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SHARK INVESTIGATION IN THE GALAPAGOS MARINE RESERVE

WHALE SHARK PROJECT FIELDWORK REPORT 2014 SEASON

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Participating organisations:



Galápagos National Park - Turtle Island Restoration Network - Galapagos Whale Shark Project - Galapagos Conservation Trust - Charles Darwin Foundation

Field Report: October 2014

INTRODUCTION

The Galapagos Marine Reserve, which straddles the equator approximately 600 nautical miles from the coast of Ecuador, is one of the largest marine reserves in the world. Its protected waters extend 40 nautical miles from a baseline connecting the major islands (Figure 1), covering a total area of 130,000 square kilometres of Pacific Ocean and featuring a dynamic mix of tropical and Antarctic currents and rich areas of upwelling. Consequently, the GMR contains an extraordinary range of biological communities, featuring such diverse organisms as penguins, fur seals, tropical corals, and large schools of hammerhead sharks. The GMR has a high proportion of endemic marine species – between 10 and 30 % in most taxonomic groups – and supports the coastal wildlife of the terrestrial Galapagos National Park (GNP), including marine iguanas, sea lions, flightless cormorants, swallow-tailed gulls, lava gulls, waved albatross and three species of booby, among others. It also appears to play an important role in the migratory routes of pelagic organisms such as marine turtles, cetaceans and the world's largest fish, the whale shark, *Rhincodon typus*.

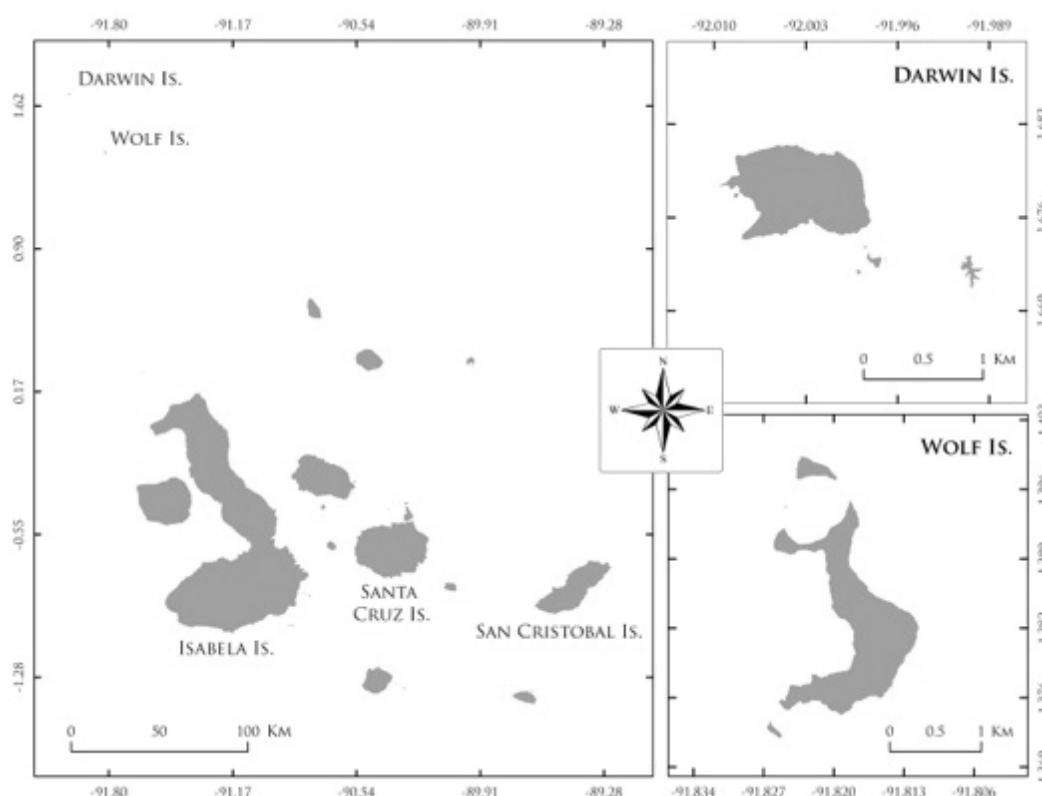


Figure 1. The Galapagos Marine Reserve.

The whale shark (Figure 2), which reaches a maximum reported length of 20 metres, was first described by a British naturalist, Stephen Smith, from a specimen from South Africa, in 1828. Since its discovery, the same species has been observed on a global scale, occurring in all tropical and warm temperate seas with the exception of the Mediterranean. Its distribution is reported to be from approximately 35–40° N to 30–35° S. The whale shark is mainly a pelagic, (open ocean), species that periodically comes close inshore for reasons as yet unknown, but apparently related to feeding and/or reproduction.

Whale sharks are capable of broad, trans-oceanic movements (Eckert and Stewart 2001; Eckert et al. 2002; Graham, 2003) timed with strong seasonal fidelity to specific sites such as Gladden Spit in Belize (Graham, 2003), Ningaloo Reef, Western Australia (Meekan et al. 2006) and Darwin and Wolf islands in the Galapagos from mid June until late November (Green, pers. obs.) Very little is known about their biology and ecology, and their movements, particularly in the Eastern Tropical Pacific.

Whale sharks feed predominantly by filter feeding on a wide variety of planktonic (microscopic) organisms but have been observed lunge feeding on nektonic (larger free swimming) prey such as schooling fishes, small crustaceans, and occasionally tuna and squid. They are generally solitary but are occasionally found in aggregations of several to over 100. The reason for this is unknown but it is assumed to be for feeding. Whale sharks are ovoviviparous with eggs hatching within the female's uteri and the female giving birth to live young. An 11m female was caught in Taiwan with 300 young (Joung et al. 1996) suggesting that the whale shark is the most prolific of elasmobranches. Sparse information exists on reproductive and pupping grounds, in addition to our lack of information on migratory routes and home range sizes.



Figure 2. Pregnant whale shark female of 12 m total length found at Darwin Island in October 2012.

Listed as Vulnerable on the IUCN Red List, whale sharks are threatened mainly by fishing activity. Traditionally hunted for their liver oil and for waterproofing wooden boats they are now being widely sold for their characteristic white meat (referred to as “tofu shark” in Taiwan and “Money shark” in China) and whole fins have been sold for as much as \$15 000 each in China (CITES Prop. 12.35) (Figure 3). Rapid reductions in numbers caught per unit effort have been seen in several areas where they have been fished including India and Taiwan, indicating that local populations are particularly susceptible to over fishing. Slow growth, late sexual maturation and potentially low reproductive rates mean that localized populations are unlikely to recover after collapse due to fishing. Nations currently involved in the exploitation of whale shark products include China Indonesia and Taiwan with illegal catches and/or non-targeted fisheries still occurring in India, Philippines, Japan, Madagascar, Mozambique, Korea, Taiwan & mainland China. (<http://www.theepochtimes.com/news/7-9-21/59960.html>)



Figure 3. Whale sharks are no longer incidental by-catch but are now targeted.

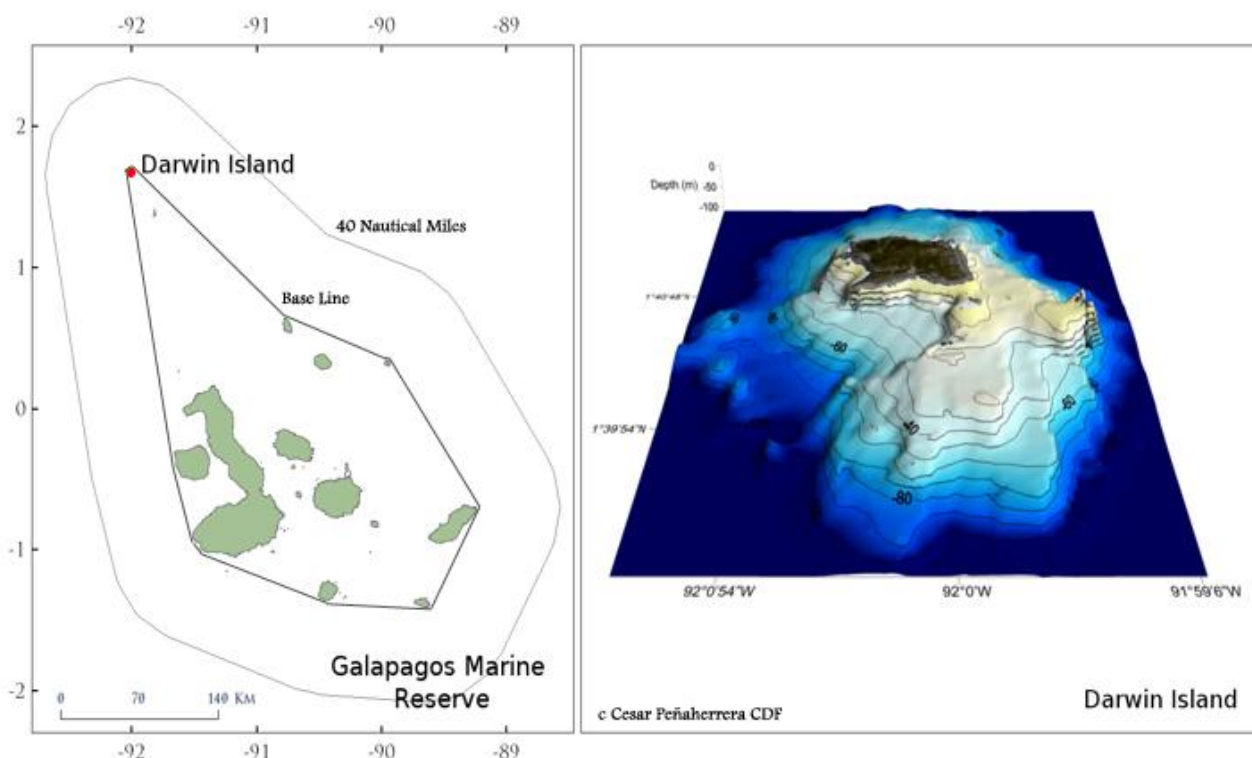
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Whale sharks provide the basis for a growing and highly lucrative encounter tourism that is potentially worth over US\$47 million a year globally (Graham 2004).

Since the beginning of the last century Galapagos has been recognised as a place with a notable abundance of sharks. From the commencement of industrial fishing in the 1930's many fishing vessels gave up fishing around the archipelago as the sharks affected the capture of tuna and marlin enormously. Presently Galapagos is one of the few places worldwide where sharks may still be observed in large numbers, similar to those observed many areas over 30 years ago. Whale sharks, Hammerheads, Galapagos, Silkies, and more recently Black tips, (common before 1990), are the principal attraction at many dive sites throughout the Galapagos Marine Reserve, (GMR), but in particular at the northern islands: Darwin y Wolf.

Thanks to a joint initiative between the CDF, DGNP and the University of Davis, California, in 2006, the Program for Investigation and Shark Conservation began. The projects' principal objective is to understand spatial and seasonal patterns and behaviour as well as the abundance and distribution of both adult and juvenile sharks. Currently five species are studied, Whale sharks (*Rhincodon typus*), Hammerhead sharks (*Sphyrna lewini*), Galapagos (*Carcharhinus galapagensis*), Silkies (*C. falciformis*) and Black tip (*C. limbatus*). Following the annual work schedule adopted by the three institutions two tagging trips were undertaken to Darwin Island between September 1st – 15th and October 10th – 25th, 2012.



Map of Galapagos Marine Reserve with baseline and 40 nm limit and Bathymetric map of Darwin Island. (Cesar Peñaherrera P. CDF).

PROJECT OBJECTIVES

The principal objectives of the Project are:

- On a local level gain a clear understanding of the importance of the GMR in the life cycle of the whale sharks.
- On a regional level increase our knowledge of movements and migratory routes of the whale sharks.
- Raise global awareness of whale sharks as charismatic ambassadors for sharks and marine conservation
- Ascertain the feasibility of creating protected areas both on a regional and global level
- Document the natural history using underwater video and photography.

The specific objectives are:

- Define the population structure and abundance of whale sharks.
- Determine the seasonality of whale sharks in the GMR.
- On a regional level and within the East Tropical Pacific, determine migratory routes, using SPOT and SeaMOD PAT satellite tags.
- Increase local awareness as to the importance of the GMR for migration of pelagic marine species, such as whale sharks.

FIELD WORK OBJECTIVES

The objectives of this field trip was:

- Tag 10-15 individual whale sharks at the dive / research site, Darwin Arch.
- Continue with photo identification work with whale sharks, compiling a database with all sightings and the pertinent details about circumstances and conditions.
- Collect tissue samples for DNA and/or Stable Isotope analysis.
- Gather basic biometric measurements of the individuals tagged and photo identified.

METHODOLOGY

The planned activities for this season followed the same basic structure and were as follows: satellite tagging, photo-identification, biometric data, genetic sampling for DNA analysis and visual census of pelagic species. These activities were carried out in the following manner:

- *Satellite Tagging.* This technique is used to evaluate spatial behaviour of whale sharks in areas of known aggregation as well as open waters within and outside the GMR. . The tags used were SPOT 12 tags, (Wildlife Computers, Figures 1) and Sea Tag GEO/PSAT tags, (Desert Star, Figure 2). The SPOT5 tags record temperature and GPS location sending data via the ARGOS satellite platform on an opportunistic basis when indicated by the external wet/dry sensor. The Sea Tag combines opportunistic GPS data with archival data of position, using the earth's magnetic field, depth and temperature. In addition the Sea Tags have an explosive release mechanism, which may be programmed for a specific release date. (This mechanism has proved unreliable in past seasons, we are awaiting results to determine if the problems have been solved). The tags were

deployed using a stainless steel multi filament cable. The tags were implanted subcutaneously, using a pneumatic spear gun, in the area close to the base of the primary dorsal fin. The diver, using standard SCUBA equipment approaches the shark from the side placing themselves above the tagging area of the shark. Additionally, data about sex, size and any distinctive markings, (scars or injuries which may help future recognition), were recorded and noted in the tagging log. A manual pressure gauge was used to maintain the guns at 260-280 psi as we had determined through previous work that the optimum pressure for implanting the dart approximately 8 – 10 cm deep was 260 psi for the type of spear gun used, (Cressi SL 100 and Cressi SL 75 at full power).

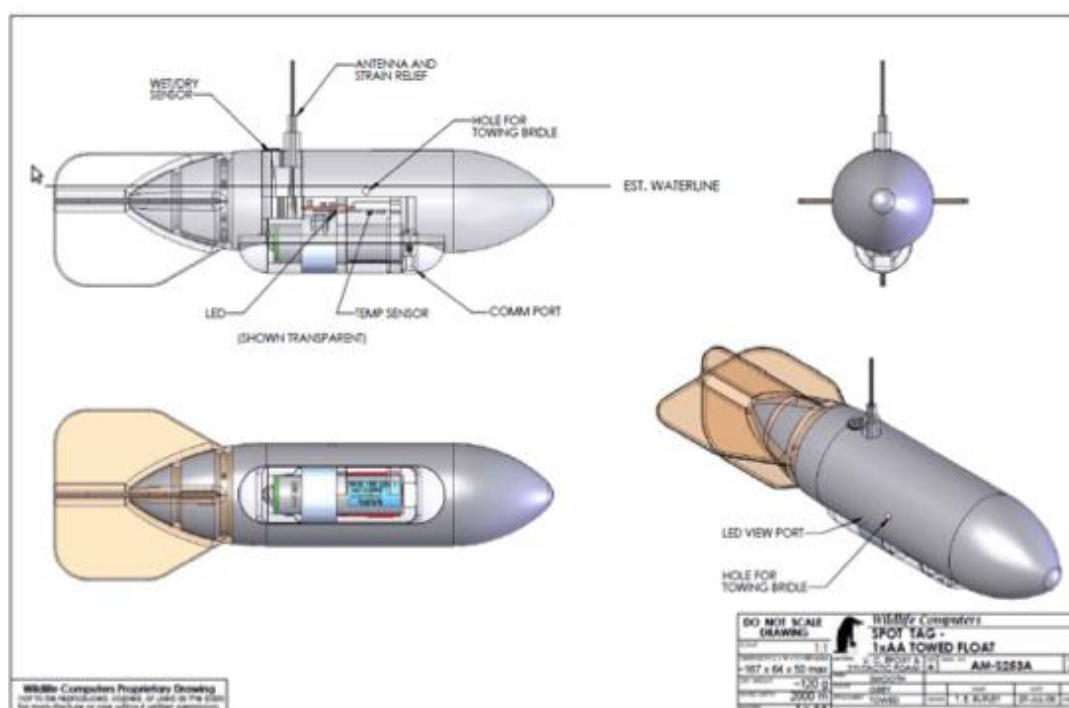


Figure 1. Diagram to show shape and construction of the SPOT 5 tag used for whale shark tagging. (Wildlife Computers, technical details, published by Wildlife Computers in 2008).



Figure 2. A SeaMOD Tag, Desert Star. The tag incorporates a solar panel for recharging the battery.
(Photo: Jonathan R. Green).

- *Photo-identification:* Photos are taken of the left-hand cephalic-branchial area, of all the whale sharks encountered during the trip, with particular emphasis on those with satellite tag. These photos are submitted to the ECOCEAN whale shark global data bank at www.whaleshark.org for their subsequent analysis using a computer software program that uses the unique white spot pattern for individual identification as the pattern of spots is similar to the human finger print and unique to the individual. The photos are also distributed to all the institutions participating for the development of local data banks.
- *Laser Photogrammetry.* This method is composed of a digital camera with two lasers, (Figure 4), that are aimed parallel and exactly 25 cm apart. Last season we had used a setup with a separation of 50cm between the lasers but this was deemed too cumbersome when pursuing the shark, particularly when the current increased in force. The photographs taken using this setup allow the measurement of the distance between the green spots of the laser on the flank of the animal to be extrapolated to determine size. (Figure 5). Each shark was photographed from the head to the base of the dorsal fin. The length between the fifth gill slit and the start of the primary dorsal fin is used to find the total length. (From Rohner et al 2011: How large is the world's largest fish? Measuring whale sharks *Rhincodon typus* with laser photogrammetry, **Journal of Fish Biology**, doi:10.1111/j.1095-8649.2010.02861.x).



Figure 4. Laser photogrammetry equipment used during the project for measuring the size of the whale sharks. The two lasers are set parallel at a distance of 25 cm apart. (Photo: © César Peñaherrera).

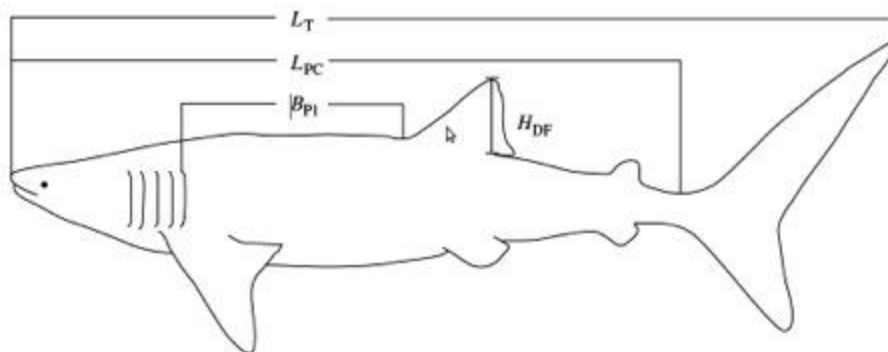


Figure 5. Shark body length to be measured with the laser photogrammetry equipment: total length (L_T), pre-caudal length (L_{PC}), first dorsal fin height (H_{DF}), and the distance between the fifth gill and the start of the dorsal fin ($BP1$) (From Rohner et al 2011).

Fieldwork 28th July – 11th August, 2014

Basic Itinerary

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Day	Site	Activities
28/07/2014	Puerto Ayora	Loading of equipment. Departure for Darwin Island
29/07/2014	Sailing	Preparation of tags and dive gear
30/07/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
31/07/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
01/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry, tissue sampling and download of acoustic receptor data
02/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
03/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry, tissue sampling and download of acoustic receptor data. Sail to Wolf Island.
04/08/2014	Wolf	Three dives to carry out endemic grouper, snapper and pelagic species census, using stereo video and stationary census. Sail to Darwin Island
05/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
06/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
07/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
08/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling and to carry out endemic grouper, snapper and pelagic species census, using stereo video
09/08/2014	Darwin	Three dives per day for satellite tagging, photo ID with laser biometry and tissue sampling
10/08/2014	Sail to Puerto Ayora	Data and report preparation
11/08/2014	Puerto Ayora	Arrival at Puerto Ayora

PRELIMINARY RESULTS

A total of 15 tags were deployed on 11 individuals. 2 were double taggings with SPOT and SeaMOD with a third tag placed on an individual that had previously been double tagged and had lost both. (See Tag Loss and Conclusions).

ID #	Sex	Pregnant	Size (m)	Date	Time	Tag Type	PTT ID #
GD140731-1	Female	Yes	12.1	31/07/2014	7:57	SPOT	139126
GD140801-1	Female	Yes	10.7	01/08/2014	6:57	SPOT	139127
GD140808-1	Female	Yes	10.7	01/08/2014	6:57	SEA TAG	141480
GD140803-1	Female	Yes	10.2	03/08/2014	11:42	SPOT	139123
GD140806-1	Female	Yes	13.1	06/08/2014	6:56	SPOT	139124
GD140806-3	Female	Yes	13.4	06/08/2014	7:15	SPOT	139122
GD140806-4	Female	Yes	12	06/08/2014	10:23	SPOT	139121 141484
GD140807-1	Female	Yes	10.8	07/08/2014	7:50	SPOT	139119
GD140808-1	Female	Yes	12.4	08/08/2014	7:33	SPOT	139120
GD140808-3	Female	No	8.2	08/08/2014	11:02	SPOT	139125
GD140808-2	Female	Yes	11.8	08/08/2014	15:43	SPOT	140648
GD140808-2	Female	Yes	11.8	08/08/2014	7:59	SEA TAG	141483
GD140808-3	Female	No	8.2	08/08/2014	15:07	SEA TAG	141481
GD140808-3	Female	No	8.2	09/08/2014	7:50	SPOT	140649

Colour XXXXXXXX denotes double tagging, XXXXXXXX denotes triple tagging

The double taggings with distinct tag types is aimed at determining which tag type, if any, is more likely to give an extended period of data and as a comparative source in the event both tags produce results. Also as a failsafe in the event of the release mechanism of the SeaMOD tags not functioning correctly.

The triple tagging occurred as BOTH the SPOT #140648 and the SeaMOD #141483 had become detached during the period from the 3rd dive on the 8th August and the 1st dive on the 9th August. She was tagged with another SPOT #140649 and departed the area shortly afterward, (as determined from the GPS track and timing of the transmissions).

2 taggings by the same diver were carried out on the 3rd dive, deploying first a SeaMOD then a SPOT tag. The shorter Cressi SL 75 spear gun, being slightly shorter than the Cressi SL 100, can be reloaded by a single diver underwater, as long as adequate precautions are taken. This is the first instance of a double tagging by 1 diver in the same dive.

Photo Identification and Laser Biometry: During this trip we had a total of 27 sightings of whale sharks, all at the dive site Darwin Arch. 12 were previously unidentified, whilst 1 individual has been sighted in both 1012 and 2013. This female, Inti GD121015-1, was seen a third time by Santiago Moran, (Dive Master on Galapagos Sky and identified by an image he provided. Inti appears in an advanced state of pregnancy each season which raises questions as to gestation periods and birthing frequency. All were confirmed as females and with the exception of 1 smaller individual, that at 8.2 m total length, may not have reached sexual maturity, appeared pregnant. The size range was between 8.2 – 13.4 m total length, (TL).

DNA tissue sampling: A total of 11 samples were collected during this field trip. These are in storage at the Charles Darwin Research Station, pto. Ayora, Galapagos.

Table of tissue samples

Date	ID #	Tag #
	GD140731-	
31/07/2014	1	139126
	GD140801-	
01/08/2014	1	139127
	GD140808-	
01/08/2014	1	141480
	GD140803-	
03/08/2014	1	139123
	GD140806-	
06/08/2014	1	139124
	GD140806-	
06/08/2014	3	139122
	GD140806-	
06/08/2014	4	139121
	GD140807-	
07/08/2014	1	139119
	GD140808-	
08/08/2014	1	139120
	GD140808-	
08/08/2014	3	139125
	GD140808-	
08/08/2014	2	140648

TAG LOSS AND CONCLUSIONS

In previous seasons we had painted the tags with a dark grey anti fouling paint. With the exception of 2 of the SPOTs, (140648/49), all of the tags came pre prepared with a transparent anti fouling paint. The shark that was double tagged during the first dive on the 1st August was re-sighted during the second dive on the same day, (confirmed by photo ID). The SeaMOD tag was no longer visible and no part of the leader remained. The SPOT appeared to have lost the antenna. A sizable Galapagos shark, (approx. 2.5 m) was also observed swimming parallel to the dorsal fin just below the SPOT tag. In previous seasons we have suffered an approximate 40% tag loss within the first 24 hours and tag transmissions have indicated that this is occurring close to the dive site at Darwin Island. We have not been able to observe actual tag loss but associated species such as other sharks, in particular Galapagos sharks, *Carcharinus galapagensis*, can frequently be seen closely following the tagged whale sharks.

The light colour of the tags with the transparent anti fouling paint made them much more visible which may have resulted in significantly higher levels of tag loss. During a subsequent trip to Darwin #139123 (GD140803-1) was re-sighted at the Arch and identified by photo ID. Her tag has given sporadic transmissions. Tagged on the 3rd August she transmitted a position approximately 200 km to the southwest of Darwin on the 7th September. 4 days later we found her back at the Arch. Her tag showed evidence of having been bitten, possibly on separate occasions. Although this cannot be confirmed the marks appear to be from another shark species.



Tag #139123 on whale shark GD140803-1



Tooth marks may be observed on the tag and fins. Just under 5 weeks since the tag #139123 was deployed barnacles are beginning to attach and grow.



Despite instruction to the contrary, dive tourists often attempt to touch whale sharks.

Argos Tag Data Whale Shark Tagging Trip – July – August 2014

Analysis 18th August 2014

SPOT

139119 No data previous 10 days

139120 Single transmission 8th Aug. Same day as tagging approx 1 mile east of Darwin Island. Possibly submerged and still on shark.

139121 No data for previous 10 days, either malfunction or shark submerged.

139122 Regular transmissions, probably floating. May have detached on the 8th August approx 10 km west of Darwin Arch. (Tagged Aug. 6th)

139123 No transmission data for last 10 days

139124 Transmissions indicate tag is floating

139125 Transmissions indicate tag is floating

139126 Transmissions indicate tag is floating

139127 No data for past 10 days. (Tag was observed on 1st Aug. apparently with antenna bitten off).

139128 Not deployed

SeaMOD

141480 Tag deployed 1st August, not present when shark re-sighted following day.

141481 Constant transmissions with wide daily spatial distribution and location class together with repeated course changes indicate this tag is floating. Dbl tagging with SPOT #139125

141482 Tag damaged, not deployed

141483 No tag data transmissions

141484 Last transmission on 6th August. Location class B approx 15 nm north west of Darwin. Tagged same day, dbl tagging with SPOT #139121. Given the active transmission this could well be an active tag but shark is submerged.

Analysis 6th October 2014

139119 No data

139120 No data. Possibly submerged and still on shark.

139121 Floating

139122 Floating

139123 No data, re-sighted 11th September, (by J.R.Green)

139124 Transmissions indicate tag is floating

139125 Transmissions indicate tag is floating

139126 Transmissions indicate tag is floating

139127 Last transmission 5th October close to the east coast of Isabela Island parallel with Cowley Islet.

139128 Not deployed

SeaMOD

141480 Tag data shut down

141481 Tag data shut down

141482 Tag damaged, not deployed

141483 No tag data transmissions, (release date Jan. 31st 2016)

141484 No tag data transmissions, (release date April 30th, 2015)

Despite varying tag leader length and materials the colour of anti fouling paint would appear to be critical in tag retention. As the tags came already painted from the manufacturers we will request that all future tags are either painted with a dark neutral grey or black, or be delivered without paint so that we may choose colour and type. We may also try a fluorescent colour such as orange to see if bright / warning colours deter associated species from attempting to bite the tags. The fact that so many of these then float indicates that the animal is not ingesting the tag but having bitten it may ascertain that it is not edible so releases it or if the tag remains on the whale shark may cause sufficient damage that the tag stops transmitting or only transmits very sporadically. This would appear to be the case of SPOT #139127.

OBSERVATIONS

Very few observations of other shark species, primarily Galapagos sharks, *Carcharinus galapagensis*, Blacktip reef sharks, *Carcharhinus melanopterus* and Silky sharks, *Carcharhinus falciformis* were made either in Wolf or Darwin, in comparison with other times of the year and previous seasons. However all three species as well as Hammerhead sharks, *Sphyrna lewini*, were observed with hooks in their mouths and some trailing nylon, long-line type, leaders, as the following images show.



© Santiago Moran Wolf Island 5 August 2014, Wolf Island. Dive site "Derumbe" (screenshot from video).



© Jonathan R. Green 12 September 2014, Darwin Island



© Jonathan R. Green 10 September 2014, Darwin Island.

The Green sea turtle, image above, was caught in a long-line of nylon and string with plastic bottles for floats. The bottles also had a short stick with flag to indicate position. The turtle was alive but in danger of drowning and was caught around the neck and left front flipper. The flipper was cut through to the tendons but we were able to release the turtle and she was able to swim away unaided. We also found a shark FAD, (fish attraction device) and 2 other long-lines caught on the rocks on the sea bottom. This evidence suggests there is a continuous targeted illegal long-line fishing operation in the northern part of the Galapagos Marine Reserve.

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