relatively flat and open, whilst BP8–BP9 is not fully protected by fringing reef (Hattingh *et al.,* 2012). This left many sections of beach in these sections vulnerable to inundation from the higher-than-average tides.

Several nests located in E and D zones were still impacted by the cyclone. Tides eroded the base of dunes, collapsing them and any nests contained within. High winds also had an effect, shifting the dunes, either suffocating or eroding nests.

Cyclonic events were recorded in previous seasons, though losses were not as severe. In the GTCP season 2011/12, Tropical Cyclone Iggy brought increased tides to Gnaraloo Bay, causing similar effects with inundation of low-lying areas and erosion of dune bases. However, the cyclone impacted after the peak turtle nesting season and only 42.3% of Sampled Nests were lost (Hattingh *et al.,* 2011). Two cyclonic events occurred during the GTCP season 2010/11, though numbers of nests lost were not recorded (Hattingh *et al.,* 2011).

Due to the heavy losses of turtle nests from cyclonic events, the practice of excavating nests found in the high-water zone and relocating them to positions higher up the beach or incubating through artificial means could be considered.

7.5.3 Hatching events

Although several nests reached 80 days of incubation, only a single hatching event was observed of the Sampled Nests. This nest was located in the dune zone and wasn't inundated or predated at any point. However, it had been disturbed by crab burrows and had been impacted by shifting sands during its incubation period.

Six Sampled Nests were not observed to hatch after 80 days of incubation. This does not necessarily mean that these nests did not hatch as they may have hatched without being observed. It is also possible that these clutches had perished before full development of the hatchlings. From data collected in previous GTCP seasons, the mean incubation period at the GBR is 67 days. All these nests had inundation events, with two having over 10 environmental impacts each. Egg predation by crabs was also recorded for all but one of these nests. This highlights the range of destructive environmental events that can destroy clutches of turtle eggs before they hatch. Very few turtle nests were present that were not impacted or only minimally impacted, by either environmental or predation events.

Another explanation is that Sampled Nests may have been incorrectly identified during the Day Surveys (being a nest as opposed to in fact being a UNA). Track interpretation can be affected by researcher judgement, degradation of identifying features by environmental factors and differences between individual turtles. It is therefore possible that an UNA could be mistaken for a nest and included in the Sampled Nests subset. Nests determined to be no longer viable after 82 days of incubation at the GBR should be excavated in future to both check if a clutch was laid, and to determine the relative development stage any eggs had reached.

It is possible that some nests will hatch outside the survey period. Although the sampling of nests was concluded on 4 January 2013, allowing the mean incubation time for loggerheads at the GBR of 67 days, clutches may take longer to hatch. Differences in nest temperature can affect both the rate of development and influence the sex ratios within the clutch, with higher temperatures resulting in faster development and increased female bias (Godley *et al.*, 2001). Clutches that have developed at a slower rate, due to lower temperatures or other environmental factors, would therefore not hatch within the survey period if laid close to this cut-off date.

7.6 Conclusion

The Sampled Nests survey was undertaken to investigate the level of biotic and abiotic impacts on turtle nests along the entirety of the GBR. The size of the sub-sample was limited, as the targeted quotas were not met by 4 January 2013. This was compounded further by the loss of many of the Sampled Nests due to severe Tropical Cyclone Narelle.

Biotic impact on nests during the GTCP 2012/13 came from crab species such as the golden and running ghost crabs, which caused disturbance to all Sampled Nests after the impact of severe Tropical Cyclone Narelle on 14 January 2013. Predation from crabs impacted just over half of the Sampled Nests. The level of ghost crab predation of the turtle nests in the GBR is high and consideration should be given to reduce predation to <5%, a level set by the NTP as being acceptable (Kellier, 2011). Ghost crab predation was the only form of predation recorded; a positive reflection on the *Gnaraloo Feral Animal Control Program*.

Environmental factors also impacted many nests across all GBR Sub-sections and beach horizontal zones. Inundation by tides was the most common form of environmental impact, largely due to both the high number of nests located in the high-water to edge of vegetation zones, and the impact of severe Tropical Cyclone Narelle. To combat the loss of nests that are positioned in areas that face frequent inundation or other environmental impacts, relocation of nests to safer locations higher up on the beach or dunes could be considered.

8 GCFR DAY TRACK SURVEYS

8.1 Introduction

This chapter sets out the findings of Day Surveys conducted in the GCFR which is situated approximately 22 kms north of the GBR. It was identified as an active turtle nesting location during the GTCP monitoring season 2009/10 after aerial survey. On-ground surveys of the GCFR commenced during the GTCP season 2011/12 and continued in 2012/13. Loggerhead turtles have been recorded as the prevalent nesting species in the GCFR. However, it remains unclear how many loggerhead turtles nest in this rookery annually, and how it compares and interacts with the GBR. The comparison to the GBR is important in determining the importance of the GCFR as a breeding area for turtles in Western Australia.

8.2 Objectives

The objectives of the day surveys in the GCFR during the season 2012/13 were:

- Collect and interpret data through track monitoring to continue to investigate the extent of presence of nesting sea turtles;
- Identify the species of nesting sea turtles and the types of nesting activities;
- Identify GCFR Sub-sections with high nesting density;
- Continue to analyse and interpret trends in turtle nesting activities at GCFR;
- Determine if an expanded on-ground monitoring program at the GCFR is justified in future;
- Compare and contrast findings at the GCFR with that at the GBR.

8.3 Material and methods

8.3.1 Survey Area

The GCFR is located adjacent to the *Ningaloo Marine Park* (**NMP**), along the entire *Cape Farquhar Marine Sanctuary Zone* (**MSZ**) of the NMP. The GCFR extends from the southernmost boundary of the Cape Farquhar MSZ (corresponding to GCFR Sub-section point GFS at -23.64168/113.61544) to the northernmost boundary of the Cape Farquhar MSZ (corresponding to GCFR Sub-section point GFN at -23.57697/113.69830), approximately 14km.

This region of coastline varies greatly in composition, from shallow protected bays with fringing coral reefs offshore, dynamic beaches with rolling waves to rocky outcrops running parallel to the coastline. The GCFR was divided into four sub-sections for survey during the inaugural GTCP surveys in 2011/12, and the same sub-sections were again used during 2012/13 (**Appendix A**), namely:

- Gnaraloo Farquhar South (**GFS**) to Gnaraloo Farquhar Hut (**GFH)** (Sub-section 1);
- Gnaraloo Runway South (**GRS**) to Gnaraloo Farquhar Runway (**GFR**) (Sub-section 2);
- Gnaraloo Farquhar Runway (**GFR**) to Gnaraloo Lagoon North (**GLN**) (Sub-section 3);
- Gnaraloo Lagoon North (**GLN**) to Gnaraloo Farquhar North (**GFN**) (Sub-section 4).

8.3.2 Survey methodology

During the monitoring season 2012/13, the GCFR was surveyed on four separate occasions over a period of four consecutive days each, namely:

- 20 – 23 December 2012;
- 3 – 6 January 2013;
- 20 – 23 January 2013;

- 7 – 10 February 2013.

Three surveys of the GCFR were undertaken by the GTCP 2011/12. Following the recommendations from 2011/12, the GTCP field team 2012/13 included an additional survey during the peak nesting period at the beginning of January and moved the final survey from the end of February to the beginning of February. This assisted researchers to identify the peak and end of the GCFR nesting period more accurately.

Over the four expeditions to Cape Farquhar, the same methodology was used each time, consisting of one day clearing and recording old turtle nesting activities on the beach before conducting three subsequent days of morning surveys. Due to the high number of old activities that were observed at the GCFR during the season 2011/12, the first day of survey during 2012/13 was always dedicated to recording and erasing the old activities from the beach. Researchers were required to walk in the vegetation or dune zone in most of the GCFR Sub-sections as this was where the majority of old nesting activities were found during the season 2011/12 surveys.

When a turtle nesting activity was encountered, the GTCP field researchers identified and recorded the species of turtle and determined the type of activity. The zone the activity was in and a GPS reading of the last known activity was also recorded. Groups of multiple activities in close proximity were counted separately unless joined by tracks. Once recorded, researchers swept away all remnants of the activity, be it turtle tracks or pits, with a broom. Performing these initial beach sweeps eliminated chance of error from old, recorded activities during later surveys. Recording old activities provides a broader view of what happens at the GCFR between surveys when researchers are not present during the season.

On the first day of each survey period, it was expected that the entire GCFR Survey Area (i.e. all 4 Sub-sections) were covered on foot, with both researchers walking together sweeping the beach. This occurred for each survey period except the first survey (20 – 23 December 2012) when researchers encountered logistical issues and swept only two GCFR Sub-sections. The remaining two sub-sections were swept on the second day of this survey.

The following three days consisted of researchers conducting beach patrols at first light covering all 4 GCFR Sub-sections. This required researchers to split up and conduct individual surveys of the Sub-sections using the same protocols and data sheets as used when surveying GBR (**Chapter 5**).

8.4 Results

8.4.1 Nesting activities

Overall, 223 activities were recorded over the four survey periods, conducted from the 20 - 23 December 2012, 3 – 6 January 2013, 20 – 23 January 2013 and 7 – 10 February 2013, with a total of 57 new activities. A total of 166 old activities were discovered during the initial sweeps.

The second survey, conducted from 3 – 6 January 2013, had the highest number of total nesting activities with 83, although the majority were old activities. The first survey, conducted from 20 – 23 December 2012, had the highest number of new activities, at 24. The least number of activities were found during the last survey, 7 – 10 February 2013, in which a total of 8 activities were found, with only 1 being a new activity (**Table 8)**.

Table 8: New and old turtle nesting activities per GCFR Sub-section during 2012/13

GCFR SUB-SECTION	GFS–GFH (1)		GRS–GFR (2)		GFR–GLN (3)		GLN–GFN (4)	
NESTING ACTIVITY	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
LOGGERHEAD	0	5	4	9	13	30	1	0
GREEN	0	0	0	2	3	6	0	0
UNIDENTIFIED SPECIES	10	0	9	3	126	2	0	0
TOTAL	**10**	**5**	**13**	**14**	**142**	**38**	**1**	**0**

Of the new nesting activities recorded at the GCFR, the majority were identified as loggerhead (77.1%), though green activities were also present (**Table 9**). Five of the nesting activities recorded could not be attributed to any species.

Table 9: Summary of new turtle nesting activities across the GCFR

	NEST	UNA	U TRACK	UNIDENTIFIED SPECIES	TOTAL
LOGGERHEAD	29	11	4	0	44
GREEN	1	6	1	0	8
UNIDENTIFIED SPECIES	1	2	0	2	5
TOTAL	**31**	**19**	**5**	**2**	**57**

Of the 57 new activities recorded across the four surveys of the GCFR, the Sub-section GFR–GLN (3) was found to have the highest number of new activities (**Figure 21**). No new activities were recorded in Sub-section GLN–GFN. The first survey had the highest number of new activities recorded for all sub-sections.

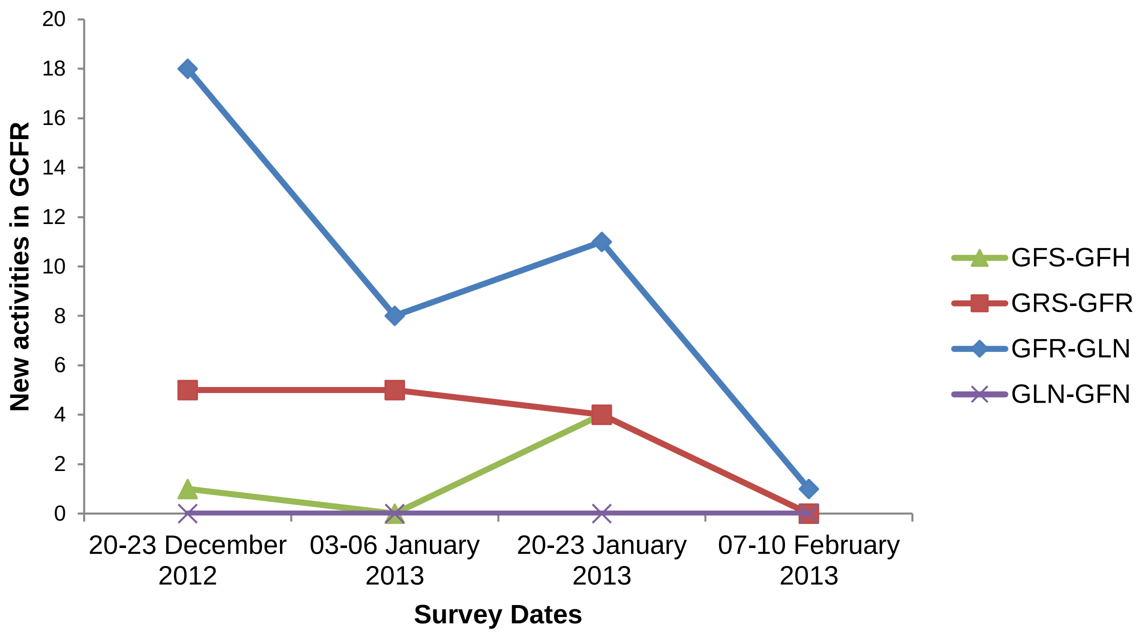

Figure 21: Total number of new activities recorded in each of the four surveys of GCFR

Of the four horizontal beach zones, no single zone was found to contain the greatest percentage of nests across all the GCFR Sub-sections. In GFS–GFH, the high-water to edge of vegetation zones and dune zones had the largest percentage of nests with the remaining nests being found between the edge of vegetation and base of the dunes. In GRS–GFR, the dunes had the highest percentage of nests, and the vegetation zone had the least, while in GFR–GLN the opposite was true (**Figure 22**). Only one new activity (recorded as an Unidentified Nesting Activity) was recorded in the intertidal zone (in Sub-section GRS–GFR) during the GCFR surveys. Note: this was not a confirmed nest.

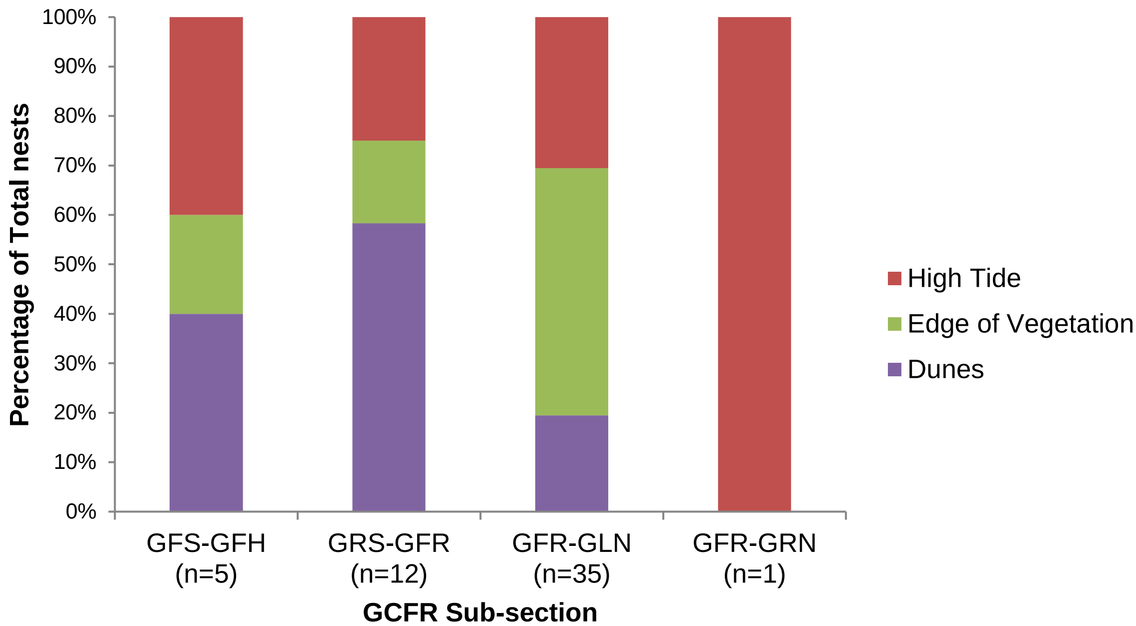

Figure 22: Horizontal zonation of new nests in each GCFR Sub-section

8.4.2 Strandings and mortalities

Any stranded or deceased turtles observed in the GCFR during the GTCP surveys during 2012/13 were examined to determine species, maturity, and sex to provide information about non-nesting turtles (i.e., males or sub-adult individuals) and possible causes of injury to turtles in the area.

During the second survey of Cape Farquhar (3 – 6 January 2013) there were 3 mortalities discovered in GCFR Sub-section 3: being GFR – GLN. One was a green male adult, and the others were sub adults of undetermined sex, one being a green and the other a hawksbill (**Table 10**).

Table 10: Turtle mortalities at GCFR during the four survey periods 2012/13

GCFR SUB-SECTION	DATE	SPECIES	MATURITY	SEX
GFR–GLN	3 January 2013	Green	Adult	Male
GFR–GLN	4 January 2013	Green	Immature	Unknown
GFR–GLN	4 January 2013	Hawksbill	Immature	Unknown

8.4.3 Comparison of GCFR with GBR

During the time periods of the four GCFR surveys, the GBR received just over double the number of nesting activities, with 132 new activities compared to the 57 new activities recorded within the GCFR (**Figure 23**). Of these new activities, the majority found were nests. Two activities in both the GBR and GCFR could not be determined due to degradation via environmental impacts.

Most nesting activities recorded at GCFR and GBR were attributed to loggerhead turtles, accounting for 77.1% and 94.7% of activities, respectively (**Figure 24**). Both rookeries also had several activities that did not allow for accurate species identification due to track degradation.

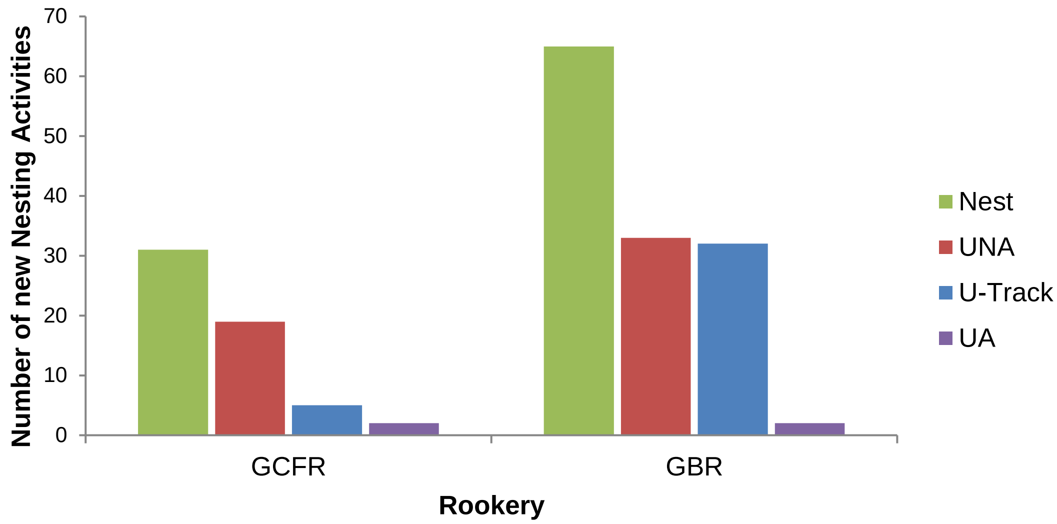

Figure 23: New activities at GBR vs GCFR during 20 - 23 December 2012, 3 - 6 January 2013, 20 - 23 January 2013 and 7 - 10 February 2013

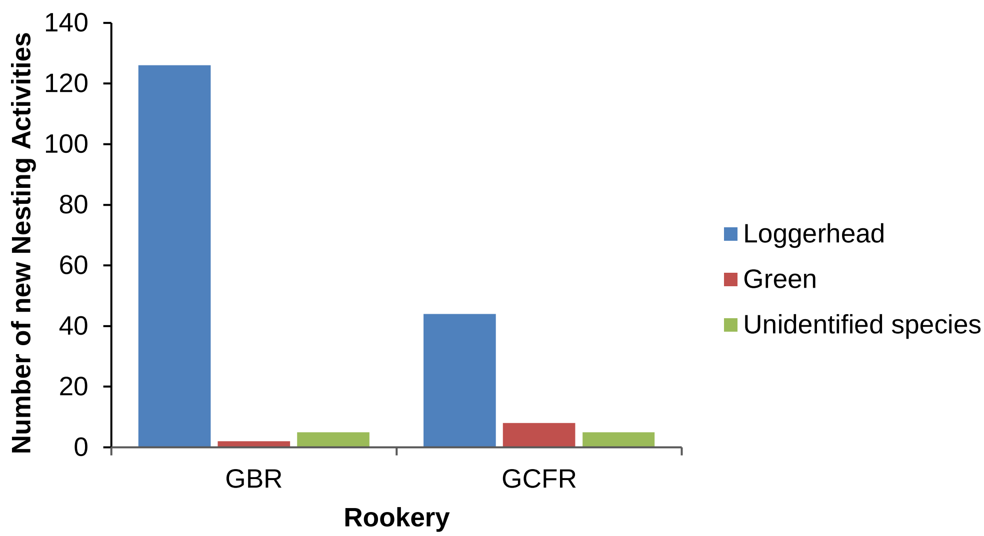

Figure 24: Turtle species at GBR vs GCFR during 20 - 23 December 2012, 3 - 6 January 2013, 20 - 23 January 2013 and 7 - 10 February 2013

8.5 Discussion

8.5.1 Species composition

The four surveys conducted at the GCFR during the season 2012/13 confirm that sea turtles use the area for nesting. The loggerhead was the predominant nesting species across the GCFR. Of the 57 new nesting activities recorded across the GCFR, 44 were attributed to loggerheads.

At GBR, the peak nesting period is around 10 January, as determined during previous GTCP seasons. The Ningaloo Turtle Program in Exmouth states that the peak nesting period falls between 21 December and 16 January (Kelliher, *et al*, 2011). It would therefore be expected that peak nesting at the GCFR would occur within a similar timeframe. However, the peak nesting period for the GCFR cannot definitively be stated based on the current available data.

Green turtles also nested at the GCFR. However, only 8 new activities were recorded during the first two surveys. This may indicate that the green turtles that frequent the area may have a different peak nesting period, occurring earlier in the season than that of the loggerhead turtles, though this trend has not been experienced at the neighbouring GBR. Also, the presence of two deceased green turtles, one a large male adult and the other a sub-adult of undetermined sex, may indicate the waters off the rookery may be used as a breeding and feeding area for green turtles.

The presence of a deceased sub-adult hawksbill indicates that the waters off GCFR may serve as feeding and/or breeding grounds for the species. Continued surveys are recommended for the future, possibly starting earlier in the season as well as additional research into the waters surrounding the GCFR.

8.5.2 GCFR Sub-sections and horizontal zonation

Across the four separate surveys of the GCFR, particular Sub-sections of the rookery were found to have a greater abundance of nesting turtles. In each of the surveys and for each individual day, Sub-section GFR–GLN (3) was consistently found to contain most of both old and new activities. Of the total 223 new and old activities recorded at GCFR, 180 (80.7%) were found within GFR–GLN (3), making it the busiest GCFR Sub-section by far.

Due to logistical problems during the 20 – 23 December 2012 survey, GFS–GFH (1) and GLN–GFN (4) were not surveyed until the second day. Any new activities on 20 December 2012 would not be recorded until the next day and would be recorded as old activities. The effects of this are minimal however, as activities were low in these sub-sections.

The horizontal zonation of nests across GCFR does vary between the different sub-sections, reflecting both the differences found in beachscape and in sample size. It is likely that differences within and between the GCFR Sub-sections regarding reefs, beaches and dunes would influence the horizontal zonation of turtle activities, though larger sample sizes would be required in some Sub-sections to accurately assess this. Across the whole rookery (not considering the separate Sub-sections), the majority of nests were found in the edge of vegetation zone, followed by the high-water zone.

Digging nests above the high-water zone reduces the chance of high tides covering nests, drowning the eggs inside. However, nests in the dune zone face other risks, such as desiccation and increased predation of newly emerged hatchlings as they head to the ocean. Therefore, nesting turtles tend to concentrate nesting efforts between the high-water and vegetation zones (Wood & Bjorndal, 1999; Kamel & Mrosovsky, 2005). This was evident within GCFR, with 70.4% of new nests occurring within the high-water and edge of vegetation zones, and the remaining 29.6% occurring in the dunes and beyond.

No old Nesting Activities were found within the intertidal zone, though this could be partly due to the nature of this zone and track interpretation. Any Nesting Activity within the intertidal zone would be highly susceptible to being degraded quickly by the tide and therefore may not be seen by day monitors using track interpretation, leading to an underrepresentation of the total activities within the zone. Only one New nesting Activity was found within the intertidal zone and was recorded as a ‘pit’. Although new, the area around the activity was significantly degraded and therefore the pit could not be properly identified as a nest.

8.5.3 Comparison of GCFR with GBR

The comparison to GBR has focused on both the total number of nesting activities found, and the presence of the various species of turtles, either within the waters of the rookery or nesting on the beaches. Over the same survey periods (20 - 23 December 2012, 3 – 6 January 2013, 20 – 23 January 2013 and 7 – 10 February 2013), the numbers of nesting activities at each of these rookeries differed. Although a total of 223 nesting activities were recorded at GCFR, most of these activities were old. The length of time that tracks can be identified depends greatly on many environmental factors and therefore cannot be used in a direct comparison as activities could be several days old when recorded. The number of new activities over the four surveys at GCFR was found to be 57, less than half of the 132 activities recorded at GBR during the same time frame.

The sampling of the GCFR is still in its initial years and aims to explore the size and importance of this nesting area. With limited data it is not yet possible to estimate the total number of females nesting in this rookery or evaluate nesting trends over time.

8.5.4 Impacts of severe Tropical Cyclone Narelle

It should be noted that severe Tropical Cyclone Narelle indirectly impacted the Gnaraloo area, with the main storm being recorded at GBR on 14 January 2013. The large tidal surges, produced by high winds, were thought to have washed away evidence of old activities in the vegetation zone and below, where the majority of turtle nesting activity occurred. This is reflected by the fact that lower numbers of old tracks were recorded during the third GCFR survey on 20 – 23 January 2013.

Higher water lines from the extreme high tides and storm surges were seen to have altered the shoreline characteristics at the GCFR. GFR – GLN (i.e., GCFR Sub-section 3) had steeply eroded dunes and recorded a larger proportion of U Tracks after the cyclone. These large, steep embankments often prevent turtles from reaching the vegetation and dune zones. This was observed during night surveys at the GBR and therefore could occur in similar areas of the GCFR.

8.6 Conclusion

The GCFR has been determined to be a nesting rookery for the loggerhead (*C. caretta*), the green (*C. mydas*) and potentially hawksbill (*E. imbricata*) turtles. Further research needs to be conducted in future to determine the peak nesting period and other nesting parameters at the GCFR. During 2012/13, in comparison to GBR, the GCFR appeared to be a lower scale rookery with fewer turtles frequenting the beach. However, only four surveys of four days each were conducted, and the number of nesting turtles can fluctuate markedly between seasons (Broderick *et al*., 2001), so continued surveys are required to more accurately compare turtle numbers and nesting use of each of these rookeries at Gnaraloo.

In addition to the recorded nesting activities, three deceased turtles (an adult male green, and green and hawksbill sub-adults of undetermined sex) and sightings of individuals of breeding size and smaller than breeding size, indicate that the waters surrounding the GCFR may be feeding and/or breeding grounds for these species. The green turtles, although making a small percentage of the total activities, were still found in higher numbers than in the entire season at GBR. This indicates that the GCFR may be used more frequently by greens for nesting, though since these species were only recorded during the first two GCFR surveys during 2012/13, these results may not accurately represent the total nesting session. As the green is ranked as being endangered, it is of importance that any potential nesting sites be protected.

Although the whole of the GCFR had recorded turtle nesting activity, Sub-section GFR–GLN (3) was found to be the busiest section for all species, whilst Sub-section GLN–GFN (4) only had the one activity recorded overall. Therefore, GFR–GLN (Sub-section 3) should be the focus in future seasons, though all Sub-sections should continue to be surveyed, as activities may fluctuate in each of the Sub-sections each season.

Across the rookery, most nests were found to be located within the edge of vegetation zone, followed by the high-water zone and the dunes and beyond. However, this was not the case in each individual GCFR Sub-section. This reflects the differences in beaches within and between the Sub-sections, and more importantly, the small sample sizes of some Sub-sections skewing the percentages. A larger sample is required to assess which horizontal beach zone is most used for nesting and whether this varies between the GCFR Sub-sections.

To gain a greater understanding of the GCFR, surveys of turtle nesting activities will need to continue during future seasons. The paucity of data collected so far limits the conclusions that can be drawn about the nesting population. As most green nesting activities occurred during the first GCFR surveys, it is possible they may nest earlier in the season at the GCFR. Continued surveys of greater length and starting earlier in the season would need to be conducted to provide a greater understanding of the significance of this rookery for each species and to provide evidence of different nesting periods.

9 EDUCATION AND COMMUNITY OUTREACH

9.1 Introduction

This chapter summarises some of the activities undertaken as part of the GTCP's education and community engagement program during 2012/13.

Public education and community engagement can help change the behaviour and attitudes of different people, which is especially important for sea turtle conservation. Turtle population declines worldwide can be partly attributed to anthropogenic threats, and different values through diverse cultural traditions may endanger sea turtle survival rates. Improving communication and education has been shown to impact social behaviour, therefore is considered a valuable conservation technique. Community involvement has therefore become an important aspect for the GTCP since the season 2010/11 when it was first introduced as an additional component to the scientific field surveys of the turtles' nesting activities at Gnaraloo.

During 2012/13, the GTCP's field Community Coordinator (formally Volunteer Coordinator), under the direction and assistance of the GTCP Project Manager and the remainder of the GTCP field team, continued to expand community engagement initiatives. The community engagement aspect of the program includes both onsite and off-site activities, including: community and school group participation in the GBR Day and Night Surveys; presentations at Gnaraloo and presentations at schools and other organisations post the GTCP survey period at Gnaraloo. All educational activities and presentations by the GCP are provided free of charge to all participants.

9.2 Objectives

The objectives for the community engagement program during 2012/13 were:

- Expand the GTCP in various ways to increase awareness about the program and sea turtle conservation at Gnaraloo;
- Gain increased exposure on the program's social media page (Facebook);

- Host community volunteers and school groups onsite at Gnaraloo during the survey period to participate with the program;
- Perform presentations to schools in Western Australia post the onsite survey period.

9.3 Outcomes

9.3.1 Onsite community participation

During the season 2012/13, groups from 3 schools participated with the GTCP: Tom Price High School from Tom Price, Nagle Catholic College from Geraldton and a reconnaissance visit by a representative of Aquinas College from Perth, which was a very successful outcome for the program.

A total of 20 students and 6 teachers participated in the survey activities of the GTCP. Tropical Cyclone Narelle negatively impacted the weather, and several mornings were declared unsafe for student groups to accompany researchers.

A total of 18 community members participated in GTCP surveys from 2 November 2012 - 28 February 2013. These consisted of visitors to Gnaraloo Station including guests and employees from various backgrounds and countries (**Figure 25**). There were a higher number of participants involved in morning monitoring than those involved in night surveys. Positive and encouraging feedback was received post the surveys from all participants.

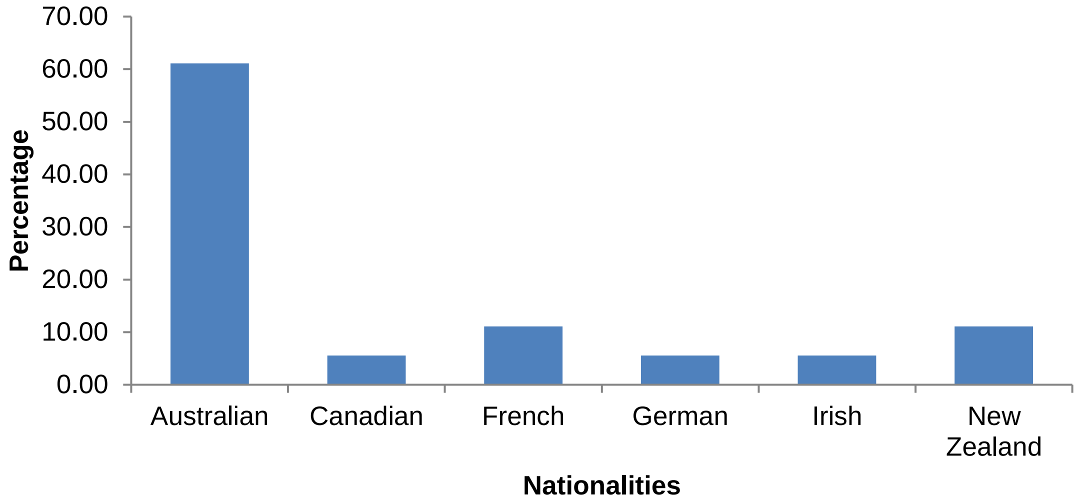

Figure 25: Nationalities involved with onsite outreach and education during 2012/13

9.3.2 Presentations at regional and metropolitan schools

The GTCP field team 2012/13 presented to 10 schools after the completion of their survey work at Gnaraloo. These were at 3 schools in Carnarvon and 7 schools in the Perth metropolitan area and included 605 students between the ages of 5 – 18 (**Table 11**).

Table 11: Off-site presentations during 2012/13

	DATE	SCHOOL	AGE GROUP (YEARS)	TOTAL NO. STUDENTS
CARNARVON	11 March 2013	East Carnarvon Primary School	5 – 13	199
	11 March 2013	Carnarvon Primary School	11 – 13	15
	12 March 2013	St Mary's Star of The Sea	11 – 16	38
	18 March 2013	South Fremantle SHS	12 – 18	80
PERTH METROPOLITAN AREA	21 March 2013	Mazenod College	13 – 18	37
	25 March 2013	Mater Dei	11 – 15	60
	26 March 2013	Presbyterian Ladies College	13 – 17	6
	27 March 2013	Aquinas College	12 – 18	110
	27 March 2013	St Mary's Anglican Girls School	13 – 15	16
	28 March 2013	Atwell College	11 – 15	44

9.3.3 Media and radio

The GTCP's Facebook page was first developed during 2010/11 to provide more accessible information to the general public about Gnaraloo's sea turtles. The page is generally used to share research throughout the season including turtle nest totals, field diaries and photos in addition to promoting interaction between the community and the GTCP research teams. The season 2012/13 continued and increased use of the page. One video posted reached 1,833 viewers.

During the season, the GTCP also produced 3 media articles and was featured on ABC Rural's website (www.abc.net.au/news/rural/) as well as participating in a live radio broadcast from Gnaraloo Station. Two articles appeared in the Northern Guardian and the third in 'The West' newspaper in Western Australia.

9.3.4 Awards

Gnaraloo received a *2012 Natural Environment Conservation Award (Midwest - Gascoyne)* from the Keep Australia Beautiful Council (WA) under its Tidy Towns Sustainable Communities Awards. Gnaraloo was also announced as the State Winner for "Natural Environment Conservation". These awards were given in recognition of the GTCP and the linked *Gnaraloo Feral Animal Control Program* (**Chapter 4** and Gnaraloo Feral Animal Control Program - Gnaraloo Wilderness Foundation).

9.3.5 Data sharing with others

At the end of each monitoring season, the GTCP freely shares its data and findings with a wide range of organisations and bodies, in Australia and overseas. This includes the State Government via their nominated web-based 'DEC Fauna Survey Database'. The DEC Fauna Survey Database contains records of West 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 and 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 Western Australian Museum FaunaBase database.

10 GLOSSARY

Clutch	All of the eggs deposited in a single nest.
Clutch frequency	Number of clutches laid per year by an individual female.
Day Survey	Morning turtle nesting activity monitoring in the GBR and/or the GCFR.
Disturbance	Signs of digging or burrowing in the nest area, without the presence of turtle eggshell fragments, whole turtle eggs, yolky turtle eggshells or dead hatchlings present at the surface, whether by native or feral predators.
Egg chamber	A deep hole dug by a female turtle into the primary body pit of a nest using the turtle's back flippers, into which eggs are deposited.
Erosion	Exposure of the egg chamber by environmental factors, for example, by tides, storms, and/or wind related sand removal.
F	The test statistic calculated in a linear regression and other statistical models.
Failed nesting attempts	A reference to Unsuccessful Nesting Attempts and U Tracks collectively.
Field monitoring season	The period during which beach monitoring surveys are conducted each year, namely from 1 November – 28 February.
GBR Survey Area	The designated area for surveys within the GBR, specifically between GBN and BP9 (inclusive of Sub-sections BP7 and BP8).
GCFR Survey Area	The designated area for surveys within the GCFR, specifically between GFS and GFN (inclusive of Sub-sections GFH, GRS, GFR, and GLN).

GTCP season	Refers to the standard annual GTCP monitoring period from 1 November to 28 February the following year, including consecutive daily surveys in the GBR, and surveys for part periods in the GCFR.
Hatching Success	Completion of incubation and hatching of turtle eggs; under the current GTCP protocol, this is a binary outcome variable (i.e. evidence of hatching versus no evidence of hatching), whereas technically the term refers to the proportion of eggs in a clutch that hatch.
Hatchling	A newly hatched turtle.
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).
Nesting phase	The phase of the on-beach portion of the nesting cycle (i.e. from emergence to return to the ocean).
Nesting Success	The proportion of emergences that resulted in a nest.
Nest site selection	Selection of a site to dig a nest and lay eggs on a nesting beach by a reproductively active adult female sea turtle.
Night survey	Night-time visual monitoring of turtle nesting activity in the GBR.
P-value	Significance statistic calculated in linear regression and other statistical models.
Phenology	The study of cyclic and seasonal natural phenomena, especially in relation to climate, plant and animal life.
Predation	Evidence of mortality at a turtle nest (e.g. turtle eggshell fragments, whole turtle eggs, yolky turtle eggshells, dead hatchlings present at the surface, or an exposed egg chamber).

r^2	A statistic calculated in linear regression models that indicates the proportion of variation in the response variable explained by the model.
Rookery	A breeding area for a large number of animals.
Sampled Nests	A statistically representative subset of nests in the standard survey area that are monitored daily throughout the monitoring period to identify and assess the extent and impact of predation (feral and native), disturbance, environmental impacts and Hatching Success.
Sub-section	Sectors that the surveyed rookeries (GBR and GCFR Survey Areas) are divided into for data collection.
Unidentified Nesting Activity	A nesting attempt with no clear characteristics, preventing a researcher from assigning a category (N, UNA, U Track).
Unsuccessful Nesting Attempt	A nesting attempt during which the turtle does not deposit any eggs, but there is evidence of digging.
U Track	A nesting attempt with no evidence of digging.

11 ABBREVIATIONS

APMS	Animal Pest Management Services
BP7	Beach Point 7 (-23.75001º S; 113.56871º E)
BP8	Beach Point 8 (-23.73631º S; 113.57448º E)
BP9	Beach Point 9 (-23.72195º S; 113.57750º E)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention)
D	The horizontal beach zone commencing at the base of a Dune
DEC	Department of Environment and Conservation, Western Australia
E	The horizontal beach zone commencing at the edge of any vegetation
ECF	Estimated clutch frequency
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
ESD	Nest erosion by shifting sand dunes
ETS	Nest erosion by tides or storms
GBN	Gnaraloo Bay North survey point (-23.76708º S, 113.54584º E)
GBR	Gnaraloo Bay Rookery
GCFR	Gnaraloo Cape Farquhar Rookery
GFACP	Gnaraloo Feral Animal Control Program
GFH	Gnaraloo Farquhar Hut survey point (-23.622023º S; 113.634134º E)
GFN	Gnaraloo Farquhar North survey point (-23.57697º S; 113.69830º E)
GFS	Gnaraloo Farquhar South survey point (-23.64168º S; 113.61544º E)

GFR	Gnaraloo Farquhar Runway survey point (-23.59641º S; 113.66083º E)
GLN	Gnaraloo Lagoon North survey point (-23.57697º S; 113.69828º E)
GPS	Global Positioning System
GRS	Gnaraloo Runway South survey point (-23.61336º S; 113.64379º E)
GTCP	Gnaraloo Turtle Conservation Program
GTCP field team	The scientific Program Assistant and Interns
H	The horizontal beach zone commencing at the high-water mark
I	The intertidal beach zone
IOSEA	Indian Ocean South-East Asian
ITS	Nest inundation by tides or storms
IUCN	International Union for the Conservation of Nature
MERI	A Monitoring, Evaluation, Reporting and Improvement management strategy
MNES	Matters of National Environmental Significance (EPBC Act)
N	Nest
NAD	Nesting Activity Determination
NMP	Ningaloo Marine Park
NTP	DEC's Ningaloo Turtle Program, Exmouth, Western Australia
RMU	Regional Management Unit
SD	Standard Deviation
SE	Standard Error
SI	Species Identification
SSD	Nest suffocation by shifting dunes
Ua	Unidentified Nesting Activity

UNA	Unsuccessful Nesting Attempt
UT	U Track

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Appendix A: MAPS

1 Sea turtle rookeries and marine sanctuary zones at Gnaraloo, GTCP 2012/13

2 Gnaraloo Bay Rookery, Survey Area, GTCP 2012/13

3 Gnaraloo Bay Rookery, Distribution of nesting activities (02/11/12 – 28/02/13), GTCP 2012/13

4 Gnaraloo Bay Rookery, Density of nesting activities (02/11/12 – 28/02/13), GTCP 2012/13

5 Gnaraloo Bay Rookery, Distribution of Nests (02/11/12 – 28/02/13), GTCP 2012/13

6 Gnaraloo Bay Rookery, Distribution of total nesting activities by Species (02/11/12 – 28/02/13), GTCP 2012/13

7 Gnaraloo Bay Rookery, Location of Sampled Nests (02/11/12 – 28/02/13), GTCP 2012/13

8 Gnaraloo Cape Farquhar Rookery, Survey Area, GTCP 2012/13

9 Gnaraloo Cape Farquhar Rookery, Distribution of nesting activities, GTCP 2012/13

10 Gnaraloo Cape Farquhar Rookery, Density of nesting activities, GTCP 2012/13

11 Gnaraloo Cape Farquhar Rookery, Distribution of Nests, GTCP 2012/13

12 Gnaraloo Cape Farquhar Rookery, Distribution of Nests by species, GTCP 2012/13

13 Gnaraloo Cape Farquhar Rookery, Previous Nesting Activity Distribution, GTCP 2012/13

14 Gnaraloo Bay Rookery, Density of Nests (02/11/12 - 28/02/13), GTCP 2012/13

15 Gnaraloo Cape Farquhar Rookery, Density of Nests, GTCP 2012/13

Appendix B: Photo Plates

1 GBN permanent marker (northern boundary of Gnaraloo Bay marine sanctuary zone), GTCP 2012/13

2 GBN looking north, GTCP 2012/13

3 BP7 looking south, GTCP 2012/13

4 BP9 looking south, GTCP 2012/13

5 GCFR Sub-section 1 looking north, GTCP 2012/13

6 GCFR – Point GFH looking north, GTCP 2012/13

7 GTCP Weather Station, GTCP 2012/13

8 GTCP Field researchers recording data, GTCP 2012/13

9 GTCP Field researcher at a Sampled Nest, GTCP 2012/13

10 GTCP Field researchers with Nagle school students, GTCP 2012/13

11 GTCP Field Team Leader presenting to Tom Price school group, GTCP 2012/13

12 GTCP Field researchers at South Fremantle High School, GTCP 2012/13

13 Feral Cat in BP8-BP9 (GBR), GTCP 2012/13

14 Running ghost crab (*Ocypode ceratophthalma*), GTCP 2012/13

15 Golden ghost crab (Ocypode convexa), GTCP 2012/13

16 Feral cat prints in GBR, GTCP 2012/13

17 GTCP Field Researcher assisting APMS with baiting, GTCP 2012/13

18 Green (*Chelonia mydas*) turtle tracks, GTCP 2012/13

19 Loggerhead (*Caretta caretta*) turtle tracks, GTCP 2012/13