Gnaraloo Turtle Conservation Program

Gnaraloo Bay Rookery
Gnaraloo Cape Farquhar Rookery

Report 2015/16

www.gnaraloo.com.au/conservation www.gnaraloo.org

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1 EXECUTIVE SUMMARY

The Gnaraloo Turtle Conservation Program (**GTCP**) is a scientific research and public outreach program aimed at identifying, monitoring and protecting marine turtle rookeries located along a 65 km stretch of beach at the southern end of the Ningaloo Reef at Gnaraloo, Western Australia (**WA**) (**Appendix A**). Since 2008, the GTCP has conducted daily beach track surveys, along with a variety of complementary research and monitoring activities (e.g. Night Surveys to verify daytime track interpretations), in the Gnaraloo Bay Rookery (**GBR**) between 1 November and 28 February. From 2011/12, surveys of the Gnaraloo Cape Farquhar Rookery (**GCFR**), located approximately 22 km north of the Gnaraloo Homestead, have been initiated to gather data on turtle nesting in this rookery, which was unreported prior to 2011. The endangered loggerhead turtle (*Caretta caretta)* is the primary species nesting in both the GBR and GCFR Survey Areas, with green turtles (*Chelonia mydas*) and possibly hawksbill turtles (*Eretmochelys imbricata*) also nesting infrequently. In this document, we report on the activities of the GTCP during the sea turtle nesting season 2015/16.

Gnaraloo Bay Rookery – Day Surveys

GBR Day Surveys were conducted during 1 November 2015 – 28 February 2016 with no days missed. A total of 480 turtle nesting activities were recorded, including 305 Nests. The first Nest in the GBR Survey Area was dug on 4 November 2015 and the last two Nests during the GTCP survey period were dug on 28 February 2015. The within-season temporal distribution of nesting activities was broadly similar to previous GTCP seasons, but lacked the distinctive mid-season peak between mid-December and late January. In previous seasons, the GBR Survey Area has received an average of approximately 75 nesting activities and 40 Nests per week during this time; during season 2015/16, approximately 35 nesting activities and 20 Nests were recorded per week during this time. However, nesting activity late in the season was above average and tracks were still being observed in the GBR Survey Area in late March 2016 by Gnaraloo staff and visitors, so nesting during season 2015/16 appears to have been delayed compared to previous seasons. This may have contributed, to some extent, to the low observed nesting activity and Nest totals. As in previous seasons, GBR Sub-section BP8 – BP9 received the majority (75%) of nesting activities, followed by Sub-section GBN – BP7 (18%) and BP7 – BP8 (7%).

In total, season 2015/16 experienced the lowest total nesting activities and Nests since monitoring began in 2008 (**Table 1, Figure 1, Figure 2**). For the second straight season, no evidence of nesting by green turtles was found. The total number of nesting activities in the GBR Survey Area during 1 November 2015 – 28 February 2016 has declined significantly since

2009/10[1], while the total number of Nests has experienced a non-significant decline since 2008/09. Seasons with the highest Nest totals have generally corresponded with high rates of Nesting success (i.e. the proportion of emergences that resulted in a Nest), which suggests that favorable local beach conditions contribute to high Nest totals during these seasons. This may mask an overall downward trend in use of this rookery as indicated by the decline in total nesting activity. However, season 2015/16 experienced a low Nest total despite an above-average Nesting success rate (64%), and total nesting activity has now declined every year for seven consecutive years. While the GBR Day Survey time series is still very short, these trends are noteworthy and potentially concerning considering the likely long-standing impact of fox predation on turtle Nests prior to the initiation of the Gnaraloo Feral Animal Control Program (GFACP) in 2008. Additional impacts associated with historical fox predation may be “in the pipeline” for this rookery, so continued declines in nesting activity might be expected in coming years.

Gnaraloo Bay Rookery – Night Surveys

We conducted Night Surveys in the GBR Survey Area during 15 November – 19 December 2015. The primary goal of Night Surveys was to verify track interpretations made during Day Surveys in terms of Species Identification (**SI**) and Nesting Activity Determination (**NAD**), as well as to estimate Nest detection bias (i.e. the likelihood of correctly identifying Nests during Day Surveys). Day Survey track monitoring had an accuracy of 98.4% for SI (consistent with previous years, which have all been > 95%) and 83.0% for NAD. Thus, current levels of training by the GTCP and experience of the seasonal GTCP field team appear sufficient for SI and NAD during Day Surveys based on pre-determined target success rates (95.0% and 80.0%, respectively). Nest detection bias during season 2015/16 was 0%, meaning that NAD errors did not result in underestimating or overestimating the number of Nests. Nest detection bias during 2010/11 – 2015/16 averaged -13.0%, but also decreased over that period, suggesting an overall tendency to underestimate Nest abundance, but improvement in Nest detection at the program level over time. Thus, Nest totals given in Table 1 are likely conservative. These results highlight the importance of implementing Night Survey verification in nesting beach programs where track surveys provide indices of Nest abundance. After accounting for Nest detection bias (data for all years were pooled due to low sample size of verified Nests during some seasons), we estimate that there is 405 loggerhead turtle Nests in the GBR Survey Area per season (refer to **Chapter 6**).

1 2008/09 nesting activity total excluded because the dates and locations of unsuccessful activities were not recorded during this season.

Gnaraloo Bay Rookery – Sampled Nest Surveys

Within the GBR Survey Area, a subset of Nests (n = 49) were designated as Sampled Nests and these were monitored daily for evidence of predation and disturbance, inundation, sand movement and hatching. No evidence of disturbance or predation of Sampled Nests by feral predators was observed. In contrast, 28 of 49 (57.1%) Sampled Nests were either disturbed or predated by ghost crabs (*Ocypode convexa* or *O. ceratophthalma*), which was a relatively low rate of crab activity compared to previous seasons. However, only 5 of the 28 (17.9%) of Sampled Nests that were disturbed or predated by crabs showed signs of hatching, and none of the Sampled Nests that were predated by crabs showed signs of hatching. The precise impact of crab disturbance and predation on turtle hatching success (i.e. completion of incubation and hatching of turtle eggs) remains unknown. In terms of environmental impacts, no major storms or cyclones occurred during the season 2015/16, so inundation of Sampled Nests by high tides and/or storm surge was infrequent, influencing only 9 of 49 (18.4%) Sampled Nests. No instances of erosion (i.e. exposure of the egg chamber by environmental factors) were observed. At the end of their monitoring period, 5 Sampled Nests were excavated in collaboration with the Department of Parks and Wildlife (**DPaW**). A key finding from these excavations was that a large proportion of eggs in one Sampled Nest that was considered hatched under the current binary approach to recording hatching success (i.e. evidence of hatching vs. no evidence of hatching) remained undeveloped, emphasizing the need for a more detailed approach to quantifying hatching success. Additional excavations in future seasons would be a valuable addition to the program.

Gnaraloo Cape Farquhar Rookery – Day Surveys

In addition to monitoring turtle nesting in the GBR Survey Area, the GTCP conducted Day Surveys in the Gnaraloo Cape Farquhar Rookery (**GCFR**), located 22 km north of the Gnaraloo Homestead, during a subset of the nesting season (27 December 2015 – 9 January 2016). A total of 133 nesting activities, including 59 Nests were recorded during these surveys, all of which were ascribed to loggerhead turtles. Season 2015/16 was the first season since 2012/13 in which the number of nesting activities and Nests in the GCFR Survey Area exceeded those in the GBR Survey Area during the overlapping monitoring period. It is not yet possible to estimate the number of females nesting in the GCFR or make full-season comparisons with nesting activity in the GBR. Nevertheless, data collected to date indicate that, on average, a comparable or slightly lower amount of nesting activity occurs in the monitored sections of the GCFR compared to the GBR Survey Area during the overlapping monitoring periods. Thus, continued work in the GCFR in coming seasons is warranted.

Additional achievements during 2015/16

The GTCP initiated and completed a satellite tagging project of loggerhead turtles in both the GBR and GCFR survey areas during the season 2015/16, which will be reported on separately.

We also prepared and submitted a manuscript to a peer-reviewed journal with summary turtle nesting data from 2008/09 – 2015/16 in the GBR Survey Area.

Gnaraloo Wilderness Foundation

Gnaraloo's management team established the Gnaraloo Wilderness Foundation, a not-for-profit organisation, on 12 January 2016 to protect native, terrestrial and marine, flora and fauna at Gnaraloo for present and future generations.

Education and community engagement

Community engagement has been a central focus of the GTCP since the season 2010/11 and continued to expand during the season 2015/16. The GTCP Field Research Team directly engaged with 3,846 persons in total (to 31 May 2016) in WA, United Kingdom, United States of America, Spain, India and Egypt. This was done partially onsite and also off-site through presentations at 44 primary and high schools, 2 post-secondary institutions and 1 science fair in WA (including the communities of Carnarvon, Geraldton, Dongara, Bullsbrook, Harvey, Australind, Bunbury, Dardanup and Perth). The GTCP also established a profile on *Skype in the Classroom* (Microsoft) and used YouTube to reach out to schools (5) located elsewhere in Australia and around the world. The Gnaraloo Wilderness Foundation developed a free Turtle Tracker App for smartphones to share the results of the GTCP's turtle satellite tagging project 2015/16, with a public fund raiser competition to name the 10 associated loggerhead turtles. It developed and used a variety of communication and educational tools to engage the public. It also offered a National Environmental Science and Geography Challenge for schools in Australia to develop a management plan for Gnaraloo Bay. The GTCP was featured in 24 media articles and various radio and television interviews during the season 2015/16. The GTCP Facebook page has over 2,770 followers as at 31 May 2016.

The GTCP also shares its data and program information with the scientific and conservation community (local, national and international) via several online repositories and websites.

Table 1: Summary of sea turtle nesting activities in the GBR Survey Area during 2008/09 – 2015/16

GTCP season		2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Loggerhead turtle *Caretta caretta*	**Nesting activities (N, UNA, U Track & Ua) recorded by Day Surveys**	N/A	731	758	700	672	635	528	479
	Nests recorded by Day Surveys	319	480	399	324	303	424	328	304
	Nest detection bias	N/A	N/A	- 17.8%	- 21.4%	- 15.8%	- 11.9%	- 11.4%	0%
	Estimated number of females	67 (61, 74)	100 (92, 111)	83 (76, 92)	68 (62, 75)	63 (58, 70)	89 (81, 98)	69 (63, 76)	64 (58, 70)
	Percentage species composition	98.2%	94.1%	98.0%	92.8%	97.7%	98.6%	100%	100%
Green turtle *Chelonia mydas*	**Nesting activities recorded by Day Surveys**	N/A	60	15	53	10	10	0	0
	Nests recorded by Day Surveys	6	30	8	25	7	6	0	0
	Estimated number of females	1	5	1	4	1	1	0	0
	Percentage species composition	1.8%	5.9%	2.0%	7.2%	2.3%	1.4%	0%	0%
Unidentified species	**Nesting activities recorded by Day Surveys**	N/A	22	28	16	17	7	11	1
	Nests recorded by Day Surveys	11	12	14	0	2	2	3	1

Total nesting activities recorded by Day Surveys (All species)	**N/A**	**813**	**801**	**769**	**699**	**652**	**539**	**480**
Total Nests recorded by Day Surveys (All species)	**336**	**522**	**421**	**349**	**312**	**432**	**331**	**305**

Notes:

1. This table supersedes all previous issued GTCP nesting summary tables. The numbers recorded for the GBR Survey Area are conservative as we do not monitor the entire rookery nor the entire nesting period, but only parts thereof due to logistical and resource constraints. This Table only reflects data collected during the now standard GTCP monitoring period (1 November – 28 February) in the now standard GBR Survey Area, being GBN – BP9.
2. If errors were identified in Day Survey track assessments based on comparison with direct Night Survey observations, they were corrected prior to data summary for this table.
3. Some minor deviations in timing occurred from the now standard GTCP monitoring period. Notably, the portion of GTCP season 2008/09 that is relevant to Table 1 ran from 1 December 2008 – 28 February 2009, while GTCP season 2010/11 ran from 13 November 2010 – 4 February 2011 (with one day missed due to a cyclone). Thus, numbers for

these seasons are conservative. During season 2011/12, 4 survey days were missed and during season 2012/13, 1 survey day was missed. Overall, the mean number of days surveyed during GTCP seasons 2008/09 – 2015/16 was 110.9 (SE = 5.5).

4. Only Nest numbers were recorded during GTCP season 2008/09, other nesting activity (i.e. UNA, UTrack and Ua) numbers were not recorded during the first year of the program. All necessary data were recorded for all nesting activity types in the remaining seasons 2009/10 – 2015/16. The Nest total for 2008/09 was included because dates and locations for all Nests were recorded.
5. Nests for which the species could not be identified were excluded from species composition calculations.
6. Particularly during the early years of the GTCP (2008/09 – 2009/10), a significant number of tracks in the GBR were considered to be from hawksbill turtles despite this species being reported to rarely nest as far south as Gnaraloo (pers. comm., R.I.T. Prince, DPaW). Because hawksbill turtle tracks can be extremely difficult to distinguish from small loggerhead turtle tracks, particularly on wind prone beaches such as those at Gnaraloo, these track interpretations had a potential for error. Since 2010/11, we have directly observed 441 turtles during Night Surveys in the GBR Survey Area (as of 28/02/2016) (this includes multiple sightings of individual turtles since they were not tagged and therefore individuals could not be identified). No hawksbill turtles have been seen. In contrast, the low proportion of green turtles seen during Night Surveys in the GBR has aligned closely with the proportion of tracks ascribed to this species during Day Surveys. Furthermore, the proportion of tracks ascribed to loggerhead turtles during Day Surveys was initially lower than the proportion seen during Night Surveys but was equivalent if the putative hawksbill tracks were re-classified as loggerhead turtle tracks. Based on this evidence, we retroactively changed all hawksbill turtle tracks in the Day Survey data set 2008/09 – 2015/16 to loggerhead turtles to minimize species identification errors. The number of hawksbill turtle Nests changed to loggerhead turtle Nests during GTCP seasons 2008/09 – 2015/16 was respectively: 14, 78, 2, 0, 1, 5, 0 and 2.
7. Nest detection bias for loggerhead turtles was determined by comparing Day Survey track interpretations with independent, direct observations of turtle nesting activities during Night Surveys, which were conducted during a subset of seasons 2010/11 – 2015/16. To be considered 'verified' during Night Surveys, the turtle had to be observed during a nesting phase that would ensure 100 % certainty of the nesting activity (i.e. Nest, UNA or U Track). For Nests, the turtle had to be seen at the laying phase at the latest and witnessed depositing eggs into the egg chamber. 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 U Tracks, 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. For each season, we extracted all verified Night Survey observations and their corresponding Day Survey track interpretations. This included cases in which a verified activity was missed entirely the following morning or incorrectly assigned to a green turtle. We then tallied the number of Nests recorded in each data set. The Night Survey Nest count was taken to represent the true (i.e. expected) value and the Day Survey Nest count represented the experimental (i.e. observed) value. We calculated the percent error between the two using the formula: % error = (observed - expected) / expected * 100. This analysis was not conducted for green turtles due to the paucity of Night Survey observations for this species.
8. Only the Nest numbers recorded by Day Surveys per season are shown in Table (i.e. not the adjusted Nest numbers per season in line with the Nest detention bias percentage for that particular season), due to the sample sizes for some of the seasons being too small. Instead, overall sample size was used and the calculation was done for the data set 2010/11 – 2015/16 as a whole.
9. To estimate the number of female loggerhead turtles likely nesting in the GBR during each season, we consulted the literature for clutch frequency estimates for this species derived from satellite telemetry. Telemetry-based estimates more accurately reflect true clutch frequency than survey-based estimates since nesting events may be missed during beach surveys if they are outside a prescribed survey area or period, or are simply not detected (Tucker, 2010). We calculated the mean and SD of the estimated clutch frequency (ECF) (of 4.78) found in currently available studies (Scott, 2006; Rees et al., 2008; Rees et al., 2010; Tucker, 2010). We then divided the number of Nests recorded during

Day Surveys within each season by the mean ECF and the mean ECF ± 1 SD to provide an estimate of uncertainty (i.e. the numbers in brackets).

10. The number of female green turtles was estimated using a clutch frequency of 6 (Limpus et al., 2001).

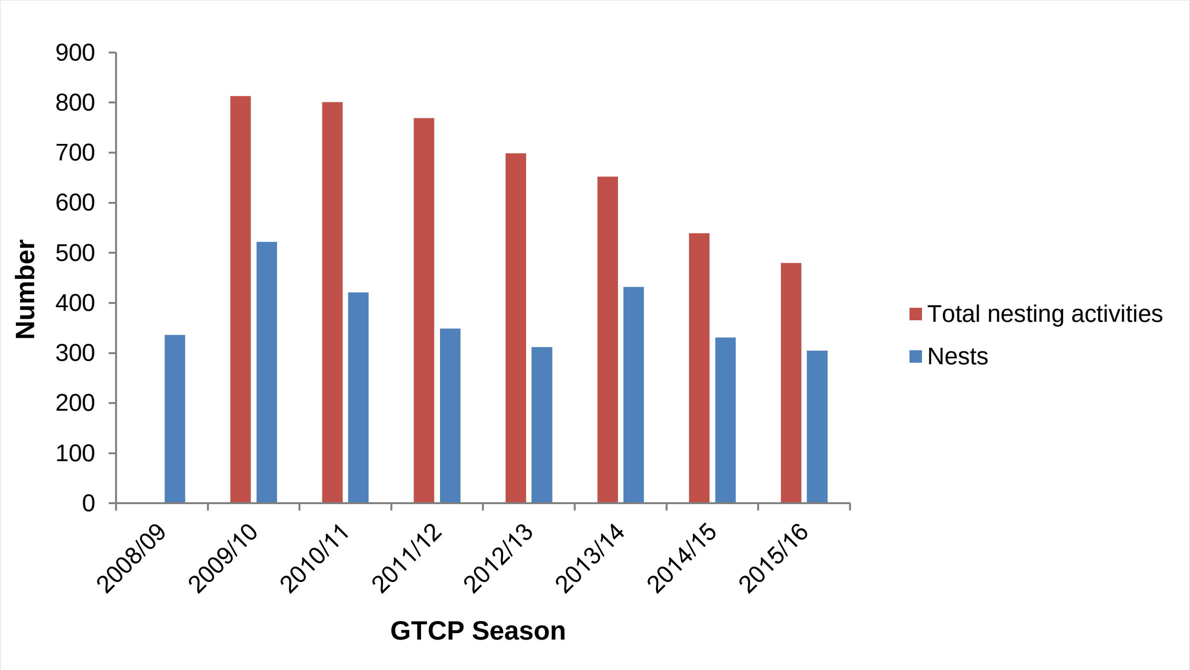

Figure 1: Sea turtle nesting activities in the GBR Survey Area during 2008/09 - 2015/16 (All species)

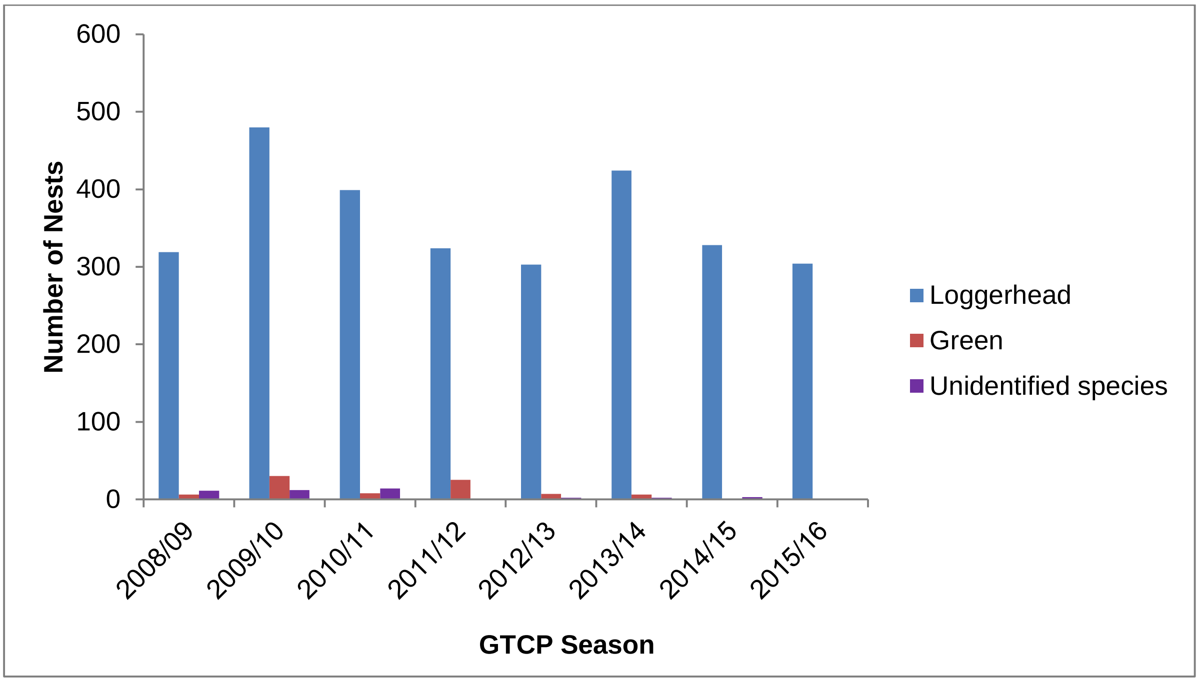

Figure 2: Sea turtle Nests per species in the GBR Survey Area during 2008/09 – 2015/16 (All species)

2 BACKGROUND

2.1 Program overview

The Gnaraloo Turtle Conservation Program (**GTCP**) is a scientific research and community engagement program aimed at identifying, monitoring and protecting marine turtle rookeries located along a 65 km stretch of coast at the southern end of the Ningaloo Reef at Gnaraloo, WA (**Appendix A**). The GTCP commenced on-ground in 2008 at Gnaraloo Station, a pastoral station and wilderness tourism business located adjacent to the *Ningaloo Marine Park*, *Ningaloo Coast World Heritage Area* and *Ningaloo Coast National Heritage Listed Area*. The GTCP currently focuses on two turtle rookeries – the Gnaraloo Bay Rookery (**GBR**) and Gnaraloo Cape Farquhar Rookery (**GCFR**) – where loggerhead turtles (*Caretta caretta*) are the primary nesting species, with green turtles (*Chelonia mydas*) and possibly hawksbill turtles (*Eretmochelys imbricata*) nesting infrequently. Since 2008, GTCP research teams have conducted early-morning beach track surveys and nest monitoring activities, using protocols adapted from the neighbouring Ningaloo Turtle Program (**NTP**)[2] in Exmouth, as well as other targeted research activities (e.g. verification of Day Survey track interpretations via direct observation during Night Surveys). The Trust also administers the Gnaraloo Feral Animal Control Program (**GFACP**) which has simultaneously conducted the control of invasive predators such as the European red fox, feral cats and wild dogs in order to reduce the impact of feral animal predation on turtle Nests and hatchlings.

In addition to monitoring and research, the GTCP conducts a growing range of educational and community engagement activities including onsite participant programs at Gnaraloo, school presentations, Skype lessons with international school groups and media appearances. The GTCP has also partnered with external scientists at several Australian universities to facilitate Honours and Masters-level research projects and is developing a substantial public profile including a Facebook page with more than 2,700 followers.

Gnaraloo's terrestrial and marine landscape is also habitat to many flora and fauna other than endangered and threatened sea turtles. The area is a unique and rare remaining remnant of Australian wilderness. Gnaraloo's management team established the Gnaraloo Wilderness Foundation on 12 January 2016. Its aim is to protect the native, terrestrial and marine, flora and fauna in, on and under the landscape at Gnaraloo for present and future generations. The Foundation is a separate legal entity to the Gnaraloo Station Trust and its Charter can be viewed

[2] http://www.ningalooturtles.org.au

on its website (www.gnaraloo.org).

2.2 Sea turtle conservation: global to regional perspectives

Globally, six of seven sea turtle species are listed as Vulnerable, Endangered or Critically Endangered on the *International Union for the Conservation of Nature* (**IUCN**) Red List of Threatened Species[3], while the seventh, the flatback turtle (*Natator depressus*), is considered Data Deficient. Australia is home to six of seven sea turtle species (i.e. all but the Kemp's ridley turtle, *Lepidochelys kempii*). Therefore, effective management and conservation of Australian sea turtles is critical to global conservation efforts for these species. Australia has signed several international agreements seeking to protect sea turtles, whose migratory movements often cross international boundaries. Since 1991, Australia has been a signatory to the *Convention on the Conservation of Migratory Species of Wild Animals* (**CMS**), also known as the *Bonn Convention*. The CMS provides a global platform for conservation of animals that pass through multiple countries within their migratory range. Australia also ratified the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (**CITES**) in 1976 and all marine turtles occurring in Australian waters are listed on CITES Appendix I (Species threatened with extinction). Australia is also a signatory to the *Indian Ocean and South-East Asian (**IOSEA**) Marine Turtle Memorandum of Understanding*, a multi-lateral agreement supported by the United Nations Environment Programme and the CMS, which seeks to reduce threats to marine turtles, conserve critical habitat, promote exchange of scientific data, increase public awareness and enhance regional co-operation on sea turtle conservation.

At the national level, Australian marine turtles are protected under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (**EPBC Act**). The EPBC Act protects and manages nationally and internationally significant flora, fauna, ecological communities and heritage places. It aims to provide broad environmental protection, especially for *Matters of National Environmental Significance* (**MNES**), which include World Heritage and National Heritage properties, nationally threatened species and ecological communities, migratory species (which include sea turtles) and commonwealth marine areas. Under the EPBC Act, loggerhead, leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*) turtles are currently listed as Endangered while green, hawksbill and flatback turtles are considered Vulnerable[4]. Conservation efforts for sea turtle population recovery in Australia are guided by the *Recovery Plan for Marine Turtles in Australia* (2003) and broader strategic plans such as *Australia's*

[3] http://www.iucnredlist.org
[4] http://www.environment.gov.au/marine/marine-species/marine-turtles

Biodiversity Conservation Strategy 2010-2030.

At the regional level, sea turtle conservation is mandated and implemented under region-specific legislation and strategic plans. In WA, the loggerhead and leatherback turtle are listed as threatened under the *Wildlife Conservation Act 1950* and all other sea turtles are protected as native fauna, although provision is made for take by indigenous people. Management of marine turtle populations and habitats in WA also falls under the purview of the *North-west Marine Bioregional Plan* (2008) of the Department of the Environment (Australian Government), which supports the implementation of the EPBC Act at the regional level.

Primary threats to Australian sea turtles include bycatch in commercial fisheries, mortality related to entanglement in or ingestion of marine debris, predation of turtle eggs by native and introduced predators, coastal human activities that endanger critical nesting, foraging or migratory habitats and direct harvest of adult turtles and eggs (Marine Species Section Approvals and Wildlife Division, Environment Australia, 2003). Climate change is also an important conservation issue for sea turtles (Hawkes *et al.* 2009) for several reasons, including that increasing sand temperatures at Nest depths can skew hatchling sex ratios and increase mortality in embryos and hatchlings (Fuentes *et al.* 2010). In order to reliably assess marine turtle population trends and develop effective management strategies to protect against these and other threats, it is critical to gain an understanding of the biology and status of nesting aggregations. Nesting beach programs in WA began relatively recently (e.g. the NTP was established in 2002), limiting our understanding of WA nesting aggregations. Thus, it is vital to undertake and expand nesting beach programs in WA to provide longitudinal data sets and enact conservation measures, as necessary, to facilitate population recovery and protection.

2.3 The GTCP and GFACP in context

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

- supporting recovery of sea turtle populations and threat abatement for species listed in the EPBC Act as MNES;
- 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 2008;
- developing and managing an annual on-ground monitoring program of seasonal sea turtle nesting and feral predator activities in the rookeries on the Gnaraloo coastline;

- annually identifying and undertaking management activities to protect Gnaraloo rookeries from threats that may impact reproductive success;
- implementing an extensive annual training and employment plan of graduate scientific professionals as future leaders and decision-makers, including a comprehensive scientific internship program (6 months, fulltime);
- collaborating with external researchers (e.g. university faculty and students) to undertake targeted research projects to address questions of ecological or conservation importance;
- 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 general public (in all categories, local, national and international);
- freely sharing information about the Gnaraloo sea turtles with government departments, universities and sea turtle experts (in all categories, local, national and international).

2.4 Focal species: the loggerhead turtle

2.4.1 Distribution and population structure globally

The loggerhead turtle is distributed throughout the world's tropical and warm temperate oceans (Bolten & Witherington, 2003). For management purposes, this species has been divided into ten putative sub-populations or regional management units (**RMUs**) based on available nesting, genetic and movement data (Wallace *et al*. 2010). According to the most recent IUCN assessment (Casale & Tucker, 2015), the northwest Atlantic Ocean and northern Indian Ocean RMUs comprise the majority of annual nesting for the species (83,717 and 70,000 Nests per year, respectively), while the southeast Indian Ocean constitutes a relatively small proportion (2,955 Nests per year) (**Table 2,** Casale & Tucker, 2015). Critically, however, the southeast Indian Ocean RMU is among the least well-studied RMUs. Therefore, vital information on loggerhead turtle reproductive biology in this region are lacking, including nesting census data from key rookeries (Hamann et al., 2013).

Table 2: Estimated sizes of the 10 loggerhead turtle sub-populations based on the most recent nesting census data, 2015

NO.	SUB-POPULATION (RMU)	NESTS PER YEAR
1	Northwest Atlantic Ocean	83,717
2	North Indian Ocean	70,000
3	Northeast Atlantic Ocean	15,000
4	North Pacific Ocean	9,053
5	Southwest Atlantic Ocean	7,696
6	Mediterranean Ocean	7,200
7	Southwest Indian Ocean	4,600
8	**Southeast Indian Ocean**	**2,955**
9	Northeast Indian Ocean	25
10	South Pacific Ocean	Data not available

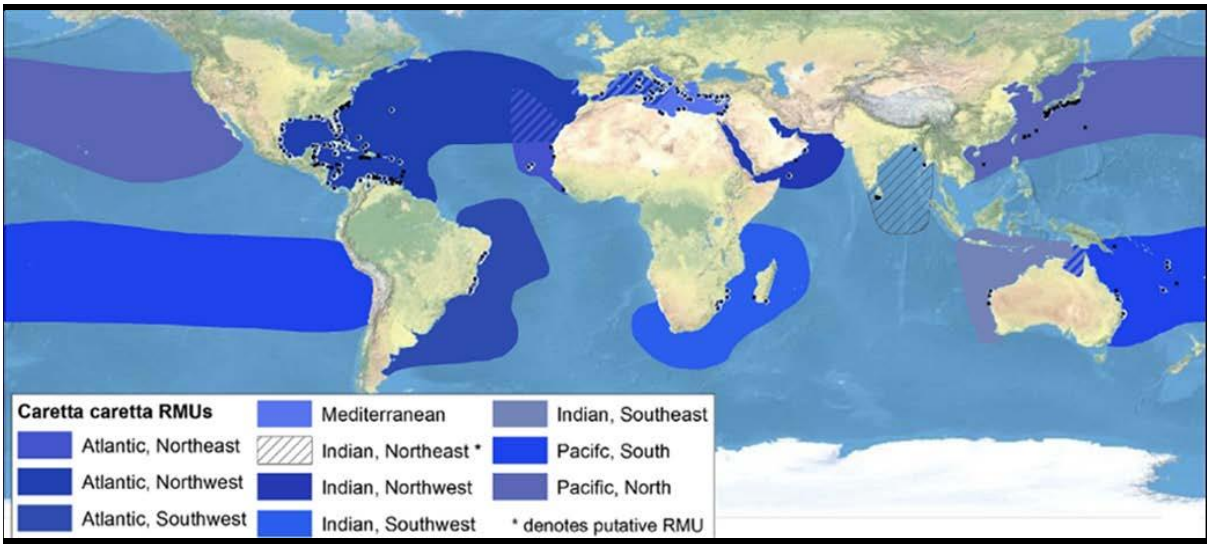

Figure 3: Distribution of the 10 loggerhead turtle sub-populations in the world, 2015

2.4.2 Nesting in WA

All known nesting by loggerhead turtles in the southeast Indian Ocean occurs in WA (Dodd 1988; Baldwin *et al.* 2003; Wallace *et al.* 2010). Primary nesting sites are located at Dirk Hartog Island, which is situated at the mouth of Shark Bay; the Muiron Islands offshore of Exmouth and on mainland beaches along the Ningaloo coast from Carnarvon to Exmouth. Dirk Hartog Island hosts approximately 70% of all nesting in WA, with an estimated 1000 – 3000 females nesting at this site annually (Baldwin *et al.* 2003; Limpus, 2009; Reinhold & Whiting, 2014). In terms of mainland rookeries, together the GBR and GCFR at Gnaraloo represent one of the largest known nesting aggregation on the Ningaloo coast. A comparable amount of nesting by loggerhead turtles may occur on beaches monitored by the NTP (Markovina & Prophet 2014), although methodological differences (i.e. length and timing of surveys) make direct comparisons difficult.

Mainland rookeries in WA tend to be much smaller than the island rookeries and this is likely due, at least in part, to historical predation by introduced foxes, which are not present at Dirk Hartog Island or the Muiron Islands, but have been active on the mainland coast since at least the 1960s (Limpus, 2009). Quantitative data on fox predation rates on sea turtles Nests in WA is lacking. However, anecdotal evidence suggests that a large proportion of turtle Nests – perhaps as much as 70% – can be destroyed by foxes in the absence of control measures (Baldwin *et al*. 2003; Limpus, 2009). This figure is consistent with data from some locations in Queensland, where foxes were reported to destroy up to 90% of turtle Nests in the late 1970s and early 1980s (Limpus, 2009). In addition to fox predation, human activity on some mainland nesting beaches (i.e. vehicle traffic) has likely also contributed to the difference in rookery sizes between mainland and island sites. Thus, it is likely that mainland rookeries in WA remain depleted relative to historic levels. Long-term monitoring and protection of these beaches is therefore critical.

2.4.3 Updated conservation status

The IUCN Marine Turtle Specialist Group conducted an assessment of the conservation status of loggerhead turtles at the global and sub-population levels in 2015. Globally, the species was downgraded from Endangered to Vulnerable (Casale & Tucker, 2015), while the southeast Indian Ocean sub-population was assessed as Near Threatened (Casale *et al.* 2015). However, the authors of these assessments emphasized well-known limitations associated with applying IUCN Red List criteria to marine turtles and other long-lived, globally distributed species (Seminoff & Shanker, 2008). Furthermore, they also note that loggerhead turtles are now largely dependent on conservation intervention (e.g. nesting beach protection) and that critical data gaps exist that preclude the assessment of the southeast Indian Ocean loggerhead turtle sub-population under most Red List criteria. Therefore, it would be a mistake to interpret the global downgrade as an indication of a reduced need for conservation of loggerhead turtles or to conclude that we have adequate information to understand and mitigate threats to this species in the southeast Indian Ocean. Rather, regional-scale programs aimed at loggerhead turtle monitoring and conservation in WA are urgently needed at this juncture to facilitate rigorous status assessments, inform management planning and undertake effective on-ground protective action.

2.5 Recruitment and field team composition

The GTCP managed its own recruitment for the seasonal GTCP Field Research Team 2015/16. The recruitment campaign focused on attracting and appointing capable candidates from local, national and international fields. The available 5 positions were advertised through print and online sources from April to May 2015 in over 10 countries. The GTCP has gained the reputation of a desirable program to be involved in and consequently the number and calibre of applicants has increased. More than 150 applications were received from Australia and overseas (98 applications for the 4 GTCP internships were received from 21 countries and 57 applications for the position of GTCP Program Assistant were received from 16 countries).

The appointed GTCP Field Research Team 2015/16 comprised of the following persons:

- *GTCP Program Assistant*: Dr. Jordan Thomson (Ph.D. in Behavioural Ecology, Canada), with previous sea turtle experience, including in WA;
- *GTCP Scientific Intern*: Mr. Alistair Green (M.Sc. in Wildlife Biology and Conservation, United Kingdom), with previous sea turtle experience;
- *GTCP Scientific Intern*: Ms. Melanie Do (Master of Conservation Biology, Australia), with previous sea turtle experience;
- *GTCP Scientific Intern*: Ms. Kimberly Nielsen (B.Sc. in Marine Science and Biology, United States of America), with previous sea turtle experience;
- *GTCP Scientific Intern*: Mr. Nicholas Goldsmith (B.Sc. in Marine Zoology, United Kingdom), with previous sea turtle experience.

2.6 Training

Since the season 2014/15, the GTCP has managed and provided training of the seasonal GTCP field teams via GTCP personnel and appointed specialist contractors. The training commences pre-season during October and includes, but is not limited to, the following elements:

- turtle track interpretation (based on NTP practices and protocols);
- feral animal track interpretation;
- venomous snake handling and relocation;

- office practices, including GTCP methodologies, practices and protocols;
- 4WD operating techniques.

Importantly, the pre-season training of the GTCP field teams is supported and enhanced by the GTCP Day and Night Surveys (during November to February) during which the learning, knowledge and experience of the field teams expand and develop significantly.

2.7 Funding and resourcing

Funding for the GTCP 2008/09 – 2014/15 was provided by the Gnaraloo Station Trust, the Australian Government under various environmental programs, Rangelands NRM WA and DPaW (**Table 3**). As this report is issued prior to the end of the financial year 2015/16, the figures for 2015/16 will be contained in the GTCP Report 2016/17.

2.8 Approvals

Research by the GTCP during 2015/16 was conducted under a Regulation 17 licence issued by DPaW under the *Wildlife Conservation Act 1950* (WA).

2.9 Report structure

This report details the activities and results of the GTCP during 2015/16. We first briefly describe the weather conditions and storm events experienced during 2015/16 at Gnaraloo (**Chapter 3**). We then summarize the results of feral predator monitoring conducted by the GTCP during Day Surveys in Gnaraloo Bay and Gnaraloo Cape Farquhar in 2015/16 (**Chapter 4**). Subsequently, we report on Day Surveys conducted in the GBR Survey Area between 1 November 2015 and 28 February 2016 (**Chapter 5**) and Night Surveys conducted in the GBR Survey Area between 15 November and 19 December 2015 (**Chapter 6**). A random sub-sample of Nests identified in the GBR Survey Area was monitored daily for signs of predation, disturbance, environmental impacts and hatching success, and this data is presented in **Chapter 7**. We then present the findings of Day Surveys conducted in the GCFR Survey Area during a two-week monitoring period (27 December 2015 – 9 January 2016) (**Chapter 8**). Finally, we summarize activities conducted as part of the GTCP education and community engagement program (**Chapter 9**).

Table 3: Funding and resourcing of the GTCP 2008/09 – 2014/15

NO.	GTCP SEASON	TOTAL PROGRAM COST	GNARALOO STATION TRUST[5]	GRANT CONTRIBUTIONS		
				AUSTRALIAN GOVERNMENT[6]	RANGELANDS NRM WA[7]	DPAW[8]
1	2008/09	$80,063.64	$55,900	$21,663.64	$0	$2,500
2	2009/10	$250,000	$250,000 Solely Funded	$0	$0	$0
3	2010/11	$220,249	$192,249	$25,000	$0	$3,000
4	2011/12	$220,249	$192,249	$25,000	$0	$3,000
5	2012/13	$243,000	$240,000	$0	$0	$3,000
6	2013/14	$481,564	$306,042	$155,022	$18,000	$2,500
7	2014/15	$502,688	$269,710	$214,978	$18,000	$0
INVESTMENT VALUE OF PROGRAM TO 30 JUNE 2015		$1,997,813.64	$1,506,150	$441,663.64	$36,000	$14,000

Note: All figures are GST exclusive of GST.

5 Financial and In-kind.

6 Financial.

7 Ibid.

8 In-kind estimates.

3 GNARALOO WEATHER

3.1 Introduction

Gnaraloo is located in the central Gascoyne region of WA, which is characterized by a moderate arid tropical climate (Gascoyne Development Commission, 2015). Mean monthly minimum temperatures in coastal parts of the Gascoyne region range from approximately 11ºC in July to 23ºC in February, while mean monthly maximum temperatures range from approximately 22ºC in July to 33ºC in February. The Gnaraloo area experiences predominantly southerly winds throughout most of the year due to the influence of the south easterly trade wind belt.

3.2 GBR Survey Area

The GTCP Field Research Team daily recorded climatic data using a Davis Vantage Pro 2 Weather Station for the duration of 2015/16, from 1 November 2015 – 28 February 2016. Located near Sub-section point BP7, about halfway along and immediately adjacent to the GBR Survey Area, 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 2015/16 was characterized by moderate daytime and mild night-time temperatures. The maximum temperature (42.3°C) was recorded on 6 February 2016, while temperatures fell to as low as 15.6°C on 7 November 2015. Gnaraloo features a prevailing southerly wind which remained relatively consistent during November 2015 – February 2016. Wind speeds reached a maximum of 66 km/h (6 November 2015), with an average of 14.9 km/h for the entire season. Rainfall was recorded on seven occasions during 2015/16, totalling 4.4 mm.

Multi-year patterns of temperature, wind speed and rainfall since season 2011/12 are shown in **Figure 4**, **Figure 5** and **Figure 6**.

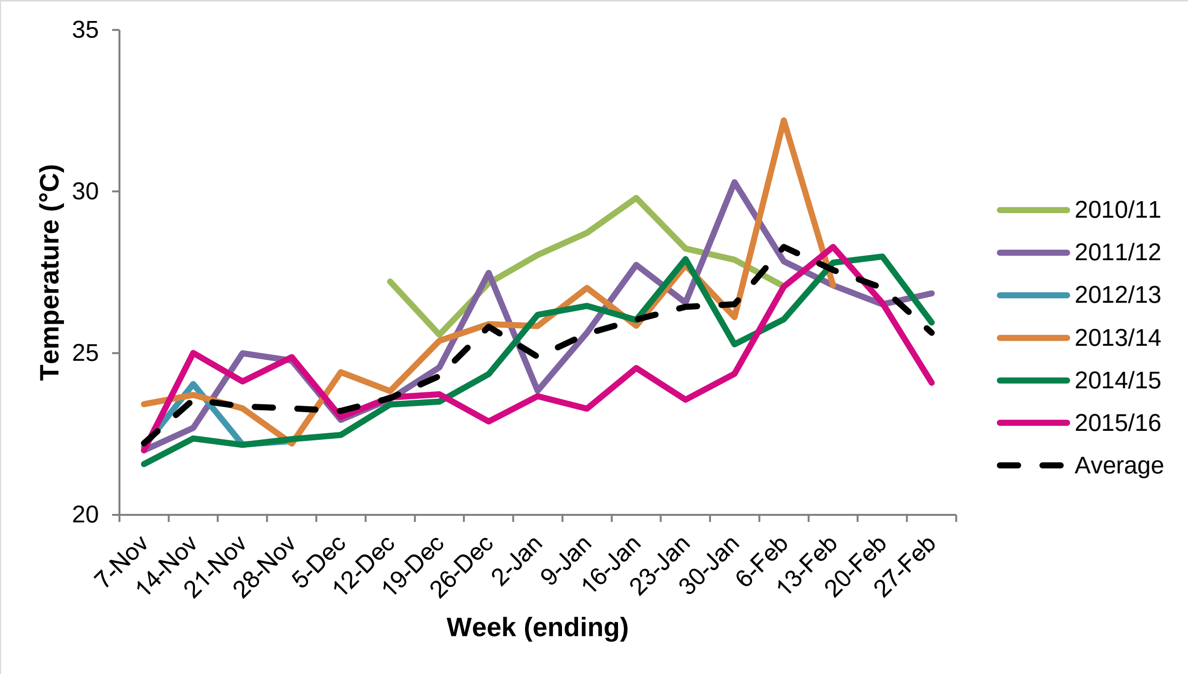

Figure 4: Weekly mean temperatures at GBR Survey Area during 2010/11 – 2015/16

Note: Weather data collection in the GBR Survey Area started in season 2009/10, but only 2 weeks of overlapping weather data were obtained (15 – 28 February 2010) at the end of the now standard monitoring period (1 November – 28 February), so this season was excluded.

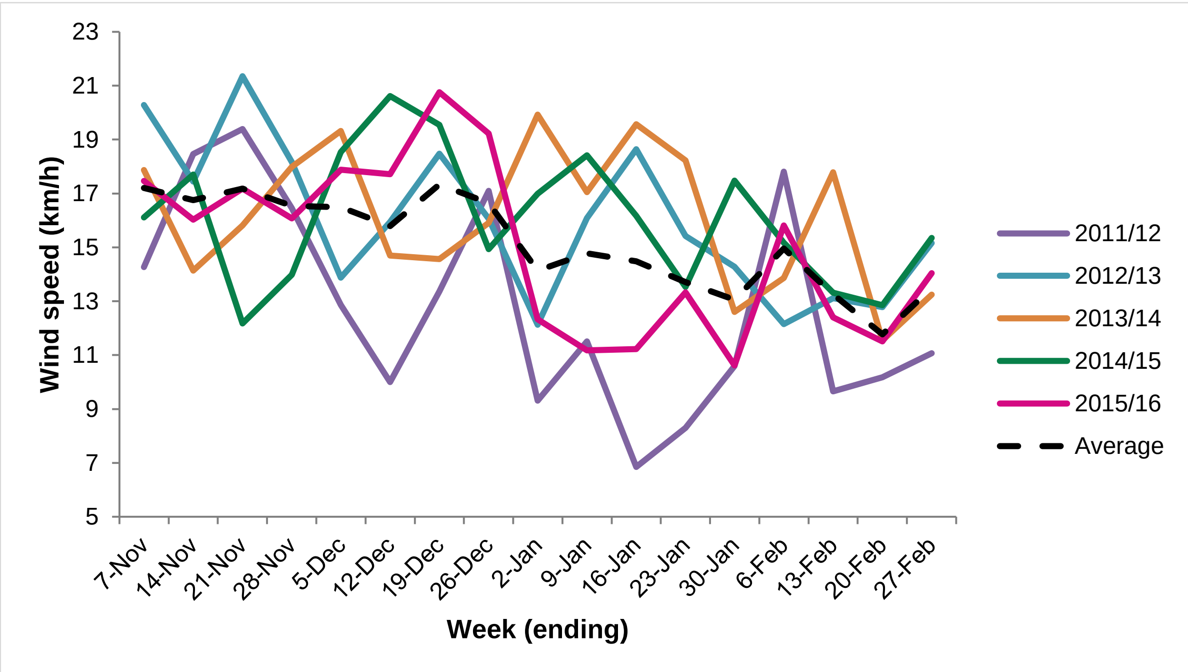

Figure 5: Weekly mean wind speeds at the GBR Survey Area during 2011/12 – 2015/16

Note: Wind speed data were not collected during season 2010/11.

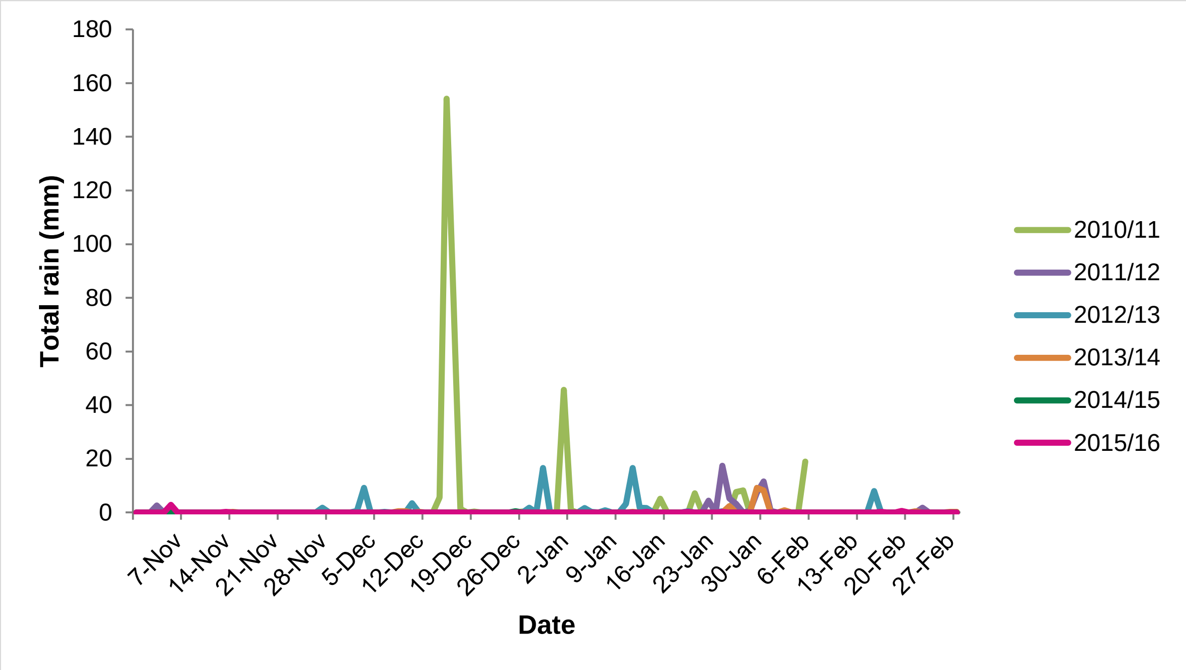

Figure 6: Daily total rain recorded at the GBR Survey Area during 2010/11 – 2015/16

3.3 GCFR Survey Area

The GTCP field team recorded climatic data using a second Davis Vantage Pro 2 Weather Station installed at the GCFR Survey Area for the duration of the sampling period for that rookery (27 December 2015 – 9 January 2016). This weather station was located at Sub-section point GFR (at the start of Sub-section 3) about a third way along and immediately adjacent to the GCFR Survey Area.

Over the 14 days of surveying, the average temperature in the GCFR Survey Area was 23.7°C compared to 23.5°C in the GBR. The average daily temperate difference between the two weather stations ranged from 0.06 – 0.51°C. No rain was recorded in the GCFR Survey Area during the monitoring period. Wind was also comparable between the two sites, with the GCFR Survey Area having a slightly higher average wind speed (15.7 km/h) than the GBR Survey Area (11.7 km/h). Daily weather data from both sites are provided in **Appendix B**.

4 FERAL PREDATOR MERI MONITORING

4.1 Introduction

The GFACP was initiated in 2008 to protect Gnaraloo sea turtle rookeries from feral predators, mainly from European red fox (*Vulpes vulpes*), but also from feral cats (*Felis catus*) and wild dogs (*Canis lupus familiaris*). Prior to the commencement of the GFACP, a large proportion of sea turtle Nests in parts of the GBR were affected by European red foxes (Butcher & Hattingh, 2013). Minimizing the impact of feral predation on turtle Nests is therefore critical to the reproductive success of the sea turtles at Gnaraloo.

The GFACP is undertaken independently of the GTCP by a specialist contractor, Animal Pest Management Services (**APMS**). However, the GTCP measures the effectiveness of the GFACP each turtle nesting season through a self-imposed Monitoring, Evaluation, Reporting and Improvement (**MERI**) link between the two programs. Here, we present results of the GTCP MERI monitoring of feral animal activity in the GBR and GCFR.

4.2 Objectives

The objectives of feral predator MERI monitoring in the GBR and GCFR survey areas during 2015/16 were to:

- record evidence of feral predator activity (i.e. tracks, scats, Nest disturbance or Nest predation) during Day Surveys;
- conduct independent monitoring of the effectiveness of the GFACP.

4.3 Methods and materials

MERI monitoring was conducted by the GTCP Field Research Team during GBR and GCFR Day Surveys for four consecutive months and two weeks, respectively (**Chapter 5**, **Chapter 8**), during the GTCP field monitoring periods 2015/16 for these rookeries. The GTCP Procedure 2015/16 (2016) and prior GFACP annual reports (e.g. Butcher & Hattingh, 2015) contain detailed methods. Briefly, while surveying for turtle nesting activities during Day Surveys, GTCP researchers also recorded the presence of fox, feral cat and wild dog tracks, scats and any evidence of disturbance or predation of sea turtle Nests. The location of all tracks was recorded (start and end points marked using a handheld GPS) and any tracks that were unclear in terms of the associated species were photographed for later consultation with experts from APMS.

Tracks were marked so they would not be counted again on a subsequent Day Survey. For data summary, a day with one or more tracks seen of a particular feral animal species was considered as a single ‘track day’ for that species. This presence-absence approach was used, because when multiple segments of track were seen, it was not possible to determine how many individuals were responsible, so a count of individuals per day was not possible.

4.4 Results

4.4.1 GBR feral predator activity

No evidence of fox presence was observed in the GBR Survey Area (i.e. GBN – BP9) during 2015/16. Feral cat tracks were observed in the GBR Survey Area on 47 / 120 (39.2%) days, while wild dog tracks were observed on 11 / 120 (9.2%) days. However, no clear evidence of cat or dog digging into turtle Nests was recorded. Cat tracks occasionally passed over Sampled Nests (cats often walked the length of the beach at the edge of the dunes where many Nests were dug) and, on one occasion, a cat appeared to have scratched itself on a stake, knocking the stake over, but did not dig toward the Nest. GBR Sub-section GBN – BP7 had the highest proportion of days with both feral cat and wild dog tracks (**Figure 7**) despite having relatively few turtle Nests (refer to **Chapter 5.4.3**).

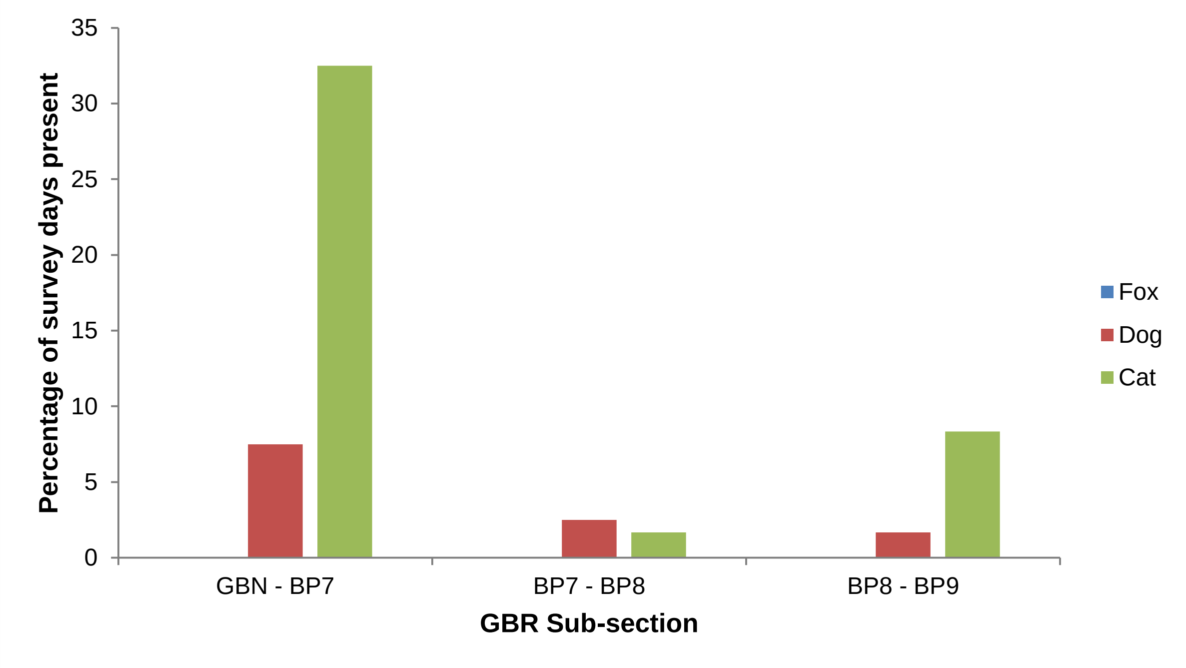

Figure 7: Feral animal presence in each GBR Sub-section during 2015/16 (01/11/2015 – 28/02/2016)

The detailed GBR MERI Monitoring Log 2015/16 is available separately.

4.4.2 GCFR feral predator activity

No evidence of feral predator presence was recorded in the GCFR Survey Area during the two-week survey period for that rookery (27 December 2015 – 9 January 2016, **Chapter 8**) during 2015/16.

The detailed GCFR MERI Monitoring Log 2015/16 is available separately.

4.4.3 Multi-year trends of feral predator activity in the GBR Survey Area

Fox presence in the GBR Survey Area has declined dramatically since the first two years of the GTCP (i.e. 2008/10) and no evidence of fox presence has been seen since season 2012/13. In contrast, the number of days with feral cat tracks in the GBR Survey Area has increased and varied widely during season 2011/12 – 2015/16. Season 2015/16 experienced a high level of feral cat presence, although no evidence of disturbance or predation of turtle Nests was observed. In contrast, the number of days with wild dog tracks in the GBR Survey Area has increased gradually since 2008/09. During 2015/16, wild dog tracks were found on 9% of survey days but, again, no evidence of disturbance or predation of turtle Nests was observed (**Figure 8**, **Figure 9**).

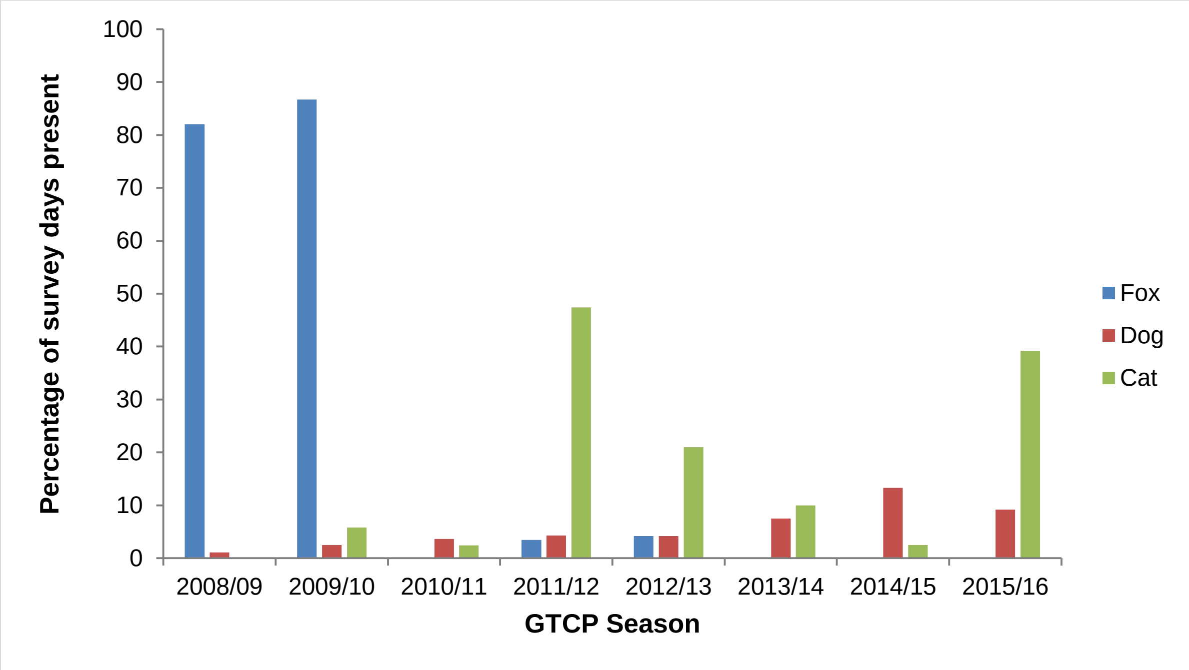

Figure 8: Percentage of survey days with feral animal presence in the GBR Survey Area during 2008/09 – 2015/16

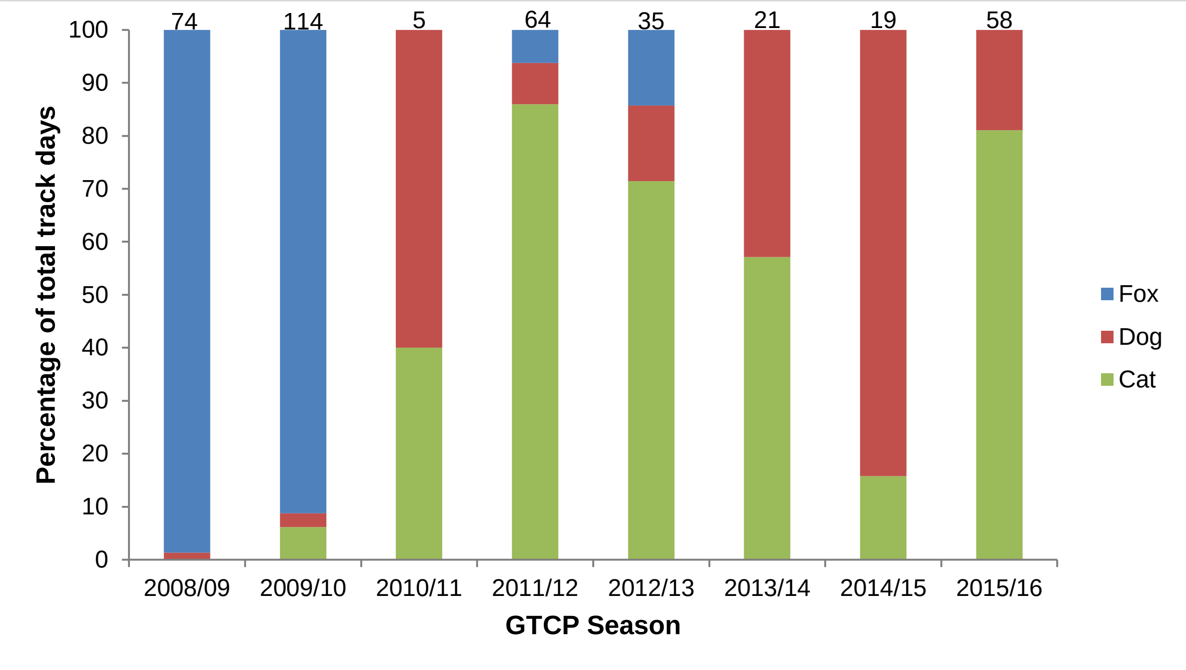

Figure 9: Feral predator composition in the GBR Survey Area during 2008/09 – 2015/16

Note: 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 Survey Area on a single day could belong to a single feral animal, not multiple animals. This type of scenario was counted as a single track day for that particular species. That means that a single survey day could yield up to 3 track days (but a maximum of 1 track day per species).

4.5 Discussion

Based on the results of the GTCP's MERI monitoring of feral activities in the GBR Survey Area since 2008/09, season 2015/16 was the sixth consecutive season (i.e. 2010/11 – 2015/16) in which 100% protection of sea turtle Nests from feral predators in the GBR Survey Area was achieved following two years of heavy fox predation in the initial years of the GTCP (i.e. 2008/09 – 2009/10) (Butcher & Hattingh, 2012, 2013). This amounts to an estimated 38,864 loggerhead turtle eggs[9] being protected from feral predation in the GBR Survey Area by the GFACP each year during 2010/11 – 2015/16.

9 Seasons 2010/11 – 2015/16 recorded a total of 2,082 loggerhead nests in the GBR Survey Area. Loggerhead turtles lay approximately 100-130 eggs per clutch, with an average of 112 (Van Buskirk & Crowder, 1994). Hence, there was an estimated total of 233,184 (38,864/year) eggs in loggerhead Nests in the GBR during 2010/11 – 2015/16. The influence of factors other than feral predation, such as native predators (e.g. crabs) and environmental impacts (e.g. shifting sand dunes, tides, cyclones), on loggerhead turtle Nests have not yet been quantified.

4.6 Conclusion

In total, an estimated 233,184 loggerhead turtle eggs have been protected from feral predation in the GBR Survey Area during the seasons 2010/11 – 2015/16. The GFACP therefore continues to be a critical component of the overall sea turtle conservation program at Gnaraloo. Future work at Gnaraloo could focus on the impacts of the shifting feral animal community (i.e. no foxes, increasing feral cats and wild dogs) on native terrestrial fauna.

5 GBR DAY SURVEYS

5.1 Introduction

Annually since 2008/09, the GTCP has conducted early morning track surveys in the GBR Survey Area to monitor marine turtle nesting activity. These surveys are conducted for 120 consecutive days during 1 November – 28 February[10], with the goal of building a long-term data set that will be useful for elucidating nesting activity trends over meaningful spatial and temporal scales. Temporal variation in the number of nesting activities or Nests per year in key rookeries can provide important insights into population trends (Limpus 2009; Witherington *et al.* 2009). Thus, daily nesting beach surveys during the breeding season can provide critical information on population health, contribute to conservation status assessments, identify populations for which management intervention is required and allow for evaluation of the efficacy of management actions (e.g. Balazs & Chaloupka, 2004). Analysis of spatial trends in sea turtle nesting activity can help identify factors that influence Nest site selection (e.g. Wood & Bjorndal, 2000) and evaluate anthropogenic factors that may negatively impact nesting and/or hatching success.

Beach surveys at Gnaraloo are particularly valuable due to the location of these rookeries between Dirk Hartog Island (Reinhold & Whiting, 2014) to the south and the rookeries located further north along the Ningaloo coast which are surveyed by the NTP in Exmouth (e.g. Markovina & Prophet, 2014). While the rookeries at Dirk Hartog Island and the north of the Ningaloo coast have been monitored for some time – Dirk Hartog Island monitoring began in 1993/94, while the NTP was established in 2002/03 – formal monitoring at Gnaraloo only began in 2008/09. Thus, monitoring at Gnaraloo will continue to bridge the data gap between the rookeries on Dirk Hartog Island and further north along the WA mainland coast.

5.2 Objectives

The objectives of Day Survey monitoring in the GBR Survey Area during 2015/16 were to:

- extend the daily nesting beach monitoring dataset which began in 2008/09;
- identify the species of nesting sea turtles;
- evaluate trends in the number of nesting loggerhead, green and possibly hawksbill turtles from 2008/09 – 2015/16;

[10] Minor deviations from this timing have occurred (refer to notes to **Table 1**).

- assess spatial and temporal trends in the distribution of loggerhead turtle nesting activities to gain insight into factors influencing Nest site selection and Nesting success.

5.3 Methods and materials

5.3.1 Study area

Daily beach track monitoring during 2015/16 was conducted in the GBR Survey Area (-23.76708° S, 113.54584° E to -23.72195° S, 113.57750° E). The GBR Survey Area is 6.7 km long and stretches from the Gnaraloo Bay North marker (**GBN**) northward to Beach Point 9 (**BP9**). Due to the differences in beach dynamics within the study site and the known differences in numbers of nesting activities between areas (refer to previous GTCP annual reports), the GBR Survey Area is separated into three Sub-sections: GBN – BP7 (3.35 km), BP7 – BP8 (1.63 km) and BP8 – BP9 (1.72 km). The GTCP Procedure 2015/16 contains more information on these Sub-sections.

5.3.2 GBR Day Survey protocol

The GTCP Procedure 2015/16 sets out the complete Day Survey protocol. Briefly, each morning during 1 November 2015 – 28 February 2016, the GBR Survey Area was walked by two researchers and sea turtle nesting activities were recorded with their location noted using a handheld Global Positioning System (**GPS**) unit. Nesting activities recorded included: Nest, Unsuccessful Nesting Attempt (**UNA**), U Track (**UT**) or Unidentified activity (**Ua**). The species responsible for each activity was assessed, if track quality allowed, based on track characteristics.

5.3.3 Estimating the number of nesting loggerhead females

To estimate the number of female loggerhead turtles likely nesting in the GBR Survey Area during each season, we consulted the literature for clutch frequency estimates for this species derived from satellite telemetry. We calculated the mean and standard deviation (**SD**) of the estimated clutch frequency (**ECF**) found in currently available studies (Scott, 2006; Rees *et al.* 2008; Rees *et al.* 2010; Tucker, 2010). We then divided the number of Nests recorded during each season by the mean 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 Summary of nesting activities

In total, 480 nesting activities (**Table 4**) were observed in the GBR Survey Area during 2015/16, including 305 Nests. This represents the lowest number of total nesting activities and Nests recorded since monitoring began in 2008/09. All activities for which the species could be identified were ascribed to loggerhead turtles[11]. No evidence of green turtle nesting activity was observed.

Note that hawksbill turtles have been seen at Gnaraloo (with available video footage of a hawksbill on the ocean floor at the GCFR on 1 March 2015, from the season 2014/15).

Table 4: Frequency of nesting activity type per species in the GBR Survey Area during 2015/16 (01/11/2015 – 28/02/2016)

SPECIES	NESTING ACTIVITY TYPE				
	NEST	UNA	UT	UA	TOTAL
LOGGERHEAD	304	121	53	1	479
GREEN	0	0	0	0	0
UNKNOWN	1	0	0	0	1
TOTAL	305	121	53	1	480

11 All hawksbill turtle nesting activities recorded during season 2008/09 – 2015/16 were retroactively changed to loggerhead turtles during 2015/16 to minimize species identification errors (refer to notes to **Table 1** for justification). This included two activities ascribed to hawksbill turtles during 2015/16.

5.4.2 Temporal distribution of nesting activities

Nesting in the GBR Survey Area during 2015/16 (i.e. 1 November 2015 – 28 February 2016) began on 4 November 2015 and was still being recorded at season's end on 28 February 2016 (2 Nests recorded on that day). Nesting activity progressed gradually through late November and early December 2015, and lacked the pronounced peak between mid-December and late January that has characterized previous seasons (**Figure 10**). However, nesting during 2015/16 lasted longer than most other seasons, with above-average nesting activity occurring in the final weeks of February 2016 (**Figure 11**). Indeed, nesting was opportunistically observed in the GBR Survey Area by Gnaraloo staff and visitors as late as 25 March 2016 (C. Guillaume, pers. comm.).

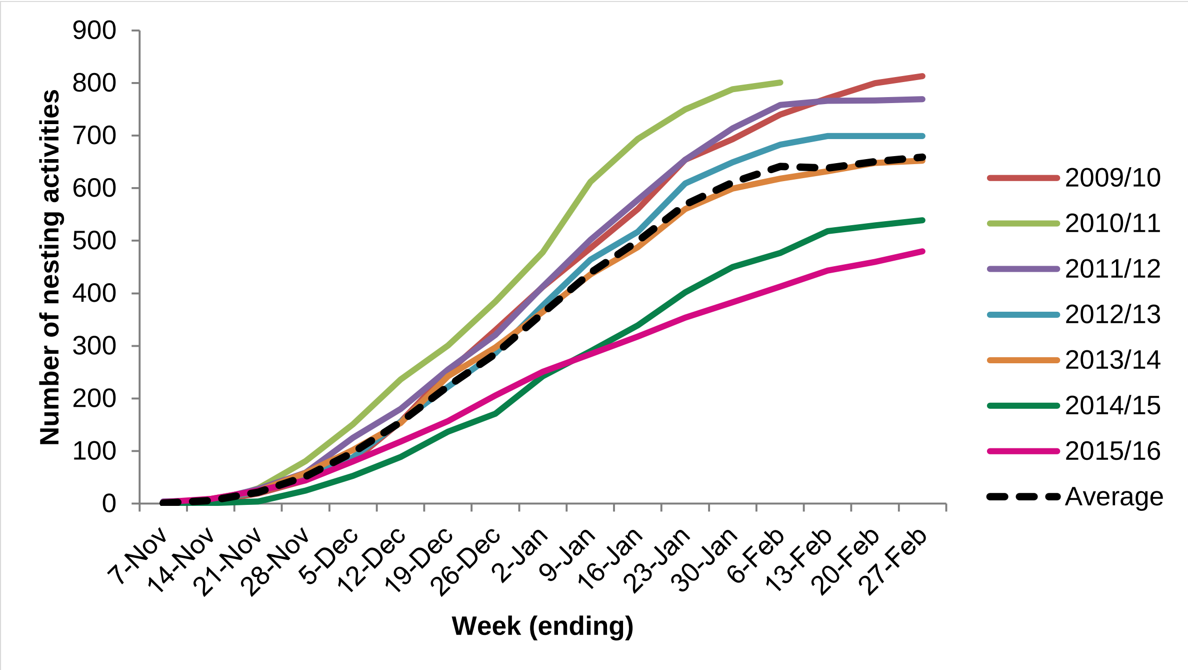

Figure 10: Cumulative weekly nesting activities in the GBR Survey Area during 2009/10 – 2015/16

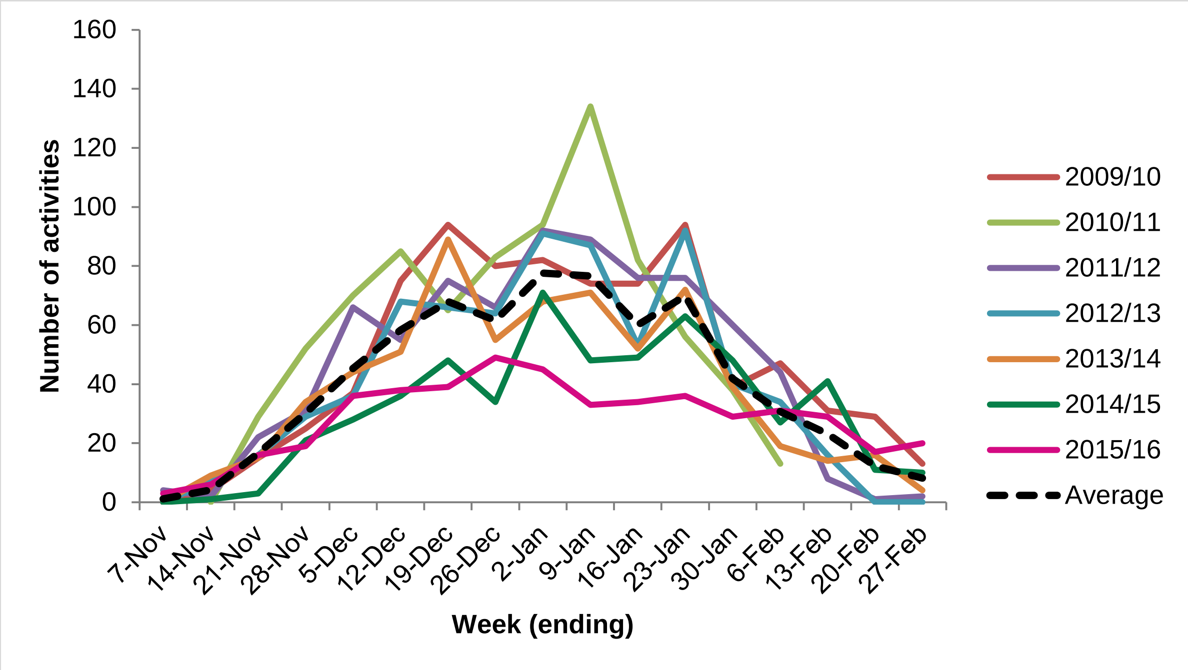

Figure 11: Nesting activities per week in the GBR Survey Area during 2009/10 – 2015/16

5.4.3 Spatial distribution of nesting activities

Nesting activities during 2015/16 were concentrated in Sub-section BP8 – BP9 (362 / 480, 75.4%), followed by Sub-sections GBN – BP7 (84 / 480, 17.5%) and BP7 – BP8 (34 / 480, 7.1%) (**Figure 12**). Nests followed the same pattern, with the majority (237 / 305, 77.7%) occurring in Sub-section BP8 – BP9, followed by Sub-sections GBN – BP7 (49 / 305, 16.1%) and BP7 – BP8 (19 / 305, 6.2 %). This distribution of nesting activities and Nests is consistent with all previous seasons. Also similar to previous seasons, mapping of Nest densities within each Sub-section revealed a patchy distribution with hotspots in Sub-section BP8 – BP9 and a more uniform distribution throughout Sub-sections GBN – BP7 and BP7 – BP8 (**Appendix A**).

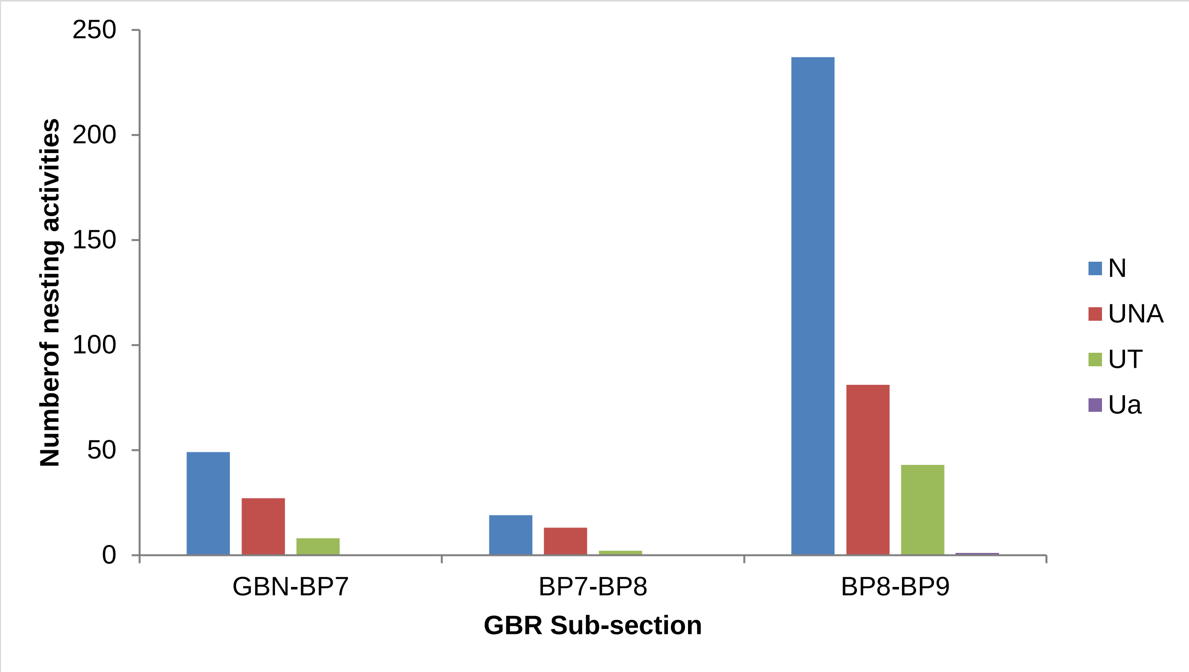

Figure 12: Distribution of each nesting activity type among GBR Sub-sections during 2015/16 (01/11/2015 – 28/02/2016)

5.4.4 Multi-year trends

5.4.4.1 Nesting activities and Nests per season since 2008/09

The total number of nesting activities (i.e. inclusive of Nests, UNA, UT and Ua) recorded per season during 2009/10 – 2015/16[12] ranged from 480 (2015/16) to 813 (2009/10), with an average of 679.0 [standard error (**SE)** = 49.1]. A significant decline in the number of total nesting activities per season was observed during season 2009/10 – 2015/16 ($F_{1,5}$ = 92.1, $P < 0.001$, r^2 = 0.95, **Figure 13**).

The total number of Nests per season during 2008/09 – 2015/16 ranged from 305 (2015/16) to 522 (2009/10), with an average of 376.0 (SE = 26.7). A weak negative trend in the number of Nests during season 2008/09 – 2015/16 was apparent, although this trend was non-significant ($F_{1,6}$ = 1.56, P = 0.26, r^2 = 0.21, **Figure 13**).

Season 2015/16 had the lowest number of total nesting activities and Nests since

[12] Only Nest numbers were recorded during 2008/09, other nesting activity (i.e. UNA, UT and Ua) numbers were not recorded during the first year of the program. All necessary data were recorded for all nesting activity types in the remaining seasons 2009/10 – 2015/16. The Nest total for 2008/09 is included because dates and locations for all Nests were recorded.

the start of monitoring in 2008/09.

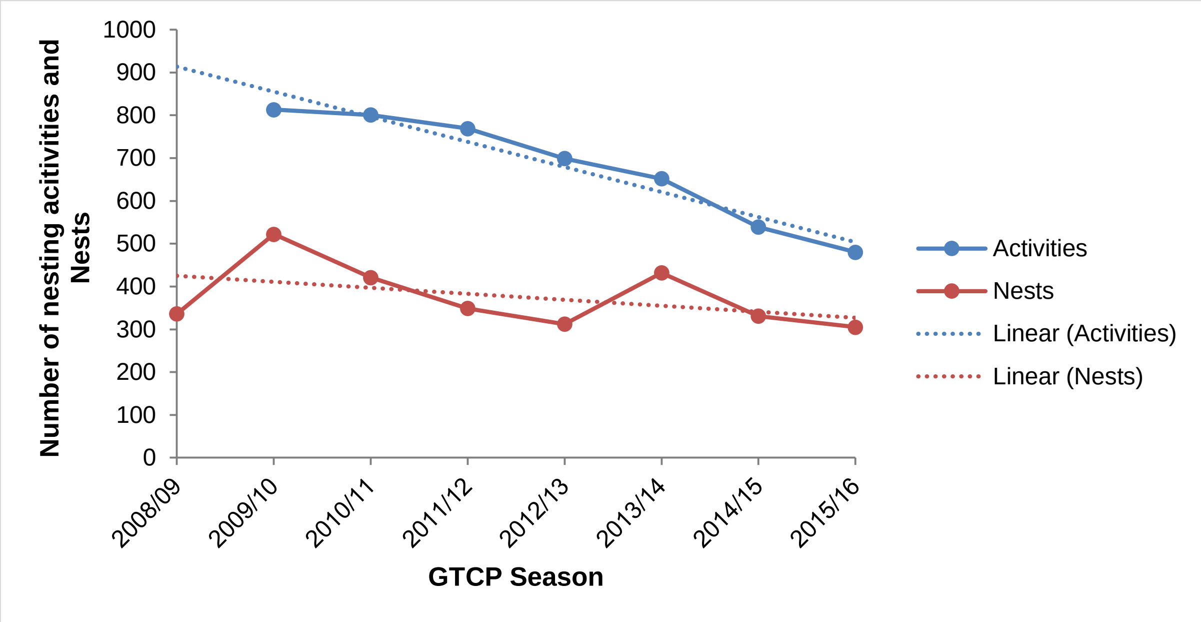

Figure 13: Total nesting activities and Nests in the GBR Survey Area per season during 2008/09 – 2015/16

Note: Season 2008/09 nesting activity data are not included since researchers did not record the details of emergences that did not result in a Nest (i.e. UNA, UT).

5.4.4.2 Nesting activities and Nests per season by Sub-section since 2008/09

The number of nesting activities recorded per season in the GBR Survey Area during 2009/10 – 2015/16 declined significantly in Sub-section GBN – BP7 ($F_{1,4} = 16.2$, $P = 0.016$, $r^2 = 0.80$) and BP7 – BP8 ($F_{1,4} = 163.6$, $P < 0.001$, $r^2 = 0.98$), and experienced a non-significant decline in Sub-section BP8 – BP9 ($F_{1,4} = 2.8$, $P = 0.167$, $r^2 = 0.42$, **Figure 14**).

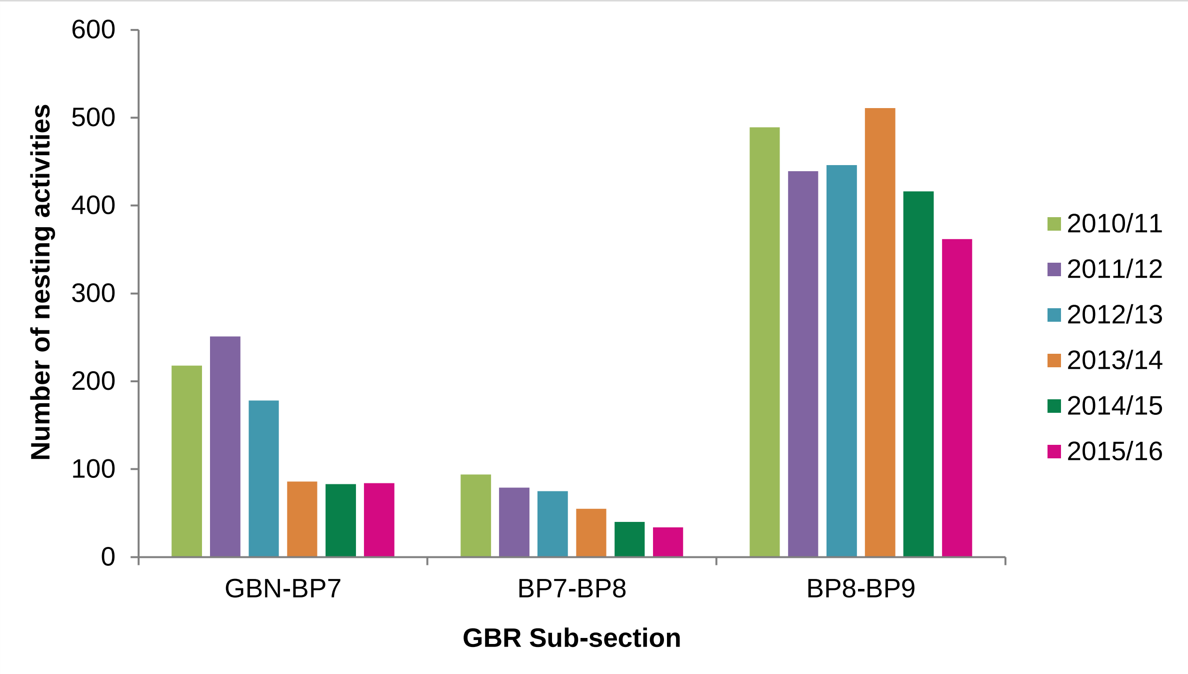

Figure 14: Nesting activities per season per GBR Sub-section during 2010/11 – 2015/16

Note: Different 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.

The number of Nests during 2008/09 – 2015/16 declined significantly in Sub-section GBN – BP7 ($F_{1,6}$ = 26.0, P = 0.002, r^2 = 0.81) and experienced a marginally non-significant decline in BP7 – BP8 ($F_{1,6}$ = 5.2, P = 0.063, r^2 = 0.46), but no trend was observed in Sub-section BP8 – BP9 ($F_{1,6}$ = 0.53, P = 0.494, r^2 = 0.08, **Figure 15**).

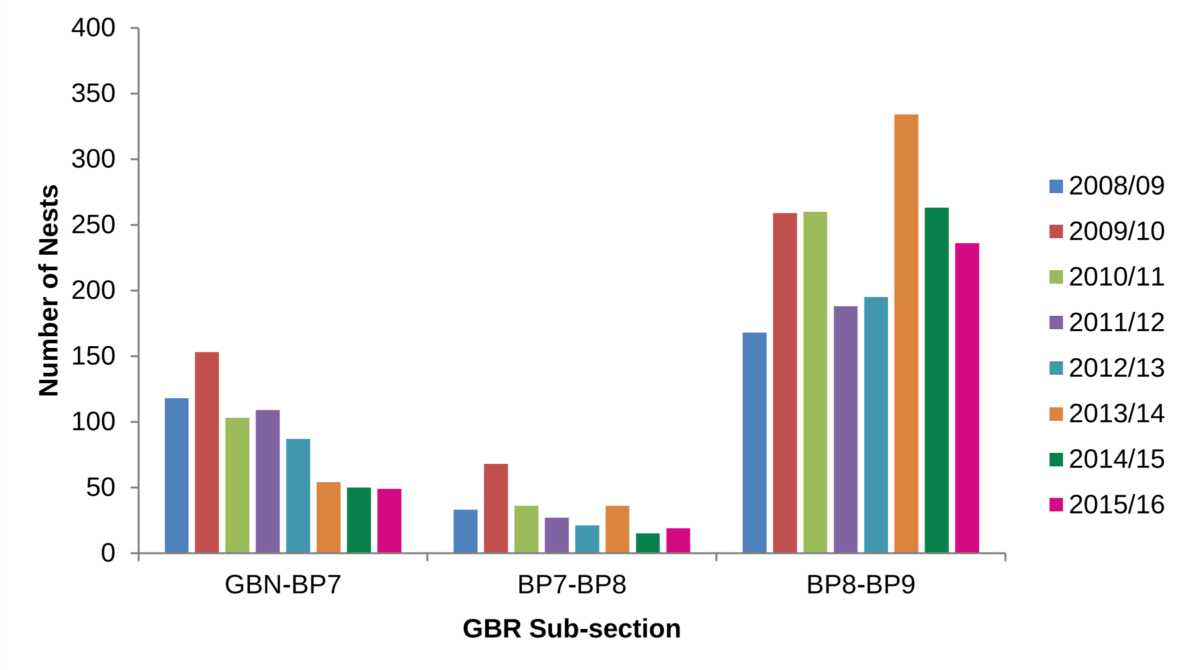

Figure 15: Nests per season in each GBR Sub-section during 2008/09 – 2015/16

5.4.4.3 Nesting success rate since 2009/10

The overall Nesting success rate in the GBR Survey Area based on Day Survey data during seasons 2009/10 – 2015/16 ranged from 46.0% (2011/12) to 67.3% (2013/14), with an average of 57.5% (SE = 3.4) (**Figure 16**). Season 2015/16 recorded a 63.7% Nesting success rate, which was above average. There was no significant trend in the seasonal Nesting success rate during seasons 2009/10 – 2015/16 ($F_{1,5}$ = 0.60, P = 0.474, r^2 = 0.11).

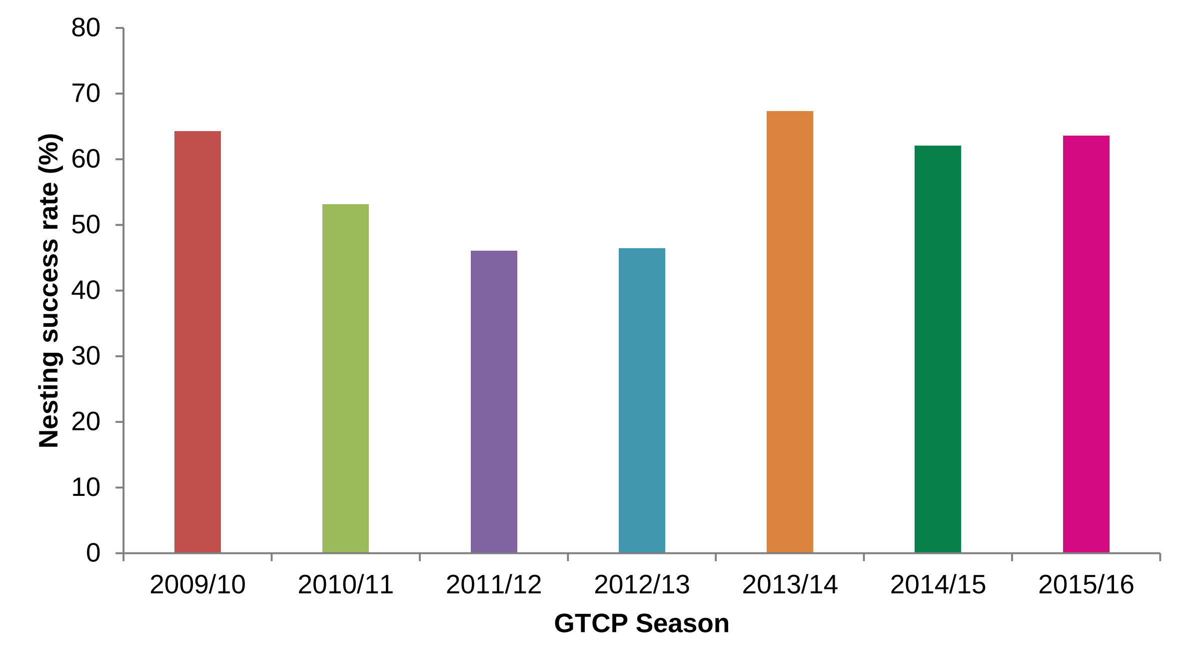

Figure 16: Nesting success rate in the GBR Survey Area during 2009/10 – 2015/16

5.4.5 Number of nesting female loggerhead turtles

A total of 304 loggerhead turtle Nests were observed in the GBR Survey Area during Day Surveys in 2015/16. The best estimate of average clutch frequency currently available for this species was 4.78 (SD = 0.45) (Scott, 2006; Rees *et al*. 2008; Rees *et al*. 2010; Tucker, 2010). Using the average clutch frequency ± 1 SD, we estimate that 64 female loggerhead turtles nested in the GBR during 2015/16, with lower and upper bounds of 58 and 70.

5.4.6 Mortalities and strandings

During 2015/16, 4 sea turtle mortalities were recorded in the GBR Survey Area (3 in Sub-section BP7 – BP8 and 1 south of GBN). All 4 mortalities were juvenile green turtles. No external signs of physical trauma were present, although all 4 turtles were extremely emaciated. The strandings were recorded on 19 November 2015, 22 December 2015, 28 January 2016 and 22 February 2016.

5.5 Discussion

Spatial and temporal patterns of nesting activity in the GBR Survey Area during 2015/16 were broadly similar to previous seasons. However, the total number of nesting activities and Nests recorded during 2015/16 were the lowest season totals to date. Furthermore, unlike previous seasons, there was a lack of the pronounced peak in nesting activity between mid-December and late January. During a typical peak season, the GBR receives an average of 70 nesting activities and 45 Nests per week. During 2015/16, the GBR received just 40 nesting activities and 25 Nests per week during this period. However, a low level of nesting was still being observed at the end of the monitoring season, with 4 activities recorded on the final day (28 February 2016), including 2 Nests, and a new track was seen by a Gnaraloo staff member on 25 March 2016 (C. Guillaume, pers. comm.). Thus, late nesting may have contributed, in part, to the low totals observed during 2015/16.

The reasons underlying the gradual progression of nesting during 2015/16, low totals and above-average rate of nesting late in the season are unclear. A range of large-scale factors, including sea surface temperature (**SST**) on breeding and foraging grounds, can influence the seasonal timing of sea turtle nesting (Weishampel *et al.* 2004; Mazaris *et al.* 2008, 2009; Weishampel *et al.* 2010; Lamont & Fujisaki, 2014). As additional years of GTCP data become available, it would be valuable to correlate the seasonal timing of sea turtle nesting in the GBR Survey Area with SSTs at various spatial scales. In-progress satellite tracking during 2015/16 of 10 female loggerhead turtles from Gnaraloo[13] will help facilitate such work by identifying habitats used by female turtles when away from the breeding ground.

While the total number of nesting activities in the GBR Survey Area has decreased each year for the past seven years since 2009/10, the number of Nests has only experienced a non-significant decline (**Figure 13**). Indeed, peaks in seasonal Nest totals occurred in 2009/10 and 2013/14 despite a concurrent decline in overall nesting activity. These seasons had the highest rates of Nesting success, which suggests that the peaks may relate to favourable local beach conditions for nesting, which could mask an overall decrease in use of the GBR Survey Area as evidenced by the decline in total nesting activity. Interestingly, however, the season 2015/16 had an above-average rate of Nesting success, but still experienced the lowest Nest total since monitoring began in 2008/09.

The decline in nesting activity during season 2009/10 – 2015/16 appears to have been driven primarily by decreases in nesting activity in Sub-sections GBN – BP7 and BP7 – BP8, although Sub-section BP8 – BP9 also experienced a non-significant decline over this time period. The

[13] Refer to http://www.seaturtle.org/tracking/?project_id=1149 or download the free Turtle Tracker App from global app stores.

total number of Nests has declined in Sub-section GBN – BP7, but not in Sub-section BP7 – BP8 or BP8 – BP9. Furthermore, the overall Nesting success rate for the GBR has not declined significantly since 2009/10 and Nesting success rates within each Sub-section have also not declined. Therefore, the negative trends in total nesting activities and Nests are most likely related to either: (a) a reduced proportion of turtles on the breeding ground emerging to nest specifically in Sub-sections GBN – BP7 and BP7 – BP8; (b) a reduced number of turtles present on the breeding ground overall; or (c) short-term variability in the time series.

While it is important to keep in mind that the GBR Day Survey time series is still extremely short, the seven-year downward trend since 2009/10 in total nesting activities per season is noteworthy and potentially concerning. This is because there are reasons to expect declines in turtle nesting activity at this site. Specifically, introduced foxes have been active in WA since the 1960s and a high rate of fox disturbance of turtle Nests in the GBR Survey Area was reported prior to the establishment of the GFACP in 2008/09 (Limpus, 2009; Butcher & Hattingh, 2012). Therefore, there are likely several decades of fox predation impacts “in the pipeline” at Gnaraloo. Furthermore, ghost crabs appear to exert a high level of predation pressure on turtle Nests at Gnaraloo, particularly toward the northern end of Gnaraloo Bay (**Chapter 7.4.2**, Hattingh *et al.* 2011). This would likely exacerbate the impacts of historical fox predation and suppress hatching success in a nesting aggregation that is already likely depleted relative to historic levels. In the future, it would be valuable to conduct experimental assessments of crab predation relative to nearby mainland and island rookeries to quantify and compare their influence on turtle hatching success. As the GTCP monitoring data set continues to grow, more robust turtle nesting activity trend analysis will be possible to determine whether further management interventions are required at Gnaraloo (e.g. protection of Nests from crab predation).

5.6 Conclusion

During 2015/16, the GBR Survey Area received the lowest total number of turtle nesting activities and Nests since formal monitoring began in 2008/09. The timing of nesting in the GBR Survey Area during 2015/16 was broadly similar to previous seasons with the notable exception of no distinct peak 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 such as SST throughout the WA loggerhead turtle range, which will ideally be revealed via satellite telemetry. Overall, there has been a significant decline in nesting activity within the GBR Survey Area since 2009/10. These trends have been driven primarily by decreases in nesting activity in GBR Sub-sections GBN – BP7 and BP7 – BP8, while Sub-section BP8 – BP9 has experienced a non-significant decline. The overall Nesting success rate within the GBR Survey Area, 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 significantly 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 still be interpreted cautiously. However, a biologically meaningful trend analysis should soon be possible and the decline in nesting activity should be carefully monitored due to the suspected long-standing impact of fox predation at Gnaraloo prior to 2008, with additional impacts on turtles still likely to be “in the pipeline”.

6 GBR NIGHT SURVEYS

6.1 Introduction

The use of daytime beach surveys to monitor sea turtle nesting activity involves considerable 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 in nesting activity identification and species assessments is challenging to achieve. Thus, for programs that rely primarily on daytime beach track surveys as an index of nesting turtle abundance, such as the GTCP, 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 Night Surveys in the GBR Survey Area during 2015/16 were to:

- determine the accuracy of Species Identification (**SI**) and Nesting Activity Determination (**NAD**) assessments during Day Surveys;
- allow for the correction of SI and NAD errors in the Day Survey spreadsheets;
- estimate Nest detection bias during Day Surveys;
- improve the interpretive skills of GTCP field researchers;
- provide a complementary estimate of Nesting success rate to the GBR Day Surveys.

6.3 Methods and materials

6.3.1 Night Survey protocol

The GTCP Procedure 2015/16 sets out the detailed Night Survey protocol. Briefly, on a given Night Survey, researchers searched the beach in the GBR Survey Area after sunset for up to 6 hours. Night surveys were conducted primarily in GBR Sub-section BP8 – BP9, where the majority of nesting activity occurs (**Chapter 5.4.3**). However, opportunistic night observations were also made in Sub-section BP7 – BP8 on the way to and from Sub-section BP8 – BP9. When a turtle was sighted, the species was identified and behavioural observations were made until the nesting activity could be verified (i.e. Nest, UNA, UT, Ua). 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). For Nests, the turtle had to be seen at the laying phase at the latest and witnessed depositing eggs into the egg chamber[14]. 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 Target sample sizes

The GTCP Procedure 2015/16 contains the target sample size calculations. For SI verification, a target sample size of 10 turtle observations was calculated (0.95 confidence interval, 0.1 margin of error, average accuracy from previous seasons of 97.5%), with a desired accuracy of 95.0%. For 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 80.0%. Upon reaching these sample sizes, the seasonal accuracy for SI and NAD was determined. If the desired accuracy (95.0% for SI and 80.0% 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.

[14] Note that the criterion for Nest verification during Night Surveys was updated for 2015/16 (i.e. eggs had to be seen being laid whereas in previous seasons if a turtle was seen covering, but laying eggs wasn't seen, it was still considered verified). The updated criterion was used when calculating NAD error for 2015/16 and Nest detection bias for all seasons in this report and will be the GTCP standard during future seasons.

6.3.3 Nest detection bias

Nest detection bias for loggerhead turtles was determined by comparing Day Survey track interpretations with independent, direct observations of turtle nesting activities during Night Surveys. For each season, we extracted all verified Night Survey observations and their corresponding Day Survey track interpretations. This included cases in which a verified activity was missed entirely the following morning or incorrectly assigned to a particular species or nesting activity. We then tallied the number of Nests recorded in each data set within each season. The Night Survey Nest count was taken to represent the true (i.e. expected) value and the Day Survey Nest count represented the experimental (i.e. observed) value. We then calculated the percent error between the two for each season (data from 2010/11 – 2015/16) using the formula: % error = (observed - expected) / expected*100[15]. This analysis was not conducted for green turtles due to the paucity of Night Survey observations for this species.

We calculated a Nest detection bias correction factor by dividing the total number of verified Nests recorded during Night Surveys by the total number of Nests counted during the corresponding Day Surveys. Data from 2010/11 – 2015/16 were used for this calculation and data from all these seasons were pooled due to the low number of verified Nests recorded in some seasons[16] (i.e. inadequate sample size for season-specific correction factors). To estimate the bias-adjusted number of loggerhead turtle Nests in the GBR Survey Area each season, we added the verified total Nest count for all available seasons (2010/11 – 2015/16) to the total unverified Nest count for all seasons (2008/09 – 2015/16), with the latter multiplied by the Nest detection bias correction factor[17]. We then divided the resulting value by the number of seasons surveyed (8).

6.4 Results

6.4.1 Summary of Night Surveys

During 2015/16, Night Surveys commenced on 15 November 2015 and concluded on 19 December 2015, for a total of 35 consecutive nights. This time period was sufficient to reach the target sample sizes for both SI and NAD (**Chapter 6.3.2**). A further 6 Night Surveys were conducted opportunistically, at the request of Gnaraloo guests, between 20 December 2015 and 29 January 2016. The opportunistic Night Surveys were shorter than

15 The average Nest detection bias was -13.0% (refer Section 6.4.4).

16 Namely, season 2011/12.

17 The Nest detection bias correction factor for all seasons pooled was 1.14 (refer Section 6.4.4).

the standard 6 hour surveys and were not used in SI and NAD calculations or to calculate the average number of turtles sighted per Night Survey. However, they were used to confirm or correct Day Survey track interpretations and to calculate Nest detection bias.

A total of 79 turtles were observed during the combined 41 Night Surveys. The number of turtles seen per Night Survey, excluding the opportunistic surveys conducted after 19 December 2015, ranged from 0 to 8, with an average of 2.0 (SD = 1.6).

6.4.2 SI accuracy

During Night Surveys, 9 of the first 10 turtles observed were correctly identified to species based on Day Survey track interpretations. Although the target sample size for SI verifications (10) was reached on 24 November 2015, SI verifications continued until the final target sample size for NAD (54) was also reached. In total, 61 / 62 turtles (98.4%) verified to species during Night Surveys (and whose tracks were seen during Day Surveys) were correctly identified as loggerhead turtles during Day Surveys. The 1 incorrect SI was a loggerhead turtle whose track was recorded as a hawksbill turtle.

6.4.3 NAD accuracy

The track for 1 of the 54 nesting activities in the NAD verification data set had been disturbed by human footprints during Night Survey and was retroactively deemed unsuitable for NAD verification. Of the remaining 53 nesting activities: 36 were Nests, 11 were UNA and 6 were UT. The GTCP Field Research Team 2015/16 achieved a NAD success rate of 83.0%, slightly higher than the desired 80.0%. Day Survey researchers had an overall accuracy of 91.7% (33 / 36) when identifying Nests, 72.7% (8 / 11) when identifying UNA and 50.0% (3 / 6) when identifying UT (**Table 5**).

Table 5: NAD discrepancies between Day and Night Surveys during 2015/16 (15/11/2015 – 19/12/2015)

ACTIVITY DETERMINED BY DAY SURVEY	ACTIVITY VERIFIED BY NIGHT SURVEY	FREQUENCY OF ERROR
N	UNA	3
UNA	N	2
UNA	UT	2
UT	N	1
N	UT	1

6.4.4 Nest detection bias

A total of 62 verified nesting activities, including those observed during Night Surveys conducted after 19 December 2015 and those that were verified during Night Surveys but whose tracks were missed during Day Surveys, were used to estimate Nest detection bias. The percent error between the Night Survey verified Nest count and the corresponding Day Survey Nest count was 0% (42 Nests in each data set). Thus, while the NAD error rate in 2015/16 was similar to previous years, there was no systematic bias in terms of Nest identification. The average Nest detection bias during seasons 2010/11 – 2015/16 was -13.0% (SE = 3.0).

The Nest detection bias correction factor for all seasons pooled was 1.14. After accounting for Nest detection bias, we estimate that there is 405 loggerhead turtle Nests in the GBR Survey Area per season. Using the bias-corrected estimate of 405 loggerhead turtle Nests per season, we estimate that 85 female loggerhead turtles nest in the GBR Survey Area annually (uncertainty based on the mean ECF ± 1 SD = 77 – 94, refer to notes to **Table 1**.

6.4.5 Observed nesting activities and phases

Of the 79 turtles observed during Night Surveys in 2015/16, the nesting activity was verified for 67[18]. The majority of verified activities were Nests (46 / 67, 68.7%), while UNA and UT were recorded more rarely (**Table 6**). Considering all 79 turtle observations, turtles were most frequently observed during the emergence, body pit, egg chamber or laying phases, with initial observations of turtles during covering, camouflaging or returning occurring rarely (**Table 7**).

Table 6: Frequency of nesting activities observed during Night Surveys in 2015/16 (15/11/2015 – 19/12/2015)

ACTIVITY SEEN	FREQUENCY	PERCENTAGE OF TOTAL
N	46	68.7
UNA	13	19.4
UT	8	11.9

Note: this table does not include 12 Ua (i.e. unidentified nesting activity).

18 This includes 5 activities that were not included in NAD or Nest detection bias calculations because the tracks were disturbed (e.g. for filming) or the turtle was still on the beach in the morning during Day Survey.

Table 7: Frequency of observations of turtles at different phases of nesting during Night Surveys in 2015/16 (15/11/2015 – 19/12/2015)

NESTING PHASE	FREQUENCY	PERCENTAGE OF TOTAL
Emerging	30	38.0
Body pit	18	22.8
Egg chamber	15	19.0
Laying	9	11.4
Covering	2	2.5
Camouflaging	3	3.8
Returning	2	2.5

Note: This table includes all 79 observations of sea turtles during Night Surveys in 2015/16, regardless of whether the activity was verified.

6.5 Discussion

6.5.1 SI accuracy

The GTCP Field Research Team 2015/16 achieved an SI success rate of 98.4%. These results are consistent with the previous 5 monitoring seasons (i.e. 2010/11 – 2015/16), which all had SI accuracies exceeding the desired 95.0%. Thus, current levels of training by the GTCP and experience of the seasonal GTCP Field Research Team appear adequate for reliable SI during Day Surveys. The one SI error was an incorrect hawksbill turtle track interpretation. GTCP guidelines for ascribing tracks to hawksbill turtles have since been updated according to the most recent NTP guidelines (refer to NTP Turtle Monitoring Field Guide, Edition 7) and made more conservative to avoid such errors in the future (described in the GTCP Data Manual 2015/16).

6.5.2 NAD accuracy

The GTCP Field Research Team 2015/16 achieved an NAD success rate of 83.0% in 53 verified Night Survey observations, so Night Surveys ceased on 19 December 2015. The most common errors in the Day Survey data set involved mistaking N and UNA, as in previous seasons. The two errors between UT and N were caused by convoluted, overlapping tracks located behind dunes or beneath vegetation, which masked or mimicked the evidence of digging activity. Overall, current levels of training by the GTCP and experience of the seasonal GTCP Field Research 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.

6.5.3 Nest detection bias

Since 2010/11, Nest detection bias in the GBR Survey Area has been consistently negative, revealing the tendency for GTCP researchers to underestimate the number of Nests during Day Surveys. However, the magnitude of this bias has decreased over time and, during 2015/16, while the NAD error rate was similar to previous seasons, the Nest detection bias was 0%, meaning that the errors were not predominantly in one direction (i.e. consistently mistaking UNA for N or vice versa). Overall, this suggests improvement at the program level as more experienced seasonal field teams are hired and each successive field team has the opportunity to 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 Survey Area 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 Survey Area 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

During 2015/16, SI and NAD accuracy were both above the desired target levels (95.0% and 80.0%, respectively). Thus, current levels of training by the GTCP and the experience of the GTCP Field Monitoring Team appear adequate for reliable track interpretation, taking into consideration that track interpretation will always involve some level of error. Particularly since the current format of Night Surveys was not conducted during the early years of the GTCP, 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 SAMPLED NEST SURVEYS

7.1 Introduction

A variety of environmental and ecological factors can negatively affect the successful incubation, hatching and emergence of sea turtle hatchlings from Nests. These include, but are not limited to, extreme sand temperatures, seawater inundation, erosion, intrusion by plant roots, disturbance by human activity (e.g. sand compaction) and predation by native and feral predators (Dodd 1988; Miller *et al*. 2003). For effective conservation of sea turtle populations, it is critical to quantify the impact of these and other threats to turtle Nests and mitigate unsustainable threats as necessary.

For sea turtle rookeries in Australia, a key ecological threat is predation by invasive species such as the European red fox, feral cats and wild dogs (Baldwin *et al.* 2003; Limpus, 2009; Hilmer *et al.* 2010). For example, on certain east coast mainland beaches, foxes were responsible for the destruction of 90 – 95% of loggerhead turtle clutches in the late 1970s and early 1980s (Limpus, 2009). On the west coast, foxes have been important predators of sea turtle eggs in the Northwest Cape region for decades as well, although the impact of fox predation has been reduced via a fox baiting program established by the Department of Conservation and Land Management (now DPaW) in 2003/04 (Limpus, 2009). At Gnaraloo, foxes affected a large proportion of sea turtle Nests in parts of the GBR prior to the onset of the GFACP in 2008, which has resulted in 0% disturbance or predation by feral animals (fox, cat, dog) on sea turtle Nests for 6 consecutive years from 2010/11 – 2015/16. However, native predators such as golden ghost crabs (*O. convexa*) and running ghost crabs (*O. ceratophthalma*) likely still have a significant impact on turtle Nests at Gnaraloo (Hattingh *et al.* 2011). While a certain level of predation by native predators was likely sustainable to historical WA sea turtle populations, it is unclear what level of predation can be sustained by contemporary, depleted turtle populations, so current rates of predation by these predators warrant investigation.

Environmental threats to sea turtle Nests in the GBR Survey Area include inundation associated with storms or tropical cyclones (Hattingh *et al.* 2011). Cyclones can significantly reduce turtle hatching success and reduce survivorship through increased flooding of Nests (Pike & Steiner, 2007; Van Houtan & Bass, 2007), and have caused a dramatic loss of turtle Nests at Gnaraloo in previous seasons (Hattingh *et al.* 2011) as well as in the greater Ningaloo region (Coote *et al.* 2013). Furthermore, with strong prevailing southerly winds (**Chapter 3**), there is a large amount of sand movement in the littoral dune system within the GBR Survey Area. This causes Nest suffocation through shifting sands. Variation in sand height above Nests may affect temperatures around the eggs, resulting in skewed sex ratios (Yntema & Mrosovsky, 1980) or even expose the eggs to lethal temperatures (i.e. > 33ºC).

Since it is not logistically possible to monitor every turtle Nest in the GBR Survey Area, each year the GTCP selects a statistically representative subset of Nests to mark as Sampled Nests and monitor throughout the season. Sampled Nests are monitored daily during GBR Day Surveys (**Chapter 5**) for a target monitoring period of 90 days (i.e. just longer than the maximum time for successful incubation in the GBR Survey Area, Hattingh *et al.* 2010). Sampled Nest data have been collected in the GBR Survey Area during Day Surveys since season 2011/12.

7.2 Objectives

The objectives of Sampled Nest surveys in the GBR Survey Area during 2015/16 were to:

- closely observe a subset of Nests that is statistically representative of the entire Nest set daily for the entire monitoring period to record their fate (i.e. whether they survive to hatching) as indicative of the fate of the entire Nest set;
- monitor the extent and impact of feral and native predators on turtle Nests;
- examine the extent and impact of environmental events on turtle Nests;
- gain insight into factors influencing hatching success of Nests.

7.3 Methods and materials

The GTCP Procedure 2015/16 contains detailed methods. Briefly, a statistically representative subset of Nests recorded during GBR Day Surveys in each Sub-section were randomly selected to become Sampled Nests and these were marked using wooden stakes. Only Nests dug on or before 4 January 2016 were used in the Sampled Nest survey. This date was selected as the cut-off date for Sampled Nests to allow researchers 90 days of observation as the GTCP monitoring period ends on 28 February each year. These Nests were then monitored on a daily basis until several days after the first evidence of hatching, for 90 days (approximately 1 week longer than the maximum observed incubation time at Gnaraloo[19], Hattingh *et al.* 2010) or until the end of the monitoring period (28 February 2016). All disturbance, predation and environmental events within 1m of the Nest, as well as evidence of hatching, were recorded daily. For inundation events, Nests were considered inundated if evidence of waves was

[19] During the season 2009/10, incubation periods for hatched loggerhead Nests in BP8 - BP9 ranged from 55 – 82 days, with the highest frequency of hatching at 60 - 70 days. Mean incubation time was 67.3 days. Nests dug earlier in the season (during November – December 2009) had longer incubation times (70.5 – 77.2 days) compared to those dug later in the season (during January – February 2010) (63.2 – 64.7 days).

observed within 1m of the stake in the direction of the egg chamber. Changes in sand height over the egg chamber, to the nearest cm, were recorded daily and the number of Nests experiencing changes ≥ 20 cm in magnitude (i.e. either increase or decrease) were noted (assumed to have the potential to influence temperatures, moisture and gas exchange in the Nest and/or to be sufficient sand movement for either Nest suffocation or erosion by sand). During 2015/16, for the first time, the GTCP excavated a small number of targeted Nests (in the main, suspected to be potential hawksbills) in collaboration with DPaW following the end of the 90-day incubation period.

7.3.1 Study area

Sampled Nests were monitored in all Sub-sections of the GBR Survey Area (-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 67 Sampled Nests was obtained using the 'sample size with proportions' equation (0.95 confidence interval, 0.1 margin of error); an average Nest predation rate by crabs (determined from Sampled Nest survey data 2011/12 – 2015/16) and the finite population correction for proportions equation (refer to GTCP Data Manual 2015/16). The resulting number was then divided between the 3 GBR Sub-sections based on the proportion of Nests found in each Sub-section in the previous 5 seasons (i.e. 2010/11 – 2014/15, during 1 November – 4 January). The target number of Sampled Nests for each Sub-section for 2015/16 was:

- GBN – BP7: 17 Nests;
- BP7 – BP8: 6 Nests;
- BP8 – BP9: 44 Nests.

Nests to be designated as Sampled Nests were selected using an online random number generator[20] with the maximum number being the average number of Nests found in each Sub-section since 2011/12 during 1 November – 4 January.

[20] http://www.randomizer.org/form.htm

7.4 Results

7.4.1 Sample size

Out of the predetermined target of Sampled Nests, 47 of 67 were established during 2015/16. In Sub-section GBN – BP7, 9 of 17 target Sampled Nests were established, 1 of 6 was established in Sub-section BP7 – BP8 and 37 of 44 were established in Sub-section BP8 – BP9 before the cut-off date of 4 January 2016. In addition, 2 suspected hawksbill turtle Nests in Sub-section BP8 – BP9, which were not part of the random sample, were staked and monitored as Sampled Nests to attempt to verify the species at hatching (these Nests were included in data summary). In Sub-section BP8 – BP9, 1 Sampled Nest was established, but the stake was lost on the following day and was not replaced[21], so was not monitored. Thus, a total of 49 Sampled Nests was monitored during 2015/16 (**Appendix A**).

Of the 49 Sampled Nests monitored, the species responsible was confirmed by Night Surveys for 15 (all in Sub-sections BP7 – BP8 and BP8 – BP9). All Sampled Nests that were confirmed by Night Surveys were dug by loggerhead turtles. The species responsible for the 2 suspected hawksbill turtle Nests was not confirmed during Night Surveys.

Of the 49 Sampled Nests, 35 were monitored until hatching or for at least 67 days, the average incubation time at Gnaraloo (Hattingh *et al.* 2010) and, 18 of the 35 nests that made it to 67 days of monitoring, were monitored until hatching or for the full 90 days.

7.4.2 Nest disturbance and predation

There was no observed predation of Sampled Nests by feral animals during 2015/16 (**Chapter 4.4**). Two instances of possible disturbance by feral cats – scratching or digging at the sand – were recorded on separate Nests in Sub-section BP8 – BP9. However, in one case, the digging was superficial (i.e. only a few cm deep) and could not be confirmed as directed at the egg chamber and, in the other, a cat appeared to have approached and dug around the margin of a crab burrow. After review, neither case was deemed sufficient to be considered disturbance.

All remaining disturbance and predation activity was the result of ghost crabs. In total, 28 of 49 (57.1%) Sampled Nests were either disturbed (12 Samples Nests) or predated (16

[21] We did not rely on GPS co-ordinates to re-stake Sampled Nests due to the large error (usually ≥ 4m) of the units. Stakes that were knocked out of place were only replaced if the hole in the sand was still visible.

Sampled Nests) by crabs[22].

Crab activity on Sampled Nests was greatest in Sub-section BP8 – BP9, where 10 of 39 Sampled Nests (25.6%) were disturbed and 16 of 39 (41.0%) were predated. In Sub-section GBN – BP7, 2 of the 9 (22.2%) Sampled Nests were disturbed, while none were predated. The Sampled Nest in Sub-section BP7 – BP8 was neither disturbed nor predated.

7.4.3 Multi-year variation in crab activity

A relatively low level of crab activity was recorded at Sampled Nests during 2015/16 compared to the previous seasons (**Figure 17**). However, with only five years of data on Sampled Nests (i.e. 2011/12 – 2015/16) in the GBR Survey Area, it is not yet possible to rigorously evaluate trends in crab impacts over time.

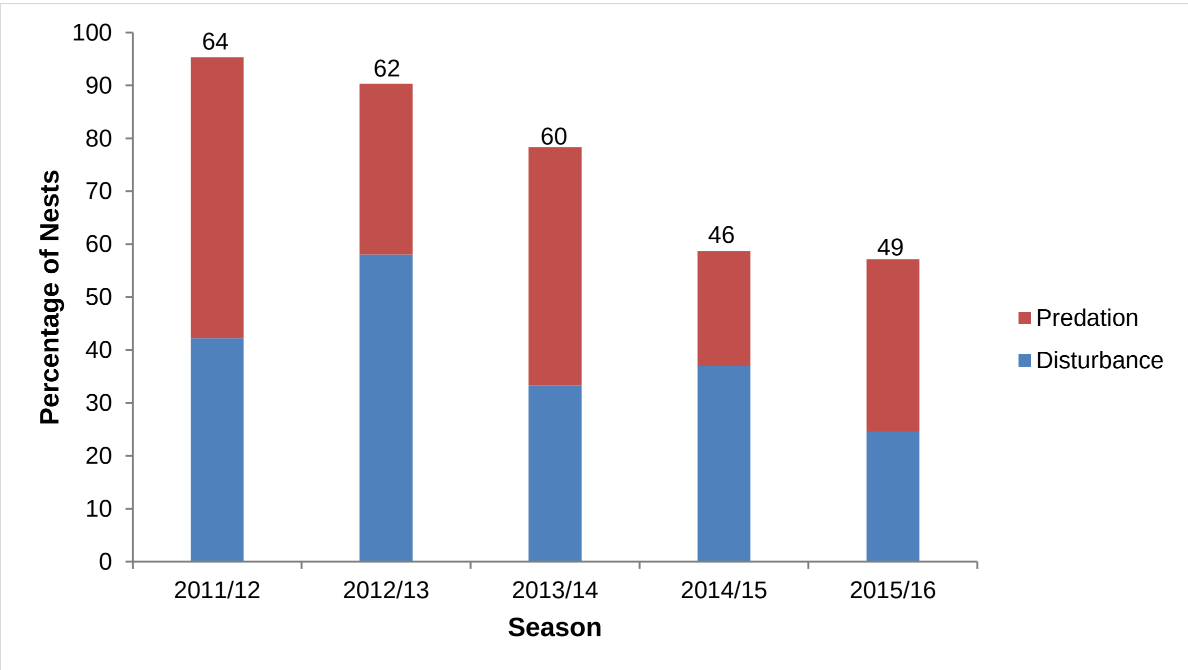

Figure 17: Percentage of Sampled Nests disturbed and predated by crabs in the GBR Survey Area during 2011/12 – 2015/16

Note: Sampled Nest predation data were collected consistently from season 2011/12, so only these GTCP data sets are included. A large proportion of Sampled Nests during season 2012/13 were washed out by Tropical Cyclone Nerelle. These data are included in this figure, but the Nests were monitored for varying, often short (i.e. several weeks) lengths of time depending on how long the Nests were dug before the cyclone. Thus, estimates of crab disturbance and predation impacts during this season

[22] By definition, a predated Nest would also have been disturbed. However, for the purposes of this report, disturbance and predation are logged separately.

are likely low compared to seasons without cyclone activity.

7.4.4 Environmental impacts

No cyclones were recorded during 2015/16. Of the 49 Sampled Nests, 9 (18.4%) experienced environmental impacts related to tides or storms, which all comprised inundation events. Impacted Nests were primarily inundated between 29 December 2015 and 21 January 2016, and 6 of the 9 inundated Sampled Nests were affected on consecutive days.

No Sampled Nests experienced erosion related to tides or storms during 2015/16 (we only considered erosion to have occurred if the egg chamber was exposed).

Sampled Nests in GBR Sub-section BP8 – BP9 were the most impacted by inundation, with 8 of the 39 (20.5%) Sampled Nests experiencing inundation. In Sub-section GBN – BP7, 1 of the 9 Sampled Nests (11.1%) experienced inundation, while the Sampled Nests in Sub-section BP7 – BP8 was not impacted.

Of the Sampled Nests, 6 of 49 (12.2%) experienced increases in sand height ≥ 20 cm relative to initial sand height throughout the monitoring period 2015/16, and 6 of 49 (12.2%) experienced decreases in sand height ≥ 20 cm. Thus, 12 of 49 (24.4%) Sampled Nests may have experienced impacts related to sand movement. However, 2 Sampled Nests that experienced increases in sand height greater than 75 cm (76 and 77 cm, respectively), still showed signs of hatching. All other Sampled Nests (37 of 49, 75.5%) experienced fluctuations in sand height < 20 cm in magnitude over the course of monitoring.

In Sub-section BP8 – BP9, 5 of 39 (12.8%) Sampled Nests experienced increases in sand height ≥ 20 cm, while 6 of 39 (15.4 %) Sampled Nests experienced decreases of this magnitude. Shifts in sand height were < 20 cm for all other Sampled Nests (28 of 39, 71.8%) in Sub-section BP8 – BP9. In Sub-section GBN – BP7, 1 of 9 (11.1%) Sampled Nests experienced an increase in sand height ≥ 20 cm, while none experienced a decrease of this magnitude. The Sampled Nests (6 in total) in Sub-section BP7 – BP8 experienced neither an increase nor a decrease in sand height ≥ 20 cm.

Changes in sand height were not compared across seasons 2011/12 – 2015/16 due to year-to-year differences in data collection methods.

7.4.5 Multi-year trends in environmental impacts

The rate of inundation by tides or storms (**ITS**) and erosion by tides or storms (**ETS**) on Sampled Nests during 2015/16 was low compared to the previous seasons (**Figure 18**). No cases of ETS were documented in either seasons 2014/15 or 2015/16. All seasons experienced lower rates of ITS and ETS than season 2012/13 due to Tropical Cyclone Nerelle during that season, which washed out a large number of Sampled Nests.

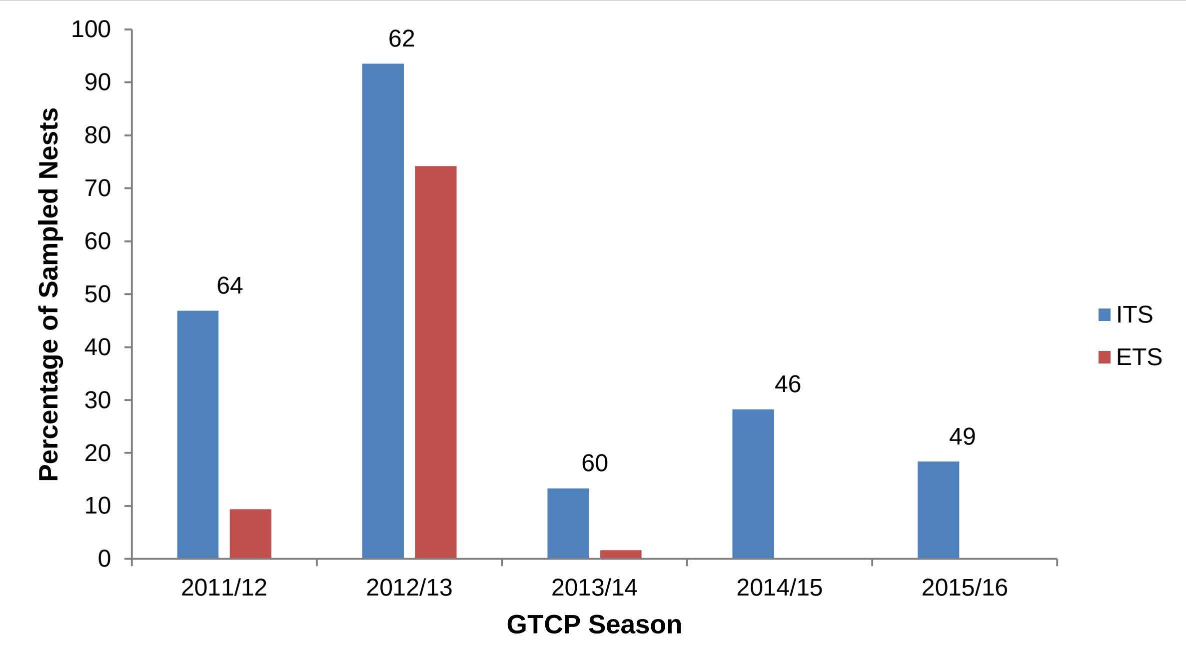

Figure 18: Percentage of Sampled Nests affected by ITS and ETS in the GBR Survey Area during 2011/12 – 2015/16

7.4.6 Evidence of hatching

Of the 49 Sampled Nests, 13 (26.5%) showed evidence of hatching during 2015/16. In Sub-section BP8 – BP9, 8 / 39 (20.5%) Sampled Nests showed signs of hatching, while 4 / 9 (44.4%) of Sampled Nests in Sub-section GBN – BP7 showed signs of hatching along with the 1 / 1 Sampled Nest in Sub-section BP7 – BP8 (**Figure 19**).

Of the 13 Sampled Nests that showed signs of hatching, 5 had been disturbed by crabs and 5 had experienced changes in sand height ≥ 20 cm. No Sampled Nests that had been affected by crab predation or ITS (N = 17) showed signs of hatching.

A total of 71 hatchlings were recorded during Samples Nest surveys in 2015/16, 27 of which were observed either within the Nest depression or crawling in the vicinity of a

Sampled Nest. Of these 27 hatchlings, 10 (37.0%) were found dead in their Nest depressions.

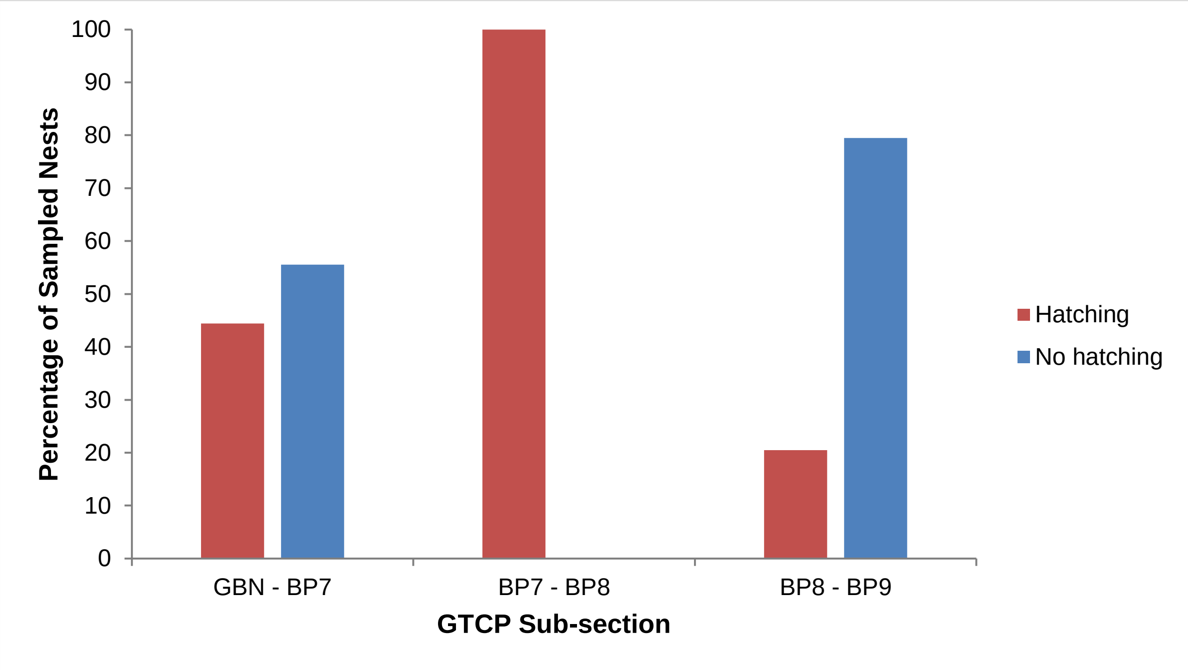

Figure 19: Percentage of Sampled Nests in the GBR Survey Area during 2015/16 that showed signs of hatching

7.4.7 Multi-year variation in hatching success

Season 2015/16 experienced an above-average rate of hatching success (26.5%) when compared with previous seasons since 2011/12 (range = 18.8 – 35.0%, average = 23.0%, **Figure 20**). Season 2012/13 experienced a negligible rate of hatching success due to Nest loss caused by Tropical Cyclone Nerelle. However, all of these estimates of hatching success need to be interpreted very cautiously due to methodological limitations (refer to Discussion).

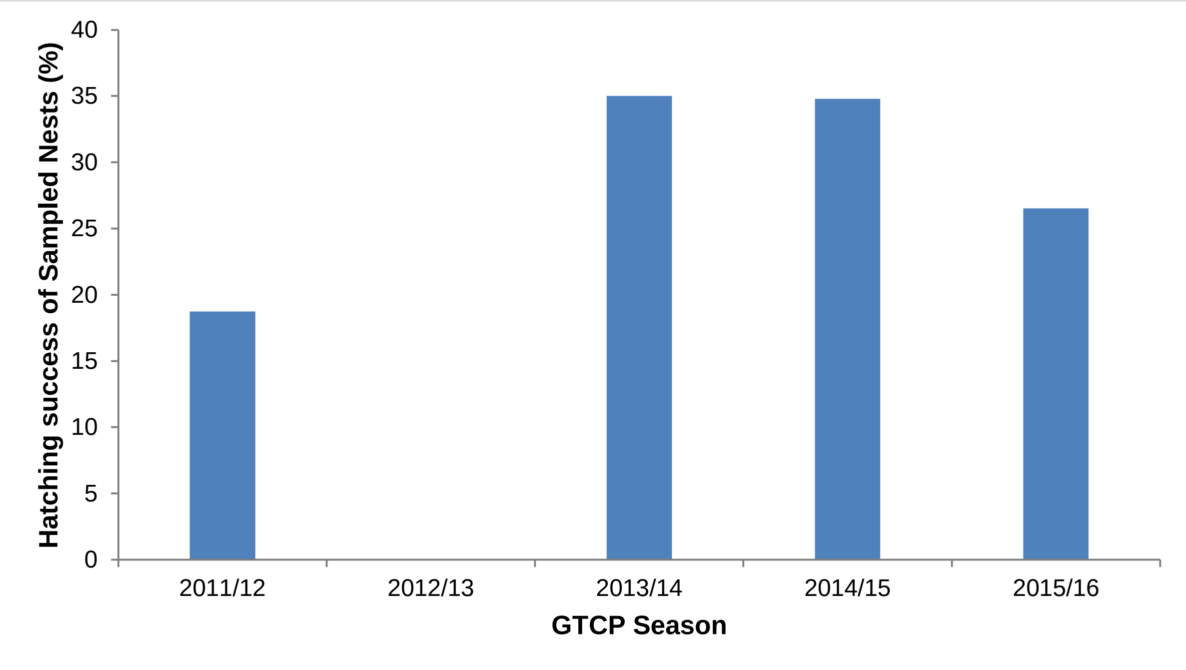

Figure 20: Rates of apparent hatching success of Sampled Nests in the GBR Survey Area during 2011/12 – 2015/16

Note: Season 2012/13 experienced a negligible rate of hatching success due to Nest loss caused by Tropical Cyclone Nerelle and was excluded from the figure.

7.4.8 Sampled Nest excavations with DPaW

On 17 February 2016, Dr. Peter Barnes (Ningaloo Marine Park Manager) and a marine park ranger (both from DPaW, Exmouth Division) visited Gnaraloo to assist the GTCP Field Monitoring Team with a small number (5) of Sampled Nest excavations. The goal was to verify the species responsible for 2 Nests that were suspected to have been dug by hawksbill turtles and possibly provide reliable evidence of the presence of hawksbills in the GBR Survey Area. The excavations would also provide preliminary insight into the usefulness of excavations for determining the fate of Sampled Nests in future and assess the value of excavations to the GTCP.

Results from the 2 suspected hawksbill Nests were inconclusive. The first Nest (with Nest identity number: 151111_BP8BP9_NA0005[23]) contained only 49 egg shell fragments and one undeveloped egg. No hatching was observed at this Nest during the Sampled Nest surveys, while crab disturbance was observed on 14 days and crab predation was

[23] The GTCP Nest identity naming protocol is as follows: reverse order date on which the Nest was recorded, then its GBR Sub-section and lastly the nesting activity sequence number, in chronological order, for that particular sub-section.

observed on 1 day, suggesting that crabs were likely the primary cause of the shell fragments (as opposed to hatching). The second Nest (151106_BP8BP9_NA0003) had been buried by a large dune and the egg chamber was not located despite extensive digging. These 2 suspected hawksbill Nests were changed to loggerhead turtle Nests following GTCP protocol implemented in 2015/16 (refer to notes associated with **Table 1**).

In Nest 151113_BP8BP9_NA0007, scattered egg shell fragments were found, but no egg chamber could be located. No hatching, crab disturbance or crab predation were observed at this Nest during the Sampled Nest surveys.

In Nest 151121_BP8BP9_NA0022, 1 live loggerhead turtle hatchling was found partially emerged from its shell with its yolk not fully absorbed. This hatchling was released into the ocean. In the same Nest, 62 undeveloped eggs and 31 shell fragments were also found. Hatchling tracks numbering 6 were observed leaving this Nest during the Sampled Nest surveys, and no crab disturbance or predation was recorded.

Finally, in Nest 151115_BP8BP9_NA0008, 148 shell fragments, 27 dead loggerhead turtle hatchlings, 11 undeveloped eggs and 4 full-term dead embryos were found. No hatchling tracks were seen from this Nest during the Sampled Nest Surveys, although a Nest depression was seen on 3 days so it was considered hatched.

7.5 Discussion

7.5.1 Influence of disturbance and predation on Nest hatching success

Since 2010/11, as a result of the control works under the GFACP, no evidence of feral animal predation of sea turtle Nests in the GBR Survey Area has been observed (**Chapter 4**). Therefore, native predators, specifically ghost crabs, are now the primary source of disturbance and predation impacts on turtle Nests. Crab activity was well below the average of 76.0% (for disturbance and predation, 2011/12 – 2015/16) for the GBR Survey Area during 2015/16, with disturbance or predation affecting 57% of Sampled Nests. However, it is currently unclear how these rates compare with crab impacts elsewhere in WA, although they are suspected to be high compared to elsewhere on the Ningaloo Coast (Dr. Peter Barnes, Ningaloo Marine Park Manager, DPaW, pers.comm.). No Sampled Nests that experienced crab predation showed evidence of hatching, which suggests a strong impact of crabs on Nest hatching success at Gnaraloo. On the other hand, 5 Sampled Nests that experienced crab disturbance did show signs of hatching. A more thorough understanding of crab impacts on sea turtle Nests at Gnaraloo would require experimental work (e.g. Nest caging to exclude crabs) with excavations and proper quantification of hatching success (i.e. the proportion of a clutch that successfully hatches) as opposed to the binary classification currently used. This should be a focus of future work at Gnaraloo since it is possible that this rookery has been depleted relative to historic levels by several decades of fox predation, and intensive crab predation may suppress potential recovery now that foxes are controlled by the GFACP.

7.5.2 Environmental Impacts

In the absence of major weather events during 2015/16, environmental impacts via inundation by tides were relatively infrequent compared to previous years since 2011/12. Only 17% of Sampled Nests experienced inundation by tides. No Sampled Nests or other Nests in the GBR Survey Area were observed to have been eroded by tides. Tidal wash and increased moisture have been shown to decrease hatching success (Caut *et al.* 2010; Foley *et al.* 2006) either due to asphyxiation from the limitation of gas exchange or changes in incubation temperature. It is important to keep in mind, however, that under current GTCP protocol, inundation is defined as any amount of water washing over the Nest area. This means that a single wave that washed over a Sampled Nest would be recorded as an inundation event. The impact of different levels of inundation on hatching success therefore remains unclear.

Gnaraloo is subject to strong prevailing southerly winds for much of the turtle nesting season (**Chapter 3**). As a result, the sand dunes within the GBR Survey Area are highly mobile and shift substantially throughout the incubation period. Data on the impact of major increases and decreases in sand height in the GBR Survey Area on the successful development of clutches is currently limited. Of the 6 Sampled Nests that experienced a ≥ 20 cm increase in sand height during 2015/16, 3 exhibited evidence of hatching. However, because only 3 of these Nests were monitored for the full 90 day incubation period, hatching success could be underestimated. Of the 6 Sampled Nests that experienced a ≥ 20 cm decrease in sand height, 2 showed signs of hatching. However, none of these Nests was monitored for the full 90 day period, so, again, hatching success may be underestimated. While the precise impacts of sand height fluctuations remain unknown, it is likely that shifts in sand height of 20 cm or more have some influence on temperatures, moisture and gas exchange in the Nests. This should be investigated in greater detail in future GTCP seasons.

7.5.3 Sampled Nests without activity

Of the 49 Sampled Nests, 12 did not display any signs of crab activity, environmental impact or hatching. There are numerous reasons why Sampled Nests may not have shown any change throughout the monitoring period. First, most Sampled Nests were not in fact verified during Night Surveys and some of these may therefore have been misidentified as Nests during Day Surveys (although this proportion would be small). Second, Sampled Nest monitoring ended on 28 February 2016, before the likely completion of incubation time for the majority of Sampled Nests. Thus, some hatching likely occurred after the end of the monitoring period. Indeed, the length of time for which Sampled Nests were monitored was highly variable (50 – 90 days, depending on when they were first dug), so directly comparing predation and environmental impact rates among these Nests is challenging. Third, wind may have caused sand to blow over evidence of environmental, predation or hatching events, and these events therefore may have been missed. To the extent possible, these methodological challenges will be addressed in future GTCP seasons.

7.5.4 The value of Nest excavations

The use of a binary outcome variable for hatching success [i.e. evidence of hatching (e.g. Nest depression, hatchling tracks or live hatchlings) or no evidence of hatching] provides only a coarse indicator of true hatching success (the proportion of eggs in a clutch that hatch and emerge from the Nest). This limits our ability to quantify the effects of crab disturbance and predation, and environmental factors on loggerhead turtle reproductive output in the GBR Survey Area because, within a Nest that shows evidence of hatching, the rate of hatching success could still range from almost nothing to 100% (refer to **Section 7.4.8**). The excavations conducted at the end of the season 2015/16 emphasize this point. For example, 6 hatchling tracks were observed at Nest 151121_BP8BP9_NA0022 during the Sampled Nest surveys, so this Nest was considered hatched. However, its excavation revealed that 62 eggs were undeveloped in the Nest at the end of the incubation period, which would likely constitute the majority of the clutch. Thus, in order to gain more biologically meaningful insight into hatching success, researchers would need to know the number of eggs deposited into the Nest – via for example direct observation at laying– and determine the fate of those eggs via excavation at the end of the incubation period. Such methods should be considered for potential GTCP or external university projects in future seasons.

7.6 Conclusion

Crab disturbance and predation were the main predator impacts on turtle Nests in the GBR Survey Area during 2015/16. However, crab predation on Sampled Nests was low during 2015/16 compared to previous seasons since 2011/12. Sub-section BP8 – BP9 recorded the highest rates of crab disturbance and/or predation. However, sample sizes of Sampled Nests were low in the other two Sub-sections, particularly BP7 – BP8 (N = 1), so spatial comparisons should be interpreted cautiously. The relative impact of crab predation at Gnaraloo compared to elsewhere on the Ningaloo Coast should be investigated, since it is possible that intensive crab predation at Gnaraloo could suppress recovery of this rookery following several decades (most likely) of fox predation on turtle Nests at Gnaraloo prior to intensive control from the season 2008/09 to 2015/16. Whilst no cyclonic activity occurred during 2015/16, 17% of Sampled Nests experienced inundation by tides. Of the Sampled Nests, 24.4% experienced increases and decreases in sand height ≥ 20 cm, but the influence of these fluctuations on hatching success remains unknown. Importantly, crab disturbance / predation, inundation as currently recorded and sand movement likely do not mean the destruction of an entire clutch, and the precise impact of varying levels of predator or environmental impacts on Nest hatching success remains unknown. Excavations should be considered during future seasons as a means of gaining additional insight into factors influencing Nest hatching success in the GBR Survey Area.

8 GCFR DAY SURVEYS

8.1 Introduction

Cape Farquhar is a remote, undeveloped and uninhabited stretch of the Gnaraloo coastline located 22 km north of the Gnaraloo Homestead (**Appendix A**). The GTCP conducted aerial surveys during the monitoring seasons 2009/10 and 2010/11, which revealed evidence of sea turtle nesting on Cape Farquhar beaches. On-ground surveys of the GCFR began in 2011/12 and significant nesting activity was recorded, primarily by loggerhead turtles (Hattingh *et al.* 2012a, b, c; Riskas, 2014). However, it remains unclear how many turtles nest in this rookery annually, how nesting abundance in the GCFR Survey Area compares with the GBR Survey Area and how important the GCFR is to turtle populations in WA. Here, we summarize findings from two weeks of Day Surveys in the GCFR Survey Area during 2015/16 and compare nesting activity in the GCFR and GBR Survey Areas over four years during the overlapping sampling periods.

8.2 Objectives

The objectives of Day Survey monitoring in the GCFR Survey Area during 2015/16 were to:

- monitor turtle nesting activities and species composition;
- assess spatio-temporal nesting patterns to inform survey protocol development;
- compare the number of nesting activities there with those observed in the GBR Survey Area during the overlapping monitoring period over four years;

8.3 Methods and materials

8.3.1 Study area

Cape Farquhar is located adjacent to the *Ningaloo Marine Park* (**NMP**). The structure of the coastline ranges from shallow protected bays with fringing coral reef to dynamic beaches with rolling waves and steep rocky outcrops.

During 2011/12 – 2013/14, the GCFR was split into four Sub-sections (approximately 14 km in length, adjacent to the *Cape Farquhar Marine Sanctuary Zone* of the NMP):

- 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**) and
- Gnaraloo Lagoon North (**GLN**) to Gnaraloo Farquhar North (**GFN**) (**Sub-section 4**).

For seasons 2014/15 and 2015/16, GCFR Day Surveys occurred in Sub-sections 2 and 3 only (7.1 km total length), now referred to as the standard GCFR Survey Area (**Appendix A**), because these were the Sub-sections with the highest number of sea turtle nesting activities in previous seasons (Hattingh *et al.* 2014).

8.3.2 Survey protocol

The GCFR Survey Area was surveyed for 14 consecutive days during the peak nesting period from 27 December 2015 to 9 January 2016. Day Surveys were conducted following the GBR Day Survey protocol (**Chapter 5.3.2**). One day prior to the start of the surveys, old turtle activity tracks were marked off to ensure only new tracks would be counted. This was the second consecutive season in which only Sub-sections 2 and 3 (the standard GCFR Survey Area) were surveyed. Changes in GCFR survey methods since 2011/12 are summarized in **Table 8**.

8.3.3 Predation, stranding and hatching

Feral animal activity and turtle hatching events were recorded following GFACP MERI monitoring and GBR Day Survey protocols (**Chapter 4**; **Chapter 5**). Turtle stranding and mortality events were documented and resolved following DPaW protocol.

Table 8: GCFR Day Survey methodology changes during 2011/12 – 2015/16

GTCP SEASON	NUMBER OF SURVEYS	DAYS PER SURVEY	TOTAL DAYS SURVEYED	SUB-SECTIONS SURVEYED	OLD ACTIVITIES RECORDED	DAYS WITH OLD ACTIVITIES ON DAY 1	DAYS WITH NEW ACTIVITIES
2011/12	3	4	12	1, 2, 3, 4	Y	3	9
2012/13	4	4	16	1, 2, 3, 4	Y	4	12
2013/14	4	4	16	1, 2, 3, 4	Y	4	12
2014/15	1	14	14	2, 3	N	-	14
2015/16	1	14	14	2, 3	N	-	14

8.4 Results

8.4.1 Summary of GCFR nesting activities

The GTCP Field Research Team recorded 133 nesting activities in the GCFR Survey Area during 2015/16, all attributed to loggerhead turtles, including 59 Nests, 67 UNA and 7 U Track (**Table 9**). Of these, 93% (124 / 133) occurred in GCFR Sub-section 3 (GFR – GLN).

Table 9: Frequency of nesting activity type per species in the GCFR Survey Area during 2015/16 (27/12/2015 – 09/01/2016)

SPECIES	NESTING ACTIVITY TYPE				
	NEST	UNA	UT	UA	TOTAL
LOGGERHEAD	59	67	7	0	133
GREEN	0	0	0	0	0
HAWKSBILL	0	0	0	0	0
UNKNOWN	0	0	0	0	0
TOTAL	59	67	7	0	133

8.4.2 Comparison of GBR and GCFR nesting activities (4 years)

During 2012/13 – 2014/15, the GBR Survey Area consistently received more nesting activities and Nests than the GCFR Survey Area during the overlapping monitoring periods (**Figure 21**, **Figure 22**). However, during 2015/16, approximately 70% more nesting activities and 18% more Nests were recorded in the GCFR Survey Area than the GBR Survey Area (**Figure 21**, **Figure 22**).

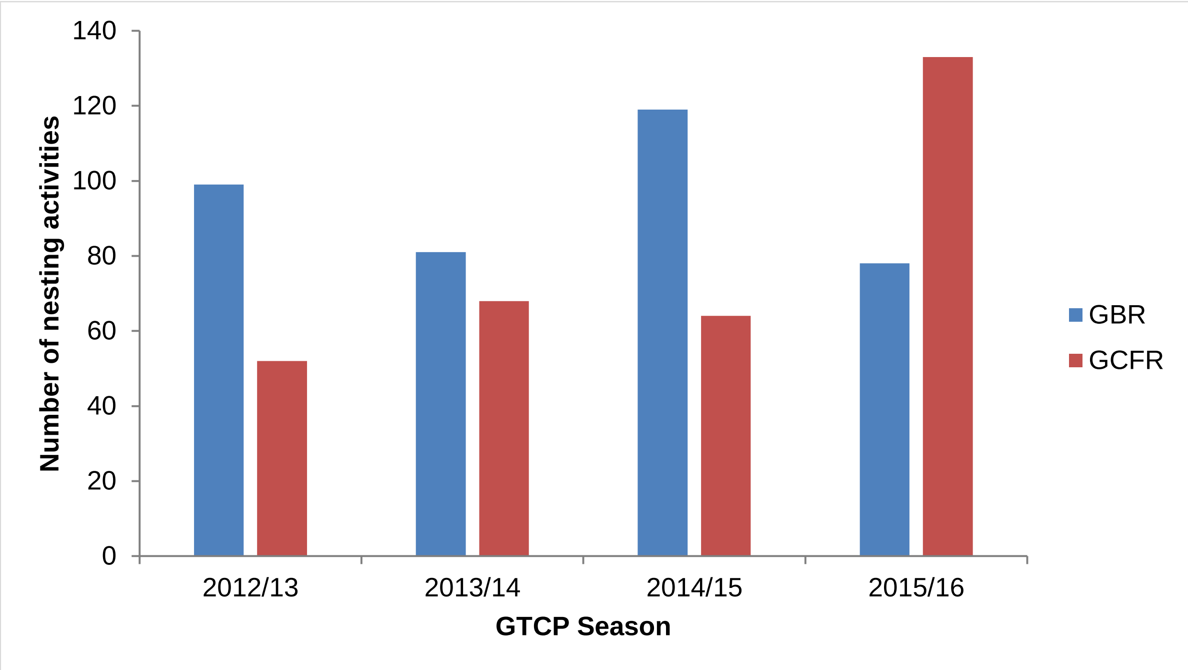

Figure 21: Nesting activities in the GBR and GCFR survey areas during the overlapping sampling periods in 2012/13 – 2015/16

Note: Bars cannot be compared across seasons because GCFR survey timing differed between seasons. However, the number of nesting activities can be compared within seasons because only data from the over lapping sampling period is included. Survey timing in the GCFR standarised from season 2014/15 – 2015/16. This applies to Figures 22 and 23 as well.

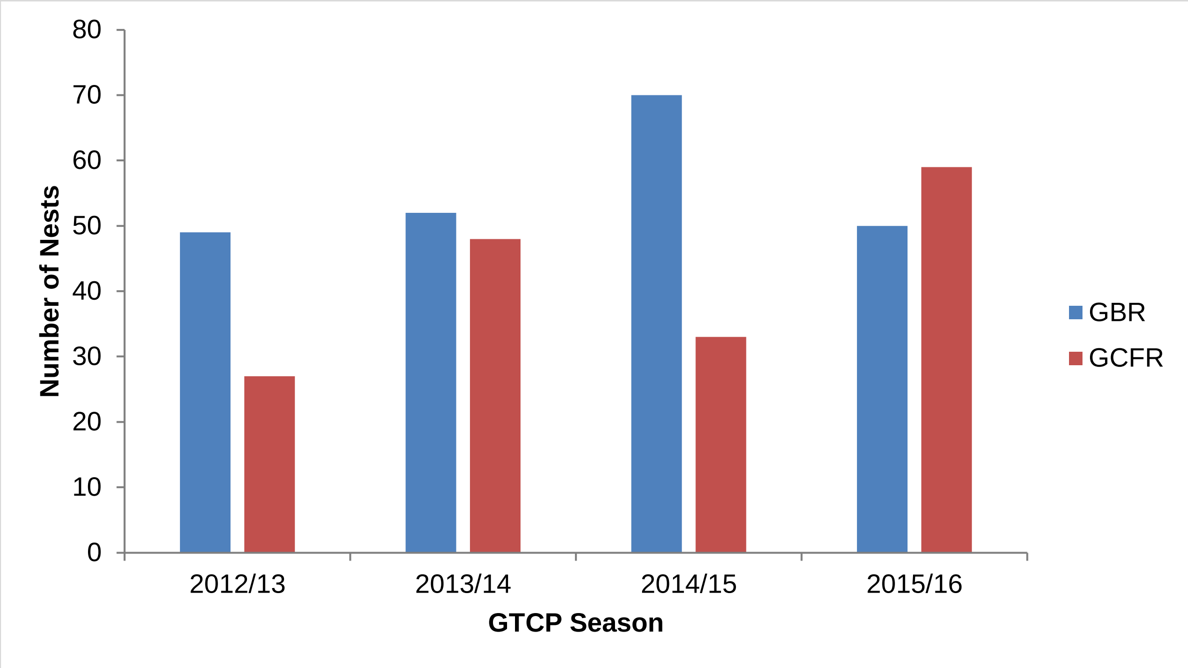

Figure 22: Nests in the GBR and GCFR survey areas during the overlapping sampling periods in 2012/13 – 2015/16

8.4.3 Comparison of GBR and GCFR nesting success rate (4 years)

Nesting success rates in the GBR and GCFR Survey Areas were comparable during seasons 2012/13, 2013/14 and 2014/15. However, despite the relatively similar number of Nests in both rookeries during 2015/16 (**Figure 22**), the Nesting success rate differed between rookeries during this season (64.1% and 44.4% for the GBR and GCFR Survey Areas, respectively) (**Figure 23**).

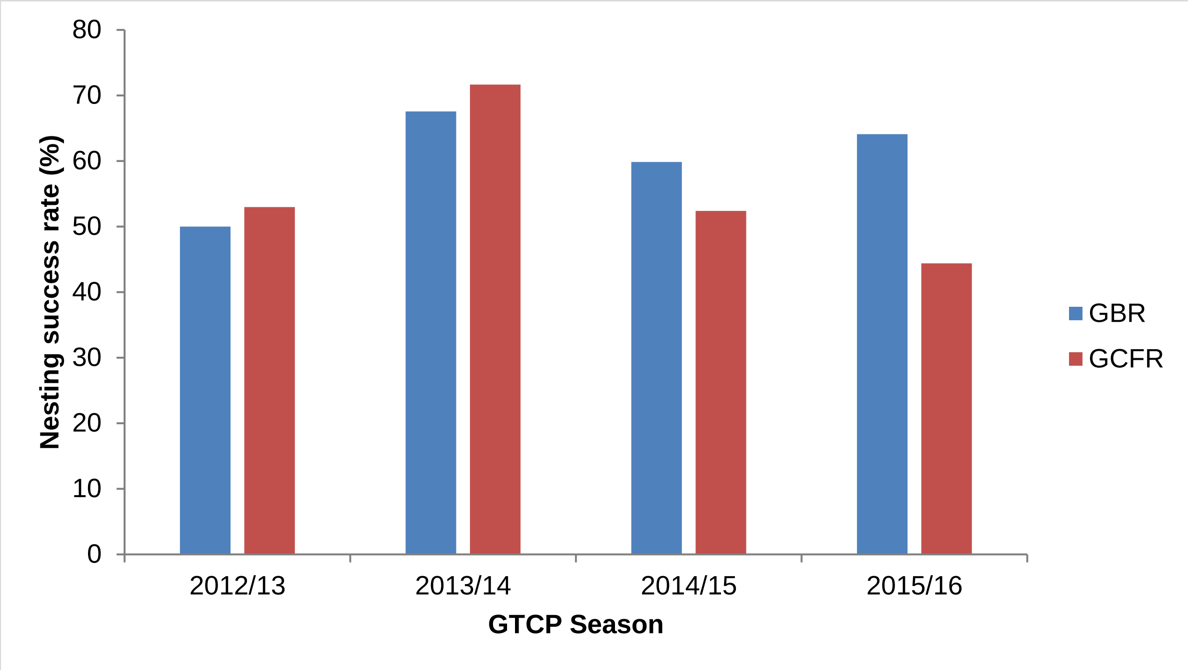

Figure 23: Nesting success rates in the GBR and GCFR survey areas during the overlapping sampling periods in 2012/13 – 2015/16

8.4.4 Predation, stranding and hatching in the GCFR

No disturbance or predation of turtle Nests by feral predators, or mortalities or hatching events, were observed in the GCFR Survey Area during 2015/16.

8.5 Discussion

Day Surveys in the GCFR Survey Area during 2012/13 – 2014/15 revealed fewer nesting activities compared to the GBR Survey Area during the overlapping monitoring periods (which have differed from year-to-year, but can still be compared within each year). However, during the season 2015/16, the GCFR Survey Area received 70% more nesting activities and 18% more Nests than the GBR Survey Area. The much greater number of nesting activities in the GCFR Survey Area during 2015/16 may be attributed to the low Nesting success rate, meaning that females often had to come ashore multiple times before laying eggs[24]. This would likely be due to unfavourable beach conditions. Based on Nests only, four years of comparisons reveal that the GCFR Survey Area receives a similar or slightly lower number of Nests each season compared to the GBR Survey Area.

24 Many UNA observed in the GCFR Survey Area during 2015/16 had a large number of body pits and one female was observed digging 23 body pits during a single emergence (Aubrey Strydom, pers. comm.).

Since the annual sampling period in the GCFR Survey Area is brief, with monitoring at different times in 2011/12 – 2013/14 as the work was investigative during its initial years to explore the size and importance of this nesting area[25], it is not yet possible to estimate the total number of females nesting in this rookery or evaluate nesting trends over time. Furthermore, year-to-year variation in nesting activity levels needs to be interpreted cautiously. For instance, it is not clear whether peak nesting in the GBR and GCFR Survey Areas align and, additionally, a two-week sampling window could experience relatively high or low levels of nesting activity in a given year just by chance. Still, based on the data collected to date, it seems justified to conclude that a comparable amount of nesting activity occurs in the GCFR and the GBR Survey Areas. It is currently unclear whether there is overlap between these rookeries, with some females nesting at both sites or whether they comprise different individuals. Satellite tracking and/or flipper tagging are needed to resolve this issue. Aerial surveys would be valuable to facilitate reliable abundance estimates for the Gnaraloo coast as a whole. As such, continued monitoring and research in the GCFR are warranted.

8.6 Conclusion

Day Surveys in the GCFR Survey Area indicate that a comparable level of loggerhead turtle nesting activity occurs in this rookery relative to the GBR Survey Area, at least during the overlapping periods sampled to date. Season 2015/16 was the first season in which the GCFR Survey Area received a greater amount of nesting activities and Nests than the GBR Survey Area, with the unusually high number of nesting activities in the GCFR Survey Area possibly a result of a relatively low Nesting success rate. Currently, the short sampling period in the GCFR Survey Area precludes estimation of the number of individuals nesting in this rookery each season. Because of this, the significance of the GCFR with respect to the overall southeast Indian Ocean loggerhead turtle sub-population remains unknown. Expanded monitoring in future GTCP seasons may help resolve this issue. Still, it is clear that this remote stretch of mainland coast situated at the southern extreme of the Ningaloo coast hosts significant and previously under-reported nesting aggregations of loggerhead turtles each year. The Gnaraloo rookeries, despite their small size, may play an important role in the dynamics of the southeast Indian Ocean loggerhead turtle sub-population and are likely still depleted relative to historic levels due to recent and possibly long-standing predation by introduced foxes. Therefore, continued long-term monitoring, research and protection of Gnaraloo beaches is critical at this juncture.

25 Since 2014/15, the GCFR Survey Area and monitoring period has been consistent.

9 EDUCATION AND COMMUNITY ENGAGEMENT

9.1 Introduction

Public education and community engagement are essential for achieving positive and lasting conservation outcomes. For sea turtles, outreach activities play a vital role in increasing public awareness of the imperilled status of turtle populations as well as the anthropogenic threats that have, in many cases, contributed to population declines (refer to **Chapter** Error! Reference source not found.). As such, education and community engagement lie at the heart of the GTCP. The formal education and community engagement component of the GTCP was initiated during the season 2010/11 and has grown in scope each subsequent season. Currently, the community engagement program includes a diverse suite of onsite and off-site activities including community and school group participation in GBR Day and Night Surveys, presentations at Gnaraloo, presentations at schools and other institutions following the GTCP survey period at Gnaraloo, Skype lessons with schools around the world, media articles, social media content and data sharing on various national and international databases. All educational activities and presentations by the GTCP are provided free of charge to participants.

9.2 Outcomes

9.2.1 Onsite educational activities

A total of 67 people participated in GTCP education and community engagement activities at Gnaraloo during 2015/16. This included a group with 13 students (ages 11 – 13) and 3 staff from the Gwoonwardu Bush Rangers in Carnarvon, who participated in both Day and Night Surveys. The remaining 51 participants comprised guests who travelled to Gnaraloo for various recreational activities (e.g. wind surfing, fishing, surfing), some who came specifically to participate in the GTCP, and groups of professional biologists and/or managers (e.g. DPaW). These guests included individuals from ten different countries[26], the majority (44) being Australian, aged between 11 and 57 (**Figure 24**). Of all the non-school-student visitors who participated in GTCP activities, 5 participated in Day Surveys, 36 participated in Night Surveys, and 10 participated in both.

[26] Australia, Canada, England, France, Germany, Ireland, Japan, Switzerland, United Kingdom, United States of America.

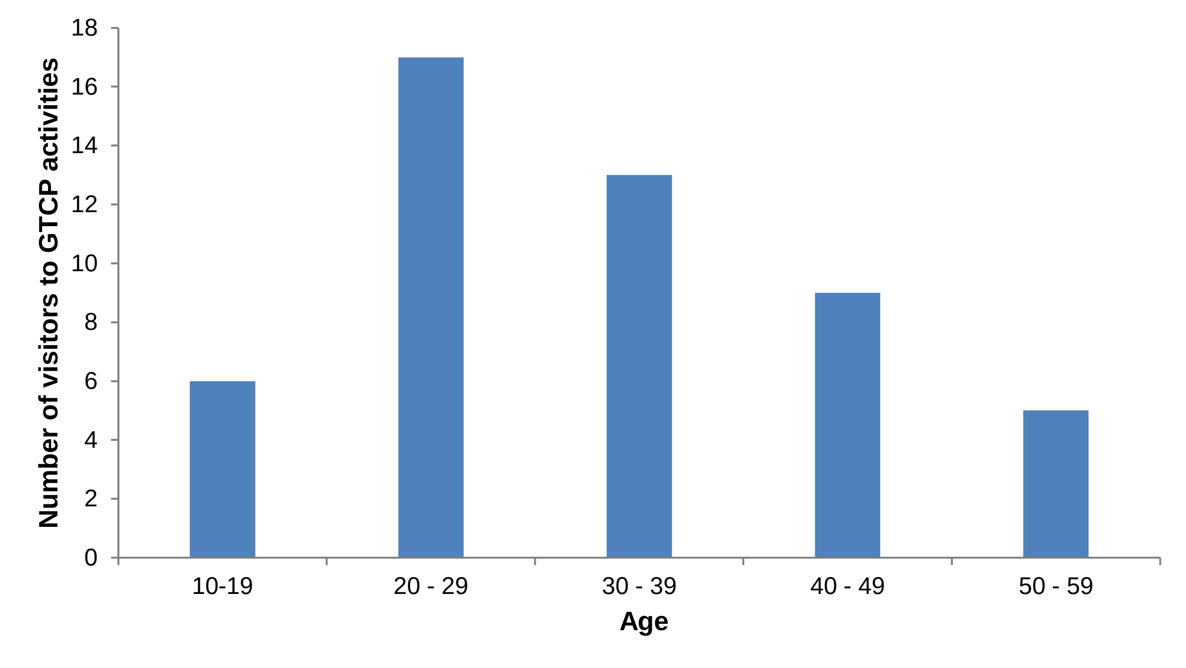

Figure 24: Ages of visitors who participated in onsite GTCP educational activities during 2015/16 (01/11/2015 – 28/02/2016)

9.2.2 Off-site educational activities

Off-site presentations during 1 March – 31 May 2016 by the GTCP Field Research Team directly reached 3,104 students and 174 teachers at 44 primary and high schools in communities in WA including Carnarvon, Geraldton, Dongara, Bullsbrook, Harvey, Australind, Bunbury, Dardanup and Perth. This included 2,005 high school students and 1,099 primary school students.

The GTCP Field Research Team also gave presentations at 2 post-secondary institutions consisting of students aged 16 – 59 years. These included the Batavia Coast Maritime Institute / Durack Institute of Technology, Geraldton, WA (2 presentations, 35 attendees), Murdoch University, Perth, WA (1 presentation, 10 attendees) and Edith Cowan University, Perth, WA (1 presentation, 18 attendees).

The GTCP Field Monitoring Team 2015/16 participated in the SciTech Science Festival in Geraldton during 30 – 31 March 2016. The festival was attended by an estimated 981 local students; 157 of which participated via the GTCP stall in its questionnaire about satellite tracking.

During 2015/16, the GTCP established a profile on *Skype in the Classroom* (Microsoft) (https://education.microsoft.com/gnaraloo) to be able to consistently reach out via free lessons to primary and high schools located elsewhere in Australia and around the world. As of 30 May 2016, the GTCP hosted 7 Skype lessons, including to classes in the United States of America (3 classes with total 124 students and 7 teachers), Spain (50 students, 2 teachers), India (2 classes with total 75 students and 5 teachers) and Egypt (10 students, 1 teacher). Accessibility to the GTCP and its educational presentations via *Skype in the Classroom* will be expanded in future seasons to enhance the reach of the program and continue to increase awareness of sea turtle biology and conservation.

the GTCP also used the platform YouTube to reach out to schools, including to Furze Platt Junior School (6 students, 1 teacher) in the United Kingdom.

9.3 Supplementary activities by the Gnaraloo Wilderness Foundation

The newly created Gnaraloo Wilderness Foundation supported the educational and outreach activities of the GTCP during 2015/16. It developed and released a free Turtle Tracker App for smartphones to invite participation with and to communicate the results of the GTCP's turtle satellite tagging project 2015/16. It also initiated a fund raiser competition to name the 10 associated loggerhead turtles. It developed and used a variety of communication and educational tools to engage the community such as brochures, a clothing range, stickers, posters, magnets and turtle colour-in pages for younger students. It also offered a National Environmental Science and Geography Challenge for primary and high schools in Australia, which was aligned with the national schools' curricula for years 5 – 9 in the Science, Technology, Engineering and Mathematics (**STEM**) field, to develop a management plan for Gnaraloo Bay. Competition entries close on 30 June 2016 and the winners will be announced during 2016/17.

9.4 Media-based activities

The GTCP was featured in 24 media articles (print and online) in WA, Australia and internationally during 2015/16, with 11 of these contributed by GTCP authors. These ranged from local and online newspapers; turtle, scientific, environmental and general interest websites; online science and news blogs; online encyclopaedia; magazines; newsletters and journals. The GTCP Project Manager, GTCP Field Research Team and the Gnaraloo leaseholder also participated in various radio and television interviews.

The GTCP maintains an active Facebook page[27] that is updated regularly throughout the season

27 https://www.facebook.com/gnaralooturtleconservationprogram

and, as of 31 May 2016, has over 2,770 followers. GTCP Facebook entries are most often written as ‘Field diaries’, but also include other regular Facebook features such as the “Gnaraloo Bay Rookery - Turtle Nest Counter” which is updated on a weekly basis throughout the monitoring period and the “Gnaraloo Wildlife Spotlight” series which highlights Gnaraloo’s unique fauna and flora. The GTCP also shares information via Instagram, Twitter and YouTube.

Approximately 4,386 GTCP educational flyers, 3,295 GTCP stickers, 54 GTCP posters and 703 GTCP colour-in pages (as at 30 April 2016) were distributed in WA.

9.5 Data sharing

The GTCP shares its data and program information with the scientific and conservation community (local, national and international) via several online repositories.

These include:

- Fauna Survey Database (DPaW, WA)[28];
- CSIRO Coastal Research Web Portal[29];
- Terrestrial Ecosystem Research Network[30];
- Australian National Conservation Values Atlas (Department of Environment, Australian Government)[31];
- Species Profile and Threats Database (Department of Environment, Australian Government)[32];
- www.seaturtle.org (International);
- State of the World’s Sea Turtles (International)[33];
- Indian Ocean-South East Asian Turtle Memorandum of Understanding (International)[34].

28 https://secure.dec.wa.gov.au/apex/pls/fauna/f?p=faunasurveypublic
29 http://coastalresearch.csiro.au/?q=node/72
30 http://www.tern.org.au/
31 https://www.environment.gov.au/topics/marine/marine-bioregional-plans/conservation-values-atlas
32 http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1763
33 http://www.seaturtlestatus.org/
34 http://www.ioseaturtles.org/

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 tide, storm 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 (1 November – 28 February) during which beach monitoring surveys are conducted each year.
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; for seasons 2014/15 and 2015/16, this was specifically between GRS and GLN (inclusive of sub-section GFR).
GTCP season	Refers to the standard GTCP monitoring time period from 1 November each year to 28 February the following year.
Hatching success	Completion of incubation and hatching of turtle eggs; under 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.

Nest detection bias	The likelihood of correctly identifying Nests during Day Surveys, via comparison of Day Survey data with independent, direct observations of nesting activities during Night Surveys.
Nesting activity	Any track or nesting attempt (i.e. Nest, Unsuccessful Nesting Attempt, U Track or Unidentified nesting activity).
Nesting phase	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	Nighttime visual monitoring of turtle nesting activity in the GBR.
P	Significance statistic calculated in linear regression and other statistical models.
Phenology	The study of cyclic and seasonal natural phenomena, especially in relation to climate and 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) and environmental events on the hatching success of Nests.
Sub-section	Sectors that the surveyed rookeries (GBR and GCFR Survey Areas) are divided into for easier data management.
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)
DPaW	Department of Parks and Wildlife, Western Australia
ECF	Estimated clutch frequency
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
ETS	Erosion by tides or storms
GBN	Gnaraloo Bay North (-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 (-23.622023º S; 113.634134º E)
GFN	Gnaraloo Farquhar North (-23.57697º S; 113.69830º E)
GFS	Gnaraloo Farquhar South (-23.64168º S; 113.61544º E)
GFR	Gnaraloo Farquhar Runway (-23.59641º S; 113.66083º E)
GLN	Gnaraloo Lagoon North (-23.57697º S; 113.69828º E)
GPS	Global Positioning System
GRS	Gnaraloo Runway South (-23.61336º S; 113.64379º E)
GTCP	Gnaraloo Turtle Conservation Program
GTCP Field Research Team	GTCP Program Assistant and Interns
IOSEA	Indian Ocean South-East Asian
ITS	Inundation by tides or storms

IUCN	International Union for the Conservation of Nature
MERI	Monitoring, Evaluation, Reporting and Improvement
MNES	Matters of National Environmental Significance (EPBC Act)
NAD	Nesting Activity Determination
NMP	Ningaloo Marine Park
NTP	Ningaloo Turtle Program, Exmouth, Western Australia
RMU	Regional Management Unit
SD	Standard Deviation
SE	Standard Error
SI	Species Identification
SST	Sea surface temperature
STEM	An acronym that refers to the academic disciplines of science, technology, engineering and mathematics
Ua	Unidentified nesting activity
UNA	Unsuccessful Nesting Attempt
UT	U Track
WA	Western Australia

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APPENDICES

APPENDIX A: MAPS

1. Sea turtle rookeries and marine sanctuary zones at Gnaraloo, GTCP 2015/16
2. Gnaraloo Bay Rookery, Survey Area, GTCP 2015/16
3. Gnaraloo Bay Rookery, Distribution of loggerhead nesting activities (01/11/15 – 28/02/16), GTCP 2015/16
4. Gnaraloo Bay Rookery, Density of loggerhead nesting activities (01/11/15 – 28/02/16), GTCP 2015/16
5. Gnaraloo Bay Rookery, Distribution of loggerhead Nests (01/11/15 – 28/02/16), GTCP 2015/16
6. Gnaraloo Bay Rookery, Density of loggerhead Nests (01/11/15 – 28/02/16), GTCP 2015/16
7. Gnaraloo Bay Rookery, Location of Sampled Nests (01/11/15 – 28/02/16), GTCP 2015/16
8. Gnaraloo Cape Farquhar Rookery, Survey Area, GTCP 2015/16
9. Gnaraloo Cape Farquhar Rookery, Distribution of loggerhead nesting activities (27/12/15 – 09/01/16), GTCP 2015/16
10. Gnaraloo Cape Farquhar Rookery, Density of loggerhead nesting activities (27/12/15 – 09/01/16), GTCP 2015/16
11. Gnaraloo Cape Farquhar Rookery, Distribution of loggerhead Nests (27/12/15 – 09/01/16), GTCP 2015/16
12. Gnaraloo Cape Farquhar Rookery, Density of loggerhead Nests (27/12/15 – 09/01/16), GTCP 2015/16

APPENDIX B: WEATHER DATA

Table 10: Daily weather summary in the GBR Survey Area, November 2015

DATE	TEMPERATURE (°C)					RAIN (mm)	WIND SPEED & DIRECTION (km/h)			
	MEAN	HIGH	TIME	LOW	TIME		MEAN	HIGH	TIME	DIRECTION
01/11/2015	23.9	29	12:00:00	20.9	07:00:00	0.0	15.1	41.8	18:00:00	S
02/11/2015	22.4	24.9	11:00:00	19.7	23:00:00	0.0	21.3	53.1	15:00:00	SSW
03/11/2015	22.2	29.7	14:00:00	17.8	07:00:00	0.0	18.6	49.9	16:00:00	SSE
04/11/2015	22.7	29.9	13:00:00	18.8	06:00:00	0.0	16.3	46.7	17:00:00	S
05/11/2015	22.0	24.1	11:00:00	19.7	07:00:00	0.0	13.3	30.6	19:00:00	W
06/11/2015	20.3	22.4	16:00:00	15.8	04:00:00	2.8	22.2	66	03:00:00	WSW
07/11/2015	20.5	24.2	17:00:00	15.6	07:00:00	0.0	15.3	45.1	17:00:00	S
08/11/2015	21.9	28.7	14:00:00	17.7	05:00:00	0.0	20.5	57.9	16:00:00	SSW
09/11/2015	24.0	33.4	14:00:00	19.2	07:00:00	0.0	20.5	51.5	16:00:00	S
10/11/2015	28.2	39.4	15:00:00	21.4	07:00:00	0.0	18.8	45.1	17:00:00	SSE
11/11/2015	28.1	40.9	13:00:00	23.9	07:00:00	0.0	16.2	37	01:00:00	SSE
12/11/2015	24.7	27.5	15:00:00	22.5	07:00:00	0.0	7.5	17.7	19:00:00	SW
13/11/2015	24.2	25.7	16:00:00	23.1	05:00:00	0.0	12.6	25.7	23:00:00	WNW
14/11/2015	23.9	25.1	16:00:00	22.9	04:00:00	0.2	16.2	33.8	16:00:00	WNW
15/11/2015	23.4	26.6	15:00:00	19.9	05:00:00	0.0	15.4	43.5	18:00:00	WSW
16/11/2015	23.0	25.4	16:00:00	19.6	04:00:00	0.0	13.1	33.8	21:00:00	W
17/11/2015	23.7	26.3	16:00:00	20.8	06:00:00	0.0	16.6	40.2	17:00:00	SW
18/11/2015	24.4	29.6	15:00:00	20.9	23:00:00	0.0	18.7	48.3	17:00:00	SSW
19/11/2015	23.7	31.6	16:00:00	18.1	07:00:00	0.0	22.4	45.1	09:00:00	S
20/11/2015	24.6	34.5	13:00:00	18.3	07:00:00	0.0	20.2	41.8	09:00:00	SW
21/11/2015	26.2	31.6	21:00:00	19.9	07:00:00	0.0	13.8	37	15:00:00	SSW
22/11/2015	29.7	41.7	14:00:00	23.9	06:00:00	0.0	17.4	43.5	15:00:00	S
23/11/2015	27.5	36.3	12:00:00	23.8	23:00:00	0.0	16.8	46.7	16:00:00	SW
24/11/2015	26.1	35	15:00:00	22.5	06:00:00	0.0	18.0	48.3	16:00:00	SW
25/11/2015	23.4	30.2	13:00:00	20.2	07:00:00	0.0	17.8	41.8	16:00:00	SW
26/11/2015	22.0	24.7	16:00:00	18.8	07:00:00	0.0	13.2	35.4	18:00:00	W
27/11/2015	22.3	25.3	17:00:00	18.2	07:00:00	0.0	12.9	37	19:00:00	SSW
28/11/2015	23.1	28.6	12:00:00	19.3	07:00:00	0.0	16.4	43.5	15:00:00	SSW
29/11/2015	22.7	27.7	12:00:00	18.3	07:00:00	0.0	18.6	51.5	15:00:00	SSW
30/11/2015	22.5	29.1	13:00:00	18.9	04:00:00	0.0	22.5	57.9	17:00:00	SSW

Table 11: Daily weather summary in the GBR Survey Area, December 2015

DATE	TEMPERATURE (°C)					RAIN (mm)	WIND SPEED & DIRECTION (km/h)			
	MEAN	HIGH	TIME	LOW	TIME		MEAN	HIGH	TIME	DIRECTION
01/12/2015	23.7	33.3	12:00:00	18.4	07:00:00	0.0	16.0	41.8	16:00:00	SSW
02/12/2015	23.7	25.4	14:00:00	21.2	03:00:00	0.0	13.1	29	16:00:00	NW
03/12/2015	23.7	25.4	14:00:00	22.2	23:00:00	0.0	16.1	30.6	15:00:00	W
04/12/2015	22.9	24.9	10:00:00	21.4	06:00:00	0.0	18.2	41.8	15:00:00	SW
05/12/2015	21.9	25.8	11:00:00	18.8	05:00:00	0.0	20.7	54.7	17:00:00	SSW
06/12/2015	21.6	29.2	16:00:00	16.4	07:00:00	0.0	18.2	57.9	06:00:00	S
07/12/2015	23.2	30.8	14:00:00	18.3	07:00:00	0.0	19.9	49.9	16:00:00	S
08/12/2015	24.6	33.4	13:00:00	19.4	07:00:00	0.0	17.3	43.5	14:00:00	S
09/12/2015	24.5	34.3	14:00:00	19.2	03:00:00	0.0	17.4	43.5	17:00:00	SSW
10/12/2015	24.0	32.7	13:00:00	19.8	05:00:00	0.0	17.8	46.7	18:00:00	SSW
11/12/2015	23.5	30.5	12:00:00	19.1	04:00:00	0.0	16.0	41.8	15:00:00	SSW
12/12/2015	24.0	30.3	11:00:00	20.1	07:00:00	0.0	17.3	43.5	15:00:00	SSW
13/12/2015	23.7	31.3	13:00:00	19.7	06:00:00	0.0	19.1	49.9	16:00:00	SSW
14/12/2015	24.8	34.1	14:00:00	19.8	06:00:00	0.0	18.1	45.1	15:00:00	SSW
15/12/2015	25.1	33.9	13:00:00	20.6	07:00:00	0.0	19.6	41.8	18:00:00	S
16/12/2015	23.9	32.5	15:00:00	19.6	05:00:00	0.0	19.1	48.3	16:00:00	SSW
17/12/2015	23.0	29.7	13:00:00	19.3	07:00:00	0.0	21.7	54.7	16:00:00	SSW
18/12/2015	22.7	26	18:00:00	19.7	06:00:00	0.0	24.1	54.7	16:00:00	SSW
19/12/2015	22.8	30.6	15:00:00	18.6	07:00:00	0.0	23.5	59.5	17:00:00	SSW
20/12/2015	22.1	28.2	12:00:00	18.4	07:00:00	0.0	21.2	48.3	14:00:00	SSW
21/12/2015	22.3	24.5	13:00:00	19.8	03:00:00	0.0	22.5	49.9	17:00:00	SW
22/12/2015	22.6	24.3	13:00:00	20.8	02:00:00	0.0	18.8	37	13:00:00	SW
23/12/2015	23.2	25.4	16:00:00	21.5	03:00:00	0.0	14.3	29	00:00:00	W
24/12/2015	23.2	24.9	17:00:00	22	23:00:00	0.0	18.4	40.2	19:00:00	WSW
25/12/2015	24.0	31.9	14:00:00	20.8	07:00:00	0.0	21.8	49.9	16:00:00	SW
26/12/2015	22.8	25.3	10:00:00	20.3	05:00:00	0.0	17.5	40.2	17:00:00	WSW
27/12/2015	23.4	25.6	16:00:00	21.2	06:00:00	0.0	10.7	25.7	20:00:00	W
28/12/2015	23.7	25.8	11:00:00	21.8	06:00:00	0.0	15.0	35.4	17:00:00	WSW
29/12/2015	23.7	25.2	13:00:00	22.5	23:00:00	0.0	15.4	29	17:00:00	WSW
30/12/2015	23.3	25.3	13:00:00	21.9	01:00:00	0.0	12.1	25.7	20:00:00	WSW
31/12/2015	23.4	25.2	15:00:00	21.8	00:00:00	0.0	13.0	27.4	04:00:00	W

Table 12: Daily weather summary in the GBR Survey Area, January 2016

DATE	TEMPERATURE (°C)					RAIN (mm)	WIND SPEED & DIRECTION (km/h)			
	MEAN	HIGH	TIME	LOW	TIME		MEAN	HIGH	TIME	DIRECTION
01/01/2016	24.2	26.7	14:00:00	22.3	04:00:00	0.0	8.3	20.9	00:00:00	W
02/01/2016	23.9	26	14:00:00	21.7	23:00:00	0.0	11.7	25.7	07:00:00	W
03/01/2016	23.4	26.3	14:00:00	20.1	17:00:00	0.0	5.4	24.1	16:00:00	W
04/01/2016	23.7	26.4	13:00:00	21	04:00:00	0.0	8.3	29	16:00:00	WSW
05/01/2016	23.2	25.6	14:00:00	21.1	05:00:00	0.0	12.9	38.6	18:00:00	SW
06/01/2016	22.9	26.4	11:00:00	20	04:00:00	0.0	14.2	45.1	18:00:00	SSW
07/01/2016	23.2	25.1	15:00:00	20.4	01:00:00	0.0	13.6	38.6	15:00:00	WSW
08/01/2016	23.6	26.2	14:00:00	21.1	06:00:00	0.0	11.9	41.8	15:00:00	SW
09/01/2016	22.9	25.3	16:00:00	20	06:00:00	0.0	11.9	38.6	16:00:00	SSW
10/01/2016	23.5	25.6	15:00:00	20.8	05:00:00	0.0	10.8	33.8	18:00:00	W
11/01/2016	23.3	25.9	15:00:00	20.9	06:00:00	0.0	13.7	40.2	15:00:00	SSW
12/01/2016	23.4	26.5	15:00:00	20.2	04:00:00	0.0	15.6	48.3	17:00:00	SSW
13/01/2016	25.1	31.1	11:00:00	22.4	03:00:00	0.0	11.7	43.5	18:00:00	SSW
14/01/2016	23.7	25.7	16:00:00	21.1	06:00:00	0.2	7.7	29	14:00:00	SSW
15/01/2016	25.9	33.4	10:00:00	21.2	05:00:00	0.0	10.0	46.7	18:00:00	SW
16/01/2016	26.9	34.3	10:00:00	23.1	03:00:00	0.0	9.0	40.2	17:00:00	SW
17/01/2016	26.0	29	13:00:00	23.6	23:00:00	0.0	8.7	40.2	17:00:00	WSW
18/01/2016	23.6	26	15:00:00	21	23:00:00	0.0	16.0	46.7	17:00:00	SW
19/01/2016	22.0	24	14:00:00	18.9	07:00:00	0.0	15.3	38.6	17:00:00	WSW
20/01/2016	22.5	24.6	14:00:00	20.3	06:00:00	0.2	12.7	30.6	09:00:00	SW
21/01/2016	22.8	25.4	10:00:00	20.4	07:00:00	0.0	12.0	35.4	18:00:00	SSW
22/01/2016	23.9	27.8	10:00:00	20.1	06:00:00	0.0	13.2	46.7	17:00:00	SSW
23/01/2016	24.1	27.1	13:00:00	21.6	03:00:00	0.0	15.4	45.1	15:00:00	SSW
24/01/2016	24.1	27.6	15:00:00	22.3	03:00:00	0.0	12.1	41.8	16:00:00	SSW
25/01/2016	23.7	26.9	10:00:00	22.6	23:00:00	0.2	2.3	25.7	11:00:00	SW
26/01/2016	24.0	27.1	16:00:00	21.6	05:00:00	0.0	11.1	38.6	16:00:00	SW
27/01/2016	24.5	29.4	11:00:00	20.7	05:00:00	0.0	11.5	41.8	16:00:00	SSW
28/01/2016	24.9	27.1	16:00:00	23	06:00:00	0.0	12.0	38.6	16:00:00	WSW
29/01/2016	24.9	26.6	12:00:00	23.7	06:00:00	0.0	10.5	37	18:00:00	WSW
30/01/2016	24.4	25.9	16:00:00	23.1	06:00:00	0.0	14.8	37	14:00:00	WSW
31/01/2016	23.9	26.7	16:00:00	20.6	06:00:00	0.0	13.1	43.5	19:00:00	SSW

Table 13: Daily weather summary in the GBR Survey Area, February 2016

DATE	TEMPERATURE (°C)					RAIN (mm)	WIND SPEED & DIRECTION (km/h)			
	MEAN	HIGH	TIME	LOW	TIME		MEAN	HIGH	TIME	DIRECTION
01/02/2016	23.9	28.1	13:00:00	21.7	07:00:00	0.0	23.1	53.1	14:00:00	SSW
02/02/2016	24.8	33.3	14:00:00	18.9	07:00:00	0.0	20.7	48.3	16:00:00	SSE
03/02/2016	28.9	36.8	12:00:00	22.8	06:00:00	0.0	16.2	38.6	18:00:00	SSE
04/02/2016	28.9	35.9	11:00:00	23.8	22:00:00	0.0	11.7	37	09:00:00	SE
05/02/2016	28.6	37.1	11:00:00	21.6	06:00:00	0.0	11.2	40.2	18:00:00	SSW
06/02/2016	30.4	42.3	12:00:00	21.8	06:00:00	0.0	14.6	46.7	22:00:00	SSW
07/02/2016	29.5	39.8	11:00:00	24.4	23:00:00	0.0	13.7	38.6	01:00:00	SE
08/02/2016	26.0	29.3	14:00:00	21.8	04:00:00	0.0	5.1	29	19:00:00	SW
09/02/2016	27.9	33.1	19:00:00	22.6	07:00:00	0.0	7.0	30.6	18:00:00	W
10/02/2016	29.0	39.3	11:00:00	24.1	23:00:00	0.0	12.9	35.4	17:00:00	SW
11/02/2016	26.8	33.6	10:00:00	22.7	07:00:00	0.0	11.5	37	18:00:00	SW
12/02/2016	29.2	39.3	13:00:00	22.5	03:00:00	0.0	14.3	40.2	19:00:00	S
13/02/2016	29.5	39	15:00:00	25.5	07:00:00	0.0	22.1	51.5	06:00:00	S
14/02/2016	27.3	35.8	17:00:00	22.7	07:00:00	0.0	12.7	37	15:00:00	WSW
15/02/2016	25.6	28.2	13:00:00	23.1	05:00:00	0.0	5.3	17.7	03:00:00	NW
16/02/2016	25.8	28.4	12:00:00	23.9	01:00:00	0.0	8.2	30.6	19:00:00	NNW
17/02/2016	25.9	28.3	12:00:00	23.5	06:00:00	0.2	13.2	43.5	18:00:00	SW
18/02/2016	29.4	40.8	14:00:00	24.1	23:00:00	0.0	17.6	41.8	16:00:00	SSW
19/02/2016	26.9	34.7	13:00:00	23.4	02:00:00	0.0	15.2	41.8	20:00:00	SSW
20/02/2016	25.1	32.3	13:00:00	23.1	22:00:00	0.6	8.2	30.6	16:00:00	SSW
21/02/2016	24.4	27.3	16:00:00	21.7	07:00:00	0.0	12.9	38.6	18:00:00	SSW
22/02/2016	24.8	29.9	11:00:00	21.7	07:00:00	0.0	15.6	43.5	17:00:00	S
23/02/2016	24.1	28.7	11:00:00	21.6	07:00:00	0.0	19.6	51.5	16:00:00	SSW
24/02/2016	23.7	29.8	13:00:00	20.2	06:00:00	0.0	18.6	51.5	16:00:00	SSW
25/02/2016	22.9	27.9	11:00:00	18.6	07:00:00	0.0	12.5	29	08:00:00	WSW
26/02/2016	24.4	26.3	16:00:00	22.4	00:00:00	0.0	7.5	22.5	22:00:00	W
27/02/2016	24.3	26.6	16:00:00	21.6	05:00:00	0.0	11.7	35.4	16:00:00	SW
28/02/2016	25.4	30.8	11:00:00	21.7	07:00:00	0.0	13.1	43.5	15:00:00	SSW

Table 14: Daily weather summary in the GCFR Survey Area, December 2015 – January 2016

DATE	TEMPERATURE (°C)					RAIN (mm)	WIND SPEED & DIRECTION (km/h)			
	MEAN	HIGH	TIME	LOW	TIME		MEAN	MAX	TIME	DIRECTION
27/12/2015	23.55	25.5	14:00:00	21.2	5:00:00	0	14.81	32.2	18:00:00	WSW
28/12/2015	23.94	26.1	17:00:00	21.7	6:00:00	0	19.66	38.6	15:00:00	WSW
29/12/2015	24.05	25.8	14:00:00	22.7	23:00:00	0	20.58	37	17:00:00	WSW
30/12/2015	23.53	25.4	15:00:00	22	6:00:00	0	15.55	29	16:00:00	WSW
31/12/2015	23.47	24.8	13:00:00	21.9	0:00:00	0	17.23	29	4:00:00	W
01/01/2016	24.05	26.5	15:00:00	21.2	6:00:00	0	10.93	25.7	2:00:00	W
02/01/2016	24.00	25.9	16:00:00	21.9	23:00:00	0	15.68	29	3:00:00	W
03/01/2016	23.46	26	13:00:00	20.3	3:00:00	0	10.46	29	19:00:00	W
04/01/2016	23.90	26.8	16:00:00	21.1	2:00:00	0	13.33	33.8	17:00:00	WSW
05/01/2016	23.71	27	16:00:00	21.2	5:00:00	0	15.20	40.2	18:00:00	SSW
06/01/2016	23.42	28.4	11:00:00	19.8	4:00:00	0	15.35	45.1	17:00:00	SW
07/01/2016	23.56	26.8	15:00:00	20.6	1:00:00	0	17.50	40.2	13:00:00	WSW
08/01/2016	23.96	27.4	14:00:00	21.2	6:00:00	0	17.37	43.5	17:00:00	WSW
09/01/2016	23.44	26.8	15:00:00	19.8	5:00:00	0	15.75	41.8	17:00:00	SW

APPENDIX C: PHOTO PLATES

1. **View northwards of BP8 in the GBR Survey Area, GTCP 2015/16**
2. **View northwards of Gnaraloo Runway South (GRS) in the GCFR Survey Area, GTCP 2015/16**
3. **Pair of mating loggerhead (Caretta caretta) turtles in the GBR Survey Area, GTCP 2015/16**
4. **Field researchers identifying and recording a new loggerhead Nest in the GBR Survey Area, GTCP 2015/16**
5. **Field researchers on Day survey with the Gwoonwardu Bushrangers in the GBR Survey Area, GTCP 2015/16**
6. **Field researcher presenting to primary school students at Carnarvon Christian School, WA, GTCP 2015/16**
7. **Playing 'The Hatchling Game' at Djidi Djidi Aboriginal School in Bunbury, WA, GTCP 2015/16**
8. **Field researcher presenting to students at Bunbury Senior High School, WA, GTCP 2015/16**
9. **Field researcher interacting with students at SciTech Science Festival in Geraldton, WA, GTCP 2015/16**
10. **Field researchers answering questions from Furze Platt Junior School in the United Kingdom via YouTube, GTCP 2015/16**

Photo 1: View northwards of BP8 in the GBR Survey Area, GTCP 2015/16

Photo 2: View northwards of Gnaraloo Runway South (GRS) in the GCFR Survey Area, GTCP 2015/16

Photo 3: Pair of mating loggerhead (*Caretta caretta*) turtles in the GBR Survey Area, GTCP 2015/16

Photo 4: Field researchers identifying and recording a new loggerhead Nest in the GBR Survey Area, GTCP 2015/16

Photo 5: Field researchers on Day survey with the Gwoonwardu Bushrangers in the GBR Survey Area, GTCP 2015/16

Photo 6: Field researcher presenting to primary school students at Carnarvon Christian School, WA, GTCP 2015/16

Photo 7: Playing 'The Hatchling Game' at Djidi Djidi Aboriginal School in Bunbury, WA, GTCP 2015/16

Photo 8: Field researcher presenting to students at Bunbury Senior High School, WA, GTCP 2015/16

Photo 9: Field researcher interacting with students at SciTech Science Festival in Geraldton, WA, GTCP 2015/16

Photo 10: Field researchers answering questions from Furze Platt Junior School in the United Kingdom via YouTube, GTCP 2015/16