Sea Turtle Conservation Research
Diego Garcia, British Indian Ocean Territory
25 June – 18 July 2018

Expedition Report

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July 2018

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Acknowledgements

We would like to thank Ernesto and Kirsty Bertarelli, and the Bertarelli Foundation, for their support of this research. We acknowledge and thank the British Indian Ocean Territory (BIOT) Administration for assistance and permission to carry out this expedition in Diego Garcia. We are grateful for the thorough logistical assistance provided by the Headquarters British Forces, BIOT and BIOT Administration in London. We thank the British Representative, Executive Officer, Logistics Officer and Environmental Officer for their excellent support of our scientific activities. Many thanks to the Natural and Cultural Resources Program Manager, NAVFACFE PWD Environmental. Finally, we wish to express our gratitude to the 122 volunteers from British Forces, US Navy, US Air Force and US and Philippine Contractors who assisted us during day and night patrols on the beach, and with daytime turtle monitoring studies at Turtle Cove that involve mark-recapture of immature foraging turtles.

How to cite this report:

Esteban N, Mortimer JA, Hays GC (2018). *Sea Turtle Conservation Research Diego Garcia, BIOT. 25 June – 18 July 2018.* Expedition Report to the Foreign and Commonwealth Office.

Contents

1. Executive summary

This scientific expedition to Diego Garcia, British Indian Ocean Territory (BIOT) from 25 June to 18 July 2018 builds on previous conservation research on the ecology of hawksbill and green turtles in the archipelago. The primary objectives were to increase understanding of breeding green turtle movements within and outside of BIOT, to expand existing knowledge of the immature turtle population within the Diego Garcia lagoon, to update nesting population data via an island-wide beach survey and to continue monitoring of incubation conditions in BIOT.

1. A presentation on sea turtle conservation research in BIOT took place to a packed audience of about 100 military and civilian residents of Diego Garcia. Volunteers signed up for day- and night-time patrols to assist the science team with surveys of sea turtles.

2. Patrols of a 4 km beach section in south east Diego Garcia to survey nesting activities were carried out between sunset and sunrise for 9 consecutive nights. Scientists were assisted by 49 volunteers from all sectors of the community. Fastloc-GPS-Argos satellite tags were attached to 12 nesting green turtles bringing the total sample size of tracked turtles by the team from Diego Garcia to 35 nesting green turtles.

3. The long-term mark-recapture study of immature foraging turtles in Turtle Cove (commenced in 1996, and following on subsequent work conducted in 1999, 2006, and 2012) continued during the June-July 2018 visit. A total of 97 turtles (including 91 hawksbills and 6 green turtles) were tagged, measured, weighed and released back into the Cove. Of the 91 hawksbills, 23% had been tagged in previous years (some as early as 1996).

4. In order to study habitat use by immature turtles within the Diego Garcia lagoon, and whether individuals depart from BIOT to other distant sites, high resolution Fastloc-GPS-Argos satellite tags were used for the first time to assess their movements. During the expedition, 10 satellite tags were attached to eight hawksbill and two green turtles captured at Turtle Cove. Larger individuals (measuring over 50 cm curved carapace length) were selected for this study. The

science team were assisted by 69 volunteers during nine days of survey at Turtle Cove.

5. Temperature loggers were deployed at two sites on the Index Site at a range of turtle nesting depths and in shaded and unshaded beach zones. The data will be recovered in 18 months.

6. Monitoring surveys of sea turtle nesting activities on the Diego Garcia index beach and all along the 60 km outer coastline of Diego Garcia were conducted on 8 days and assisted by 13 volunteers. Survey data will provide an updated assessment of available nesting habitat, distribution of nesting activity along the perimeter of Diego Garcia, estimated green turtle and hawksbill nesting numbers and patterns of seasonality.

7. By the end of the expedition, initial satellite tracking locations showed that all of the nesting green turtles remained just offshore of the nesting beach with haulout locations indicating that individuals were returning to nest within the expected inter-nesting interval of approximately 12 days. The immature turtles remain close to Turtle Cove with some forays up the lagoon.

8. Ongoing sea turtle nesting surveys by the Natural and Cultural Resources Program Manager (on Diego Garcia) and by the Senior Fisheries Patrol Officer (SFPO) (on remote islands) were organised. Data files (six sites) were exchanged for the ongoing Baited Remote Underwater Video (BRUV) study conducted by the SFPO on the Great Chagos Bank.

9. Updates throughout the expedition were posted on Twitter (links to @BIOTscience) and on the Facebook site *Chagos Turtles.* Membership has reached almost 200 followers and updates of sea turtle locations will be posted in the forthcoming months.

2. Introduction and Methods

The primary research objective of this expedition to Diego Garcia was to increase understanding of sea turtle movements within and outside of the British Indian Ocean Territory (BIOT). Satellite tags were attached to nesting green turtles as well as immature hawksbill and green turtles in Diego Garcia lagoon. The long-term mark-recapture monitoring programme at Turtle Cove in the south of Diego Garcia lagoon was continued. Additional objectives were to conduct an island-wide survey of turtle nesting activities, to deploy temperature loggers recording sand temperature to monitor turtle nesting incubation conditions in different beach zones and to survey littoral vegetation associated with turtle nesting sites for validation of a littoral vegetation mapping study using remote sensing.

We commenced the expedition with a presentation about sea turtle research in BIOT. The talk was widely publicised via Facebook Group (*Chagos Turtles*), radio and all-personnel emails and we presented to a packed audience of around 100 military and civilian residents of Diego Garcia. A schedule for up to eight people per patrol was drawn up with over 100 people volunteering to assist on the planned day- and night-time surveys during the three week expedition. More volunteers signed up as the expedition progressed as some could not attend the talk and others learned about the opportunity when their ships called into port. All volunteers have to sign and acknowledge the approved Guidelines before assisting on surveys.

Figure 1. a) Expedition team (from Left: Nicole Esteban, Jeanne Mortimer, Graeme Hays, Antenor Guzman) on the first day of immature turtle surveys at Turtle Cove. b) Packed audience attend the sea turtle conservation research talk & volunteer sign-up at the start of the expedition.

2.1 Satellite tracking of nesting green turtles, Chelonia mydas

This expedition contributes to our programme to attach satellite tags to nesting green turtles so that we can continue to assess the extent of their post-nesting migration from Diego Garcia (Figure 2; Hays et al. 2014). At the same time, we will analyse location data at the breeding ground and foraging ground to learn more about space use of green turtles within and outside BIOT, building on previous studies of nesting locations at Diego Garcia (Esteban et al. 2017) and home range of foraging grounds in Great Chagos Bank and further afield (Christiansen et al. 2017). This includes the discovery of green turtle foraging grounds in BIOT, on the Great Chagos Bank (Esteban et al. 2018).

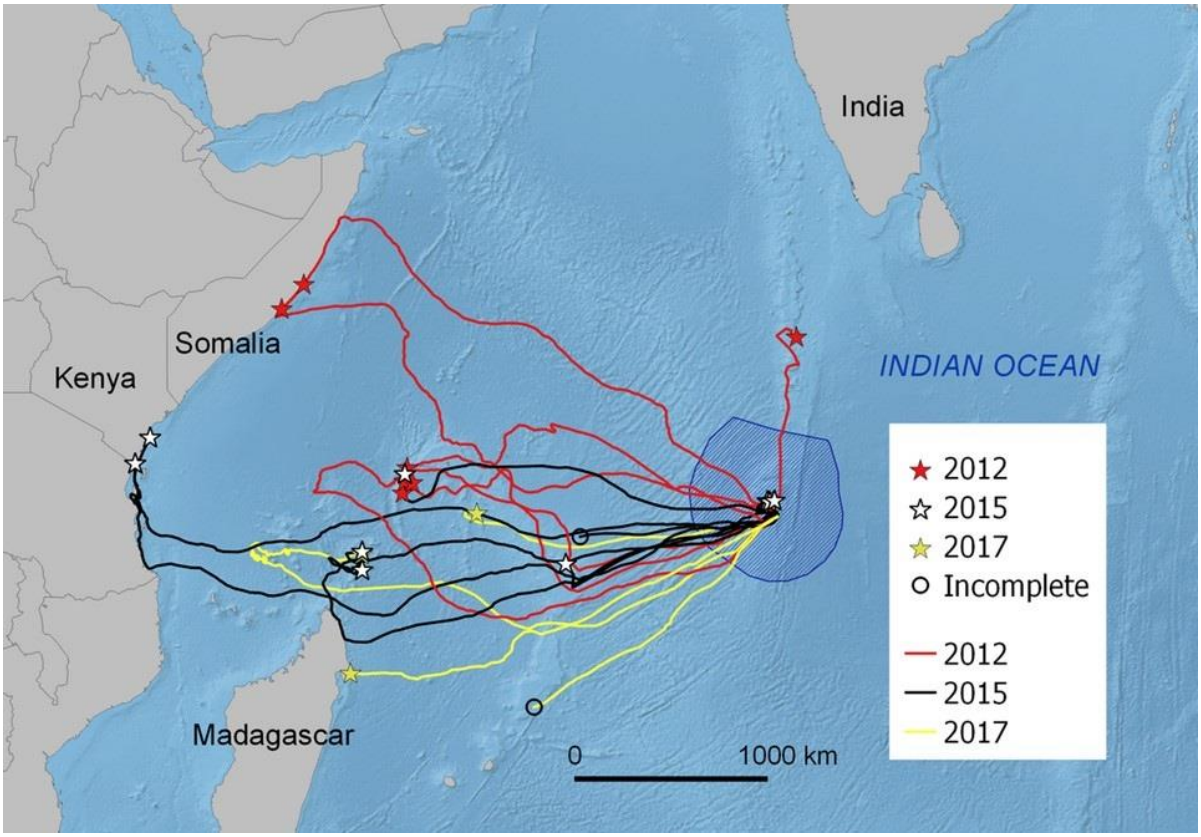

Figure 2. The tracks of 23 adult female green turtles equipped with satellite tags while ashore nesting on Diego Garcia. Stars show the foraging grounds which mark the end-point of migration. Circles show the end point for 2 tracks that ended prematurely in the open ocean

Prior to this expedition, we have attached satellite tags to 23 nesting green turtles. At the end of the nesting season these turtles have migrated to a broad array of sites. Four turtles have travelled to mainland Africa (> 4000 km away from Diego Garcia), 5 to the Great Chagos Bank (only 80 km distant), one to the Maldives, one to

Madagascar and the remainder to islands in the Seychelles or to remote submerged oceanic banks (Figure 2). These tracking data reveal not only the value of the Chagos Marine Protected Area (MPA), but also the importance of conservation measures in remote foraging grounds outside the Chagos MPA. We are using these data to inform conservation management of the species.

Figure 3. Volunteers assisting with a) observations during satellite tag attachment to nesting green turtles at night and b) observing sleeping turtle after the retaining box had been lifted.

We used methodologies previously tested and successful in Diego Garcia (the same satellite tag brand/product, identical attachment methodology), and attached Wildlife Computer Splash-10 Fastloc-GPS-Argos satellite tags to green turtles nesting on the beach. Similar to past expeditions (8-26 October 2012, 29 June-21 July 2015, 20 September-13 October 2017), we patrolled beaches in South East Diego Garcia (Figure 3) at night to locate nesting females. A wooden box was placed around each turtle (after nesting) to prevent return to the sea (Figure 3). The transmitter was then attached with quick-setting epoxy and covered with antifouling paint. Attachment of the tag takes approximately two hours to allow time for epoxy to set and paint to dry after which time the turtle is released. After release of the turtle, all location data are acquired via Fastloc-GPS location transmissions to the Argos satellite. Locations can be transmitted for 1-2 years.

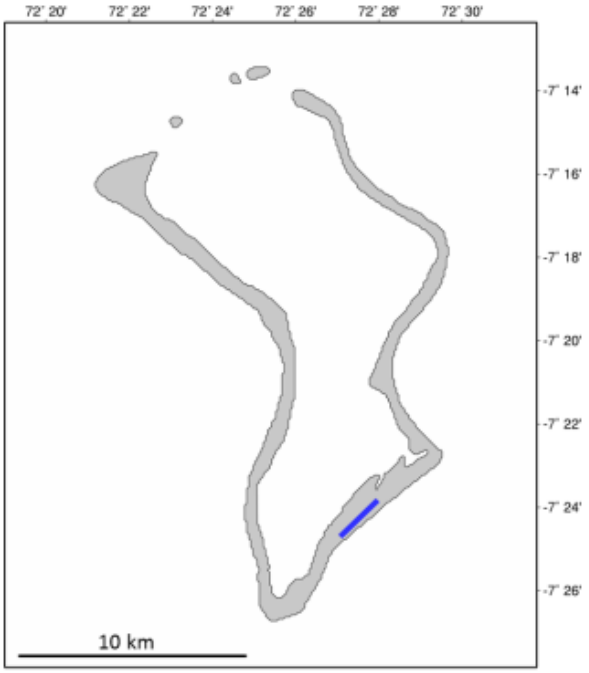

Figure 4. Location of Diego Garcia index beach (2.75 km) selected for satellite tag attachment due to relative high density of recorded turtle nesting track activities.

2.2 Continuation of long-term mark-recapture study of immature turtles in Turtle Cove

The mark-recapture study of immature turtles in Turtle Cove was initiated by J.A. Mortimer (JAM) during the Warwick Expedition to Chagos in February/March 1996 after Base personnel called attention to an aggregation of immature sea turtles that appeared to be resident in Turtle Cove. At the time, they were assumed to be green turtles, but most proved to be Critically Endangered hawksbill turtles. Over a five-day period, 42 immature hawksbills were captured in the shallow waters. Each was flipper tagged, using the standard methodology employed by sea turtle biologists all over the world during the past 75 years. A series of carapace and body measurements were taken, along with genetic samples. The turtles ranged in size from 4 to 34 kg (9 to 75 lbs) (Mortimer & Day 1999).

In February 1999, JAM returned to Turtle Cove and captured 41 turtles, 66% of which had been captured and tagged in 1996 (Mortimer 2000). This showed that many turtles are resident in Turtle Cove over long periods of time, and that growth rates of immature turtles could be studied there. Growth rate data enables us to estimate how long turtles take to reach adulthood. Preliminary data indicated that on average,

Turtle Cove hawksbills grew at a rate of 1.4 cm per year (Mortimer et al. 2002), which means that the turtles are likely taking 30-40 years to reach adulthood. This has important implications for management of their populations as it demonstrates how vulnerable they are to over-exploitation. JAM returned to continue the Turtle Cove mark-recapture study in 2006 (48 turtles captured) and in 2012 (72 turtles captured with the help of DG Base personnel).

The 2018 visit provides an opportunity to extend the study over a period of 22 years providing long-term perspective on the ecology of this interesting aggregation of immature turtles. The additional assistance provided by the Diego Garcia volunteers will enable us to catch and process more turtles and maximize our data collection.

Analysis of the genetic samples collected in Chagos showed that the hawksbill turtles of Chagos are closely related to those of Seychelles and other populations in the Western Indian Ocean but have no relationship to those of western Australia (Mortimer & Broderick 1999; Mortimer et al. 2002; Vargas et al. 2016). Additional genetic samples collected during the June-July 2018 visit will enhance our ability to discern genetic relationships between turtles foraging in Turtle Cove and the nesting populations from which they derive in the wider Indo-Pacific region.

Figure 5. Assistance was provided by 69 volunteers during nine days of mark-recapture study sampling of immature hawksbill and green turtles at Turtle Cove. a) Guidance and safety briefing to volunteer group and b) After a successful day of capturing, measuring, flipper tagging and satellite tag attachment.

2.3 Movements of immature turtles within Diego Garcia lagoon

The mark-recapture study of immature hawksbill and green turtles has increased our knowledge of the ecology of the aggregation of turtles at Turtle Cove (section 2.2). In order to study their habitat use within the Diego Garcia lagoon, and whether turtles depart from BIOT to other distant sites, we are using high resolution Fastloc GPS ARGOS satellite tracking to assess their movements. This expedition is the first stage of our programme to tag individuals of both species across different years and seasons to identify inter-annual and seasonal variation.

2.4 Island-wide survey of turtle nesting activities

Nesting beach surveys of the coastline of Diego Garcia enable us to assess what sections of the beach are most suitable for nesting turtles, the distribution of turtle nesting activity along the coastline, the population status of sea turtles nesting at Diego Garcia, and also the seasonality of nesting of each of the two species of sea turtle.

The entire coastline of Diego Garcia had been surveyed in January/February 1999 (Mortimer 2000). The recent visit in June/July 2018 enables the exercise to be repeated 19 years later and at a different time of the year (i.e., peak green turtle nesting season).

The survey involves walking along the beach with a GPS device and marking waypoints to indicate the locations of interesting features. The entire coastline is categorized according to availability of nesting habitat to nesting turtles. For example, steep erosion cliffs or lack of suitable sand substrate would preclude nesting. The location of any evidence of turtle digging above high tide line (body pits) or any tracks visible on the beach are recorded and described in terms of species and approximate age of the track.

A time-lapse photography trial was set up to assess whether turtle nesting tracks can be observed over long periods of time when foot patrols are not possible. Three camera traps were set up on beach heliotrope (*Tournefortia argentea*) trees at the edge of the vegetation zone on the Index Beach. Results will be assessed when camera traps are collected during the next expedition to inform future survey plans.

2.5 Assessment of sea turtle nesting incubation conditions

The sand temperature at nest depths is very important for developing sea turtle eggs as temperature determines whether eggs develop into male or female hatchlings, a phenomenon known as Temperature Dependent Sex Determination. Furthermore, incubation temperature also influences the survival of eggs. Our work monitoring the sand temperatures on Diego Garcia and other islands in the Chagos Archipelago has shown that the extensive vegetation behind beaches helps cool the sand at nest depths. Consequently both male and female hatchlings are produced in approximately equal numbers and temperatures are optimum for egg survival. We are continuing to monitor sand temperatures at nest depths to assess if these good conditions for incubation continue into the future.

2.6 Assessment of littoral vegetation associated with sea turtle sites

In collaboration with Kew Botanical Garden and Chagos Conservation Trust, we have received WorldView satellite images of Diego Garcia for an MSc remote sensing dissertation to assess the littoral vegetation adjacent to sea turtle nests on Diego Garcia.

During the expedition we conducted surveys of the plant species closest to recorded green turtle nests. We also carried out ground-truthing surveys of littoral vegetation to support remote sensing analysis by the MSc student and preparation of vegetation maps by Kew Botanical Gardens. We will continue surveys in forthcoming expeditions. The outputs of this study may inform future coastal revegetation policies.

3. Results and discussion

3.1 Satellite tracking of nesting green turtles, Chelonia mydas

We were assisted by 49 volunteers from all different sectors of the Diego Garcia community: UK military personnel, US Navy, US Air Force and contractors. Night time surveys of the index nesting beach in Diego Garcia (Figure 4; between the Plantation and Antenna field) were conducted on nine consecutive nights (see Appendix 1 for dates and volunteer names) covering a patrol distance of 4 km. During the nine nights, 12 nesting green turtles were tagged along this stretch of coastline (Table 1).

Table 1. Overview of nesting green turtles (*Chelonia mydas*) tagged with satellite transmitters during July 2018.

Argos ID	CCL	Date	Adult/ Immature	Species	Previous tag	Name
41086	102.2	1-2/07/18	Adult	Cm	N	Jenny Wren
41097	105.5	2-3/07/18	Adult	Cm	N	Big Liz
41100	110.7	3-4/07/18	Adult	Cm	N	Tracey
41102	109.0	4-5/07/18	Adult	Cm	N	Linda
41082	106.5	4-5/07/18	Adult	Cm	N	Barnie
52214	113.5	5-6/07/18	Adult	Cm	N	Caroline
52215	103.0	5-6/07/18	Adult	Cm	N	Sandy
52202	114.0	6-7/07/18	Adult	Cm	N	Norma
52221	108.0	7-8/07/18	Adult	Cm	N	Sneaky
52189	111.0	7-8/07/18	Adult	Cm	N	Tiki
52223	110.0	8-9/07/18	Adult	Cm	N	Ellie
52222	108.0	9-10/07/18	Adult	Cm	N	Midnight

By the end of the expedition, all turtles remained in shallow waters just offshore of the nesting beach (less than 50 m depth). Haul-out locations indicate that the turtles have laid subsequent clutches at the expected inter-nesting interval of approximately 12 days. We will monitor locations and update volunteers of movements via the Facebook group *Chagos Turtles.*

Our 2012-2017 green turtle satellite tracking results indicate a very broad range of foraging destinations for the 23 individuals nesting on Diego Garcia. If the 12 individuals tracked during this expedition migrate to new destinations, we will then need to extend plans and track more individuals so the full extent of space use across the Indian Ocean can be gauged and hence the appropriate conservation measures instigated across this ocean basin.

3.2 Continuation of long-term mark-recapture study of immature turtles in Turtle Cove

During our visit in June/July 2018, we were able to capture and process more immature foraging turtles from Turtle Cove than in any previous season: 1996 (N=42); 1999 (N=41); 2006 (N=50), 2012 (N=76); and 2018 (N=97). In part this was thanks to the assistance received from the volunteer personnel of Diego Garcia (Figure 6), but there is also evidence that the numbers of turtles foraging in Turtle Cove are increasing. Such an increase is likely attributable to protection afforded breeding turtles on nesting beaches throughout British Indian Ocean Territory, (i.e. within the boundaries of the Chagos MPA) as well as at other sites in the region (such as Seychelles).

Of the 97 turtles captured, tagged, weighed and measured during June/July 2018, 91 were hawksbills and 6 were green turtles. Of the hawksbills, 21 (23%) had already been tagged in previous years (Table 2). Two were first tagged in 1996, one in 1999, one in 2006, and the rest in 2012. No green turtles had been previously tagged.

Table 2. Overview of numbers of turtles captured during each visit since 1996, and the number of turtles encountered each year that had been tagged during a previous season.

Year	HAWKSBILLS		GREEN TURTLES	
	Total Turtles	Number Already Tagged (%)	Total Turtles	Number Already Tagged (%)
1996	42	0 (0%)	1	0 (0%)
1999	41	27 (66%)	2	0 (0%)
2006	48	21 (44%)	2	0 (0%)
2012	72	9 (13%)	4	0 (0%)
2018	91	21 (23%)	6	0 (0%)

Amongst the 97 turtles captured in Jun/July 2018, the average weight was 10.7 kg (23.5 lb), ranging from 2.9 to 36.0 kg (6.4 to 79.2 lbs). The average over-curve carapace length was 47.4 cm, ranging from 32.3 to 74.5 cm.

Figure 6. Volunteers helped catch turtles in Turtle Cove over a period of nine days so they could be tagged, measured and weighed.

Further data analysis will be conducted to evaluate growth rates, population structure, and site fidelity of the Turtle Cove turtles. The satellite transmitters applied to 10 of the Turtle Cove turtles (see sections 2.3, 3.3.) will provide new insights into the behaviour and ecology of the Turtle Cove aggregation.

3.3 Movements of immature turtles within Diego Garcia lagoon

For the first time we attached satellite tags to immature green and hawksbill turtles in the Diego Garcia lagoon at Turtle Cove. We used the same type of tag we have used on adult nesting green turtles (Argos linked Fastloc GPS tags), but configured in a smaller size with fewer batteries. Turtles were captured by hand at low tide in Turtle Cove by creeping up on them while they were feeding in shallow water. The carapace was then cleaned using our standard operating procedures (alternate sanding of the carapace and then degreasing with acetone). Each tag was then embedded in epoxy and the attachment smoothed to provide a streamlined shape (see Figure 7). The tag and attachment were then painted with antifouling paint to reduce epibiont growth and, once the paint was dry, the turtle was released.

Figure 7. A smaller sized Fastloc-GPS-Argos satellite tag was attached to immature turtles. a) Embedding of tag with (red) epoxy. b) Release of turtle after antifouling paint (black) has dried.

These satellite tag attachments will allow us to investigate, for the first time, the extent of movements of immature turtles at Diego Garcia and hence will allow us to identify key areas used by the turtles. In total, we attached satellite tags to 8 immature hawksbill turtles and 2 immature green turtles, with these turtles ranging in size from 13 to 36 kg. Of note, several of these satellite tagged turtles had been flipper tagged in previous year by Dr Jeanne Mortimer, some as long ago as 1996, and so we have background information on their growth rates and length of residence at Turtle Cove.

Table 3. Overview of immature turtles tagged with satellite transmitters in June-July 2018. Species are hawksbill (Ei; *Eretmochelys imbricata*) and green turtle (Cm; *Chelonia mydas*).

Argos ID	CCL (cm)	Date	Adult/ Immature	Species	Previous tag	Name
52227	51.1	29/06/18	Immature	Ei	Y	Chloe
52231	60.0	29/06/18	Immature	Ei	Y	Leon
52226	55.6	30/06/18	Immature	Ei	Y	Brit Rep
52224	50.7	30/06/18	Immature	Cm	N	Stella
52232	74.5	30/06/18	Immature	Ei	Y	Crush
52252	57.2	13/07/18	Immature	Ei	N	Kylie
52234	59.3	13/07/18	Immature	Ei	N	Gerhard
52237	75.1	13/07/18	Immature	Ei	Y	Sebastian
52253	53.8	14/07/18	Immature	Cm	N	Damian Jr
52236	57.7	15/07/18	Immature	Ei	N	Tigger

3.4 Island-wide survey of turtle nesting activities

Nesting beach surveys were conducted by J.A. Mortimer along the entire 60 km coastline between Barton Point and the Base at the north west tip of the island. She was accompanied by volunteers from amongst the DG personnel during all surveys.

Figure 8. Volunteers who accompanied Mortimer on the survey between GEODDS site and Donkey Gate.

The most important turtle nesting activity was found along the east coast of Diego Garcia, especially from Horsburgh Point to the stretch of beach just south of the GEODDS site. Heavy beach erosion was encountered along much of the southern and western coasts. Nevertheless, turtle nesting activity was also recorded along the coastline south of the airstrip, along the southern portions of the airstrip, and north of the airstrip near Eclipse Point, and also along pockets of sandy beach in the vicinity of the Base.

3.5 Assessment of sea turtle nesting incubation conditions

On the current expedition we deployed 12 temperature loggers (Gemini Tinytag TGP-4017) at a range of nest depths (30-70 cm) and in shaded and unshaded conditions on the eastern section of the Index Beach. These loggers will record temperature for up to 18 months, at which time they will be removed from the sand for data download.

3.6 Assessment of littoral vegetation associated with sea turtle sites

Two sets of vegetation surveys (approximately 10 km apart) recorded species, canopy closure, dominant species and understorey species every 50 m. The data and photos have been passed onto Kew Botanical Gardens to assist with validation

of vegetation classification from remote sensing. The plant species closest to 15 recorded turtle nests was noted, and included scaevola (*Scaevola taccada*), bay cedar (*Suriana maritima*), beach heliotrope (*Tournefortia argentea*) and coconut palm (*Cocos nucifera*) (Figure 9). This study will continue in forthcoming expeditions to record plant species associated with hawksbill and green turtle nests.

Figure 9. Green turtle nests recorded under a) beach heliotrope tree and b) under scaevola shrub at the edge of the littoral vegetation fringe. All turtle nests were recorded under or immediately in front of vegetation fringe during this expedition.

3.7 Other sea turtle observations

1. **Injured hawksbill turtle, Turtle Cove**:

On 3 July 2018, a small hawksbill weighing only 5.9 kg was found in a weakened condition wedged under a rock in the shallow waters upstream of Turtle Cove. Examination showed that the turtle had swallowed one end of a fishing line and the rest of it was wrapped around its left front flipper (Figure 10).

Figure 10. The turtle had swallowed one end of the fishing line, and the remainder was tangled around its left front flipper which interfered with its ability to swim or feed itself.

When we removed the line from the fore-flippers a callus was apparent indicating that the turtle had probably been entangled for weeks. The Brit Rep who was volunteering on that day brought the turtle to the Base Clinic so that it could be x-rayed for evidence of a fishing hook that might be removed if necessary. No hook was detected in the x-rays; and fortunately, the Veterinarian arrived on DG the following day. After he injected the turtle with a reptile-suitable anti-inflammatory drug and an antibiotic, we released the now energetic turtle back into Turtle Cove (Figure 11).

Figure 11. Veterinarian injecting turtle with antibiotics and subsequent release.

We do not know how or where the turtle intercepted the fishing line. Nevertheless, this incident demonstrates how vulnerable the turtles are to entanglement, and how important it is to continue to restrict fishing activities from the Turtle Cove area.

2. **Outer island surveys by Senior Fishery Patrol Officer (SFPO)**

Meetings took place to exchange survey information with the SFPO who has been recording turtle nesting tracks on outer islands. Video survey files (from six sites) were exchanged for the ongoing Baited Remote Underwater Video (BRUV) study of fish abundance on seagrass meadows that is being conducted by the SFPO on the Great Chagos Bank where opportunities arise whilst the patrol vessel is at anchor.

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Appendix 1: Turtle survey patrol details

Table A1. Turtle survey patrol details: patrols to locate and satellite tag nesting green turtles were led by Hays & Esteban (Index beach; 9 nights). Day-time island-wide surveys (Track surveys; 8 days) and mark-recapture of immature turtles (Turtle Cove; 8 days) was led by Mortimer. Satellite tag attachment of immature hawksbill and green turtles were led by Hays & Esteban (Turtle Cove; 5 days). 115 volunteers assisted the team in June-July 2018, some helping on several days.

Date	Location
29 June	Turtle Cove
30 June	Turtle Cove
1 July	Turtle Cove
1 July	Index Beach
2 July	Turtle Cove
2 July	Index Beach
3 July	Turtle Cove
3 July	Index Beach
4 July	Turtle Cove
4 July	Index Beach
5 July	Beach surveys
5 July	Index beach
6 July	Beach surveys
6 July	Index beach
7 July	Beach surveys
7 July	Index beach
8 July	Beach surveys
8 July	Index beach / Beach surveys
9 July	Index beach
10 July	Beach surveys
10 July	Index beach
11 July	Beach surveys
12 July	Temperature logger surveys / Vegetation surveys
13 July	Turtle Cove
14 July	Beach surveys
14 July	Turtle Cove
15 July	Turtle Cove / Vegetation surveys