SHARK INVESTIGATION IN THE GALAPAGOS MARINE RESERVE

WHALE SHARK PROJECT

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FIELDWORK REPORT 2015 SEASON

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Participating organisations:

Parque Nacional GALÁPAGOS Ecuador

Turtle Island Restoration Network

Galapagos Conservation Trust

Hubbs-SeaWorld Research Institute 50 Years Sea Life Solutions

Galapagos Whale Shark Project

Georgia Aquarium

Fundación Megafauna Marina del Ecuador

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.*

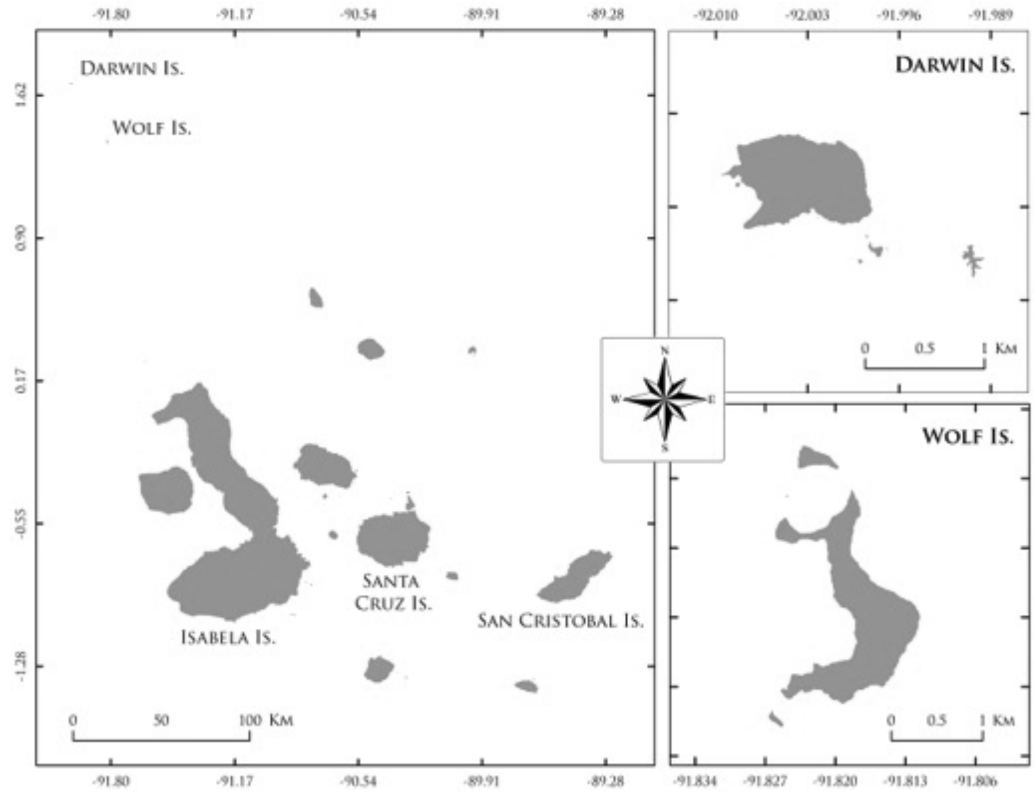

Figure 1. The Galapagos Marine Reserve.

The whale shark (Figure 2), which reaches a maximum reported length of 20 meters, was first described by a British naturalist, Andrew 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.

Photo: ©Jonathan R. Green 2014

Figure 2. Apparently pregnant whale shark female of 14 m total length found at Darwin Island in September 2014.

(note distended abdomen).

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 for their fins and oil for medicinal products

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.

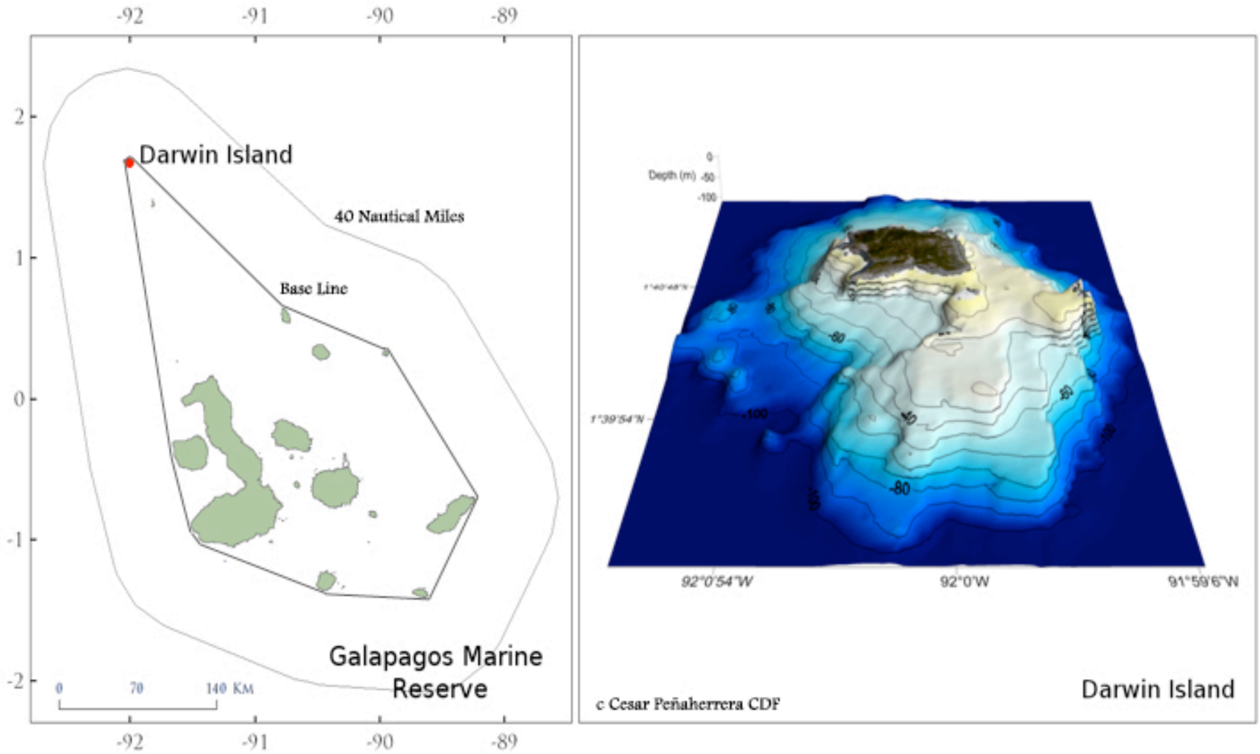

Figure 4 Map of Galapagos Marine Reserve with baseline and 40 nm limit and Bathymetric map of Darwin Island. (Cesar Peñaherrera P. CDF).

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, SPLASH and miniPAT satellite tags.
- Determine reproductive state through blood chemical analysis.

- Using Stable Isotope and Fatty Acid analysis determine dietary habits, trophic level and subsistence.
- Plankton collection as indicators of trophic levels with stable isotopes
- 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.
- Deploy a CATSCam, (camera tag) on a whale shark to capture behaviour and interaction with associated species.
- 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/Fatty Acids analysis.
- Obtain blood samples to ascertain hormonal/general health and possible pregnancy data
- Gather basic biometric measurements of the individuals tagged and photo identified.

METHODOLGY

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:
  6 x SPOT5 and SPOT6, (Wildlife Computers)
  1 SPLASH, (Wildlife Computers)
  4 x miniPAT, (Wildlife Computers. Figure #5)
  1 CATSCam with VHF pinger and SPOT6 tag for satellite location, (http://www.cats.is)(Figure #6)
  1 Sea Tag GEO/PSAT tags, (Desert Star).

  The SPOT5 & 6 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 SPLASH tag records GPS location, Depth / Temperature Time-Series, Diving Behavior: Dive-Duration Histograms, Dive-Max-Depth Histograms, Dive-Profile Log, Time-at-Depth Histograms, Haulout Behavior: 20-Minute Timeline, %-Dry Timeline, Dry-Deep-Neither Timeline. Temperature Profiles: Profile of Depth and Temp (PDT), Time-Series Temperature, Time-at-Temperature Histograms. 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. (Given the lack of reliable data and results this was a final deployment of this type of tag**).**

  The MiniPATS record vertical depth movement Environmental temperature Tracking Data: Light-based Geolocation Depth/Temperature Time-Series: Detailed sampled data Diving Behavior: Time-at-Depth Histograms, Time-Series Depth Temperature Profiles: Profile of Depth and Temp (PDT), Mixed Layer Analysis, Time-Series Temperature, Time-at-Temperature Histograms Mortality Detection Argos quality pop-up locations.

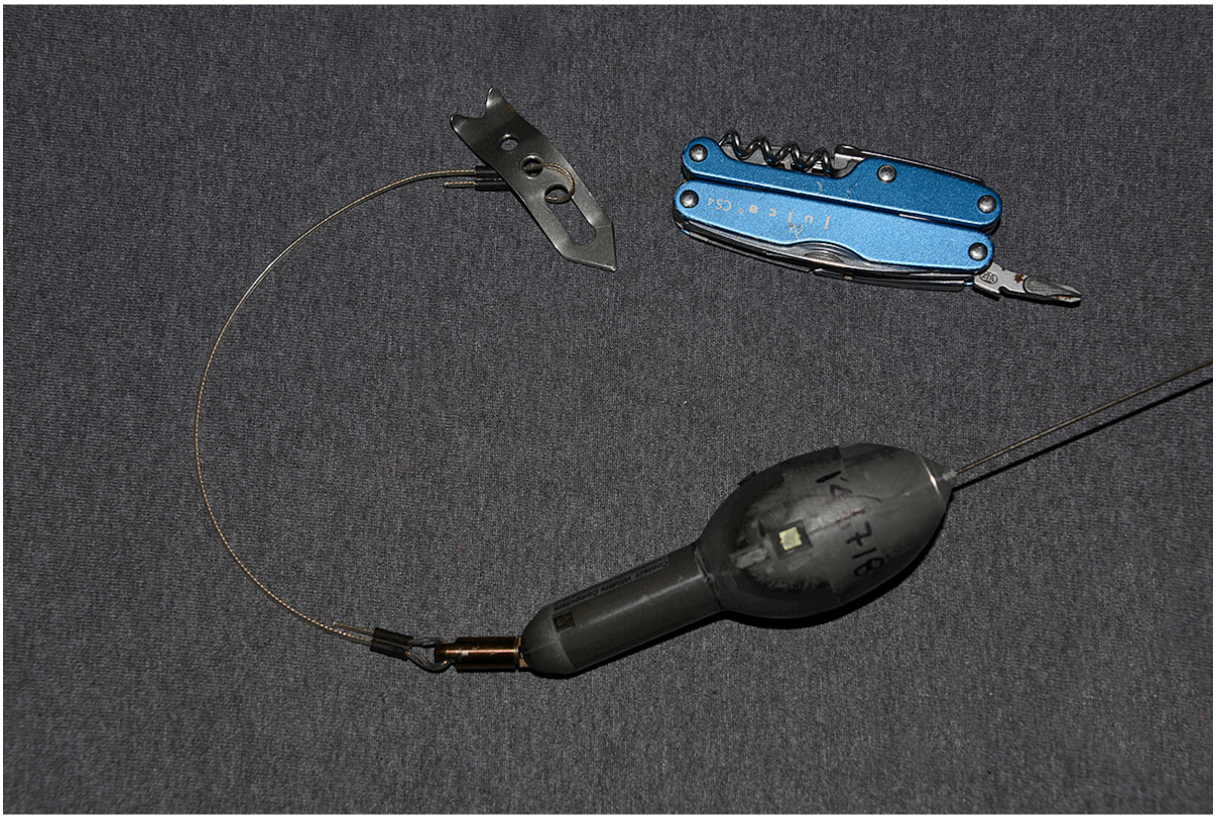

Figure 5. MiniPAT tag with modified anchor dart and short, (20cm approx.) tether. (Wildlife Computers http://wildlifecomputers.com/our-tags/minipat/) (Jonathan R. Green FMME/GWSP/DPNG).

The CATSCam combines an HD camera with a Daily Diary to record high-resolution video up to 4K 60fps with a wide-angle 170˚ field of view. The data recording includes IMU (Accelerometer, Magnetometer, Gyroscope), a high-def. speed-sensor, depth-, temperature- and light sensor which when analysed using the NAVKA software allows 3D viewing. It is assembled with a floatation device and incorporates a SPOT6 with VHF pinger as well as an independent VHF pinger for retrieval.

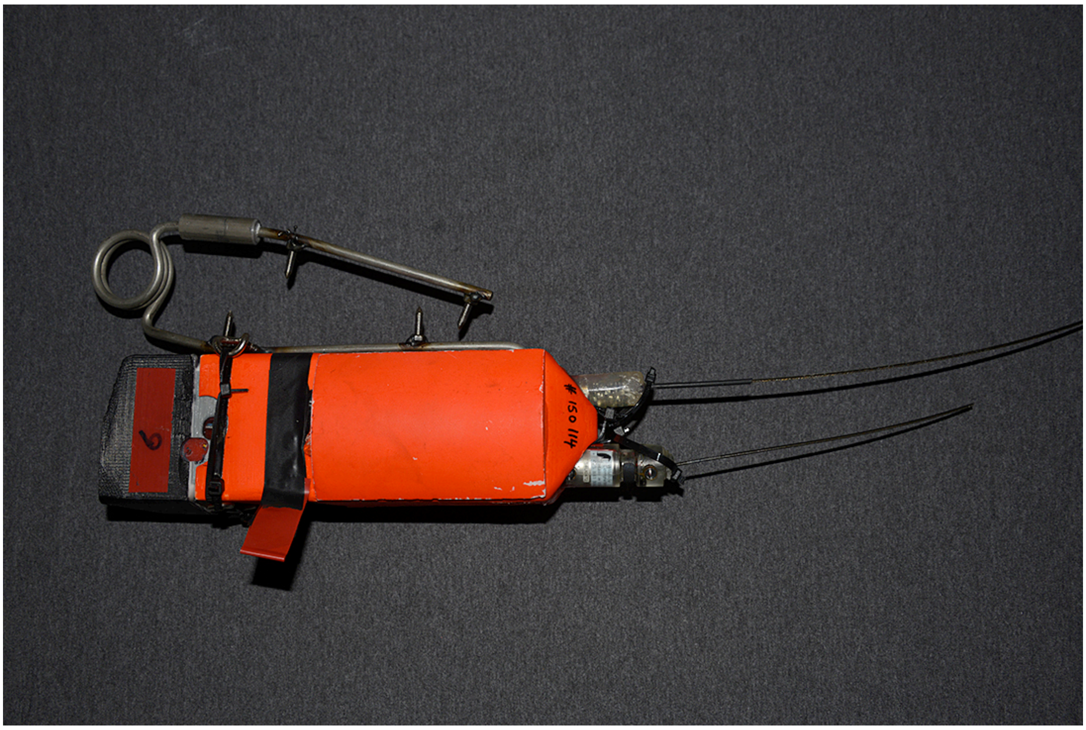

Figure 6. CATSCam camera tag with fin bracket, SPOT6 satellite tag and VHF pinger for location and retrieval. (Jonathan R. Green FMME/GWSP/DPNG).

CATSCam deployment was using scuba. The whale shark was approached from the side, parallel to the dorsal fin. The sprung bracket was opened manually and placed aver the dorsal fin approximately one third of the way up the fin from the body. As these brackets were designed for smaller animals the points did not pierce the skin but the method was successful. The tag was attached to the bracket with a sacrificial anode that released after 12 hours, (estimating mean water temperature to be 20˚C). The bracket also has a bracket that released after approximately 72 hours. No part of the tag remains on the whale shark, the camera tag floats to the surface from depths up to 1000m and is then localised using the satellite tag and VHF pinger.

The satellite tags were deployed using a stainless steel multi filament cable. The tags were implanted subcutaneously, using a pneumatic spear gun, in the area fore and 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 280 - 300psi as we had determined through previous work that the optimum pressure for implanting the dart approximately 10 - 12cm deep was 290 psi for the type of spear gun used, (Cressi SL 70 at full power).

- *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 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).
- *Blood Draw*. This technique has only been successful thus far in controlled conditions with whale sharks in aquariums. The pectoral sinus provides the easiest access. The blood draw equipment, (Figure #7), uses a four-way stopcock to prevent salt-water contamination. Al Dove of the Georgia Aquarium is the lead in this procedure. The needle gauge is #16 and syringe 2cl. Once the blood vessel has been located the blood is drawn into the lateral syringe first, then in to the principal syringe.

Figure 8. Blood Draw setup with 16 gauge needle, 4 way stopcock, lateral syringe for contaminated blood and principal 12ml syringe for sample. (Photo Jonathan R. Green/Blood Draw Kit Al Dove, Georgia Aquarium)

PRELIMINARY RESULTS

2015-16 has been forecasted as an El Niño event of major proportions, possibly exceeding the 1997-98 event that is considered the strongest El Niño Southern Oscillation, (E.N.S.O) in recorded history. Despite this forecast we carried out the field work as planned and a late season fall in water temperatures brought a favourable increase in marine activity around the dive site of Darwin Arch. This has been a noticeable pattern for the last 3 seasons.

Photo identification:
We identified 15 sharks that were new to the global database, raising the total number recorded from Galapagos to 158. We also identified one shark, G-081, first recorded from Darwin in 2011. This shark was pregnant in 2011, and pregnant again in 2015. This is our first indication of reproductive frequency in whale sharks. Two of the other sharks we saw were also noteworthy, in that they were males #3 and #4 ever recorded from the Galapagos. Both were ~6 m juveniles.

A total of 12 taggings were carried out with the following results: 6 SPOT tags of which 2 detached within 24 – 48 hours. 2 gave data for 2 months. 1 provided sporadic data for 3 months then after submerging has given no further data. 1 SPOT tag #132074 is still deployed and last position was on the 15th December at 06:12:42 **Latitude** :-9.02311 **Longitude** :-81.19082. (See Figure #9) The transmission was a Class B which is common when still attached to the shark. This is the furthest south that any of the tagged sharks have given data.

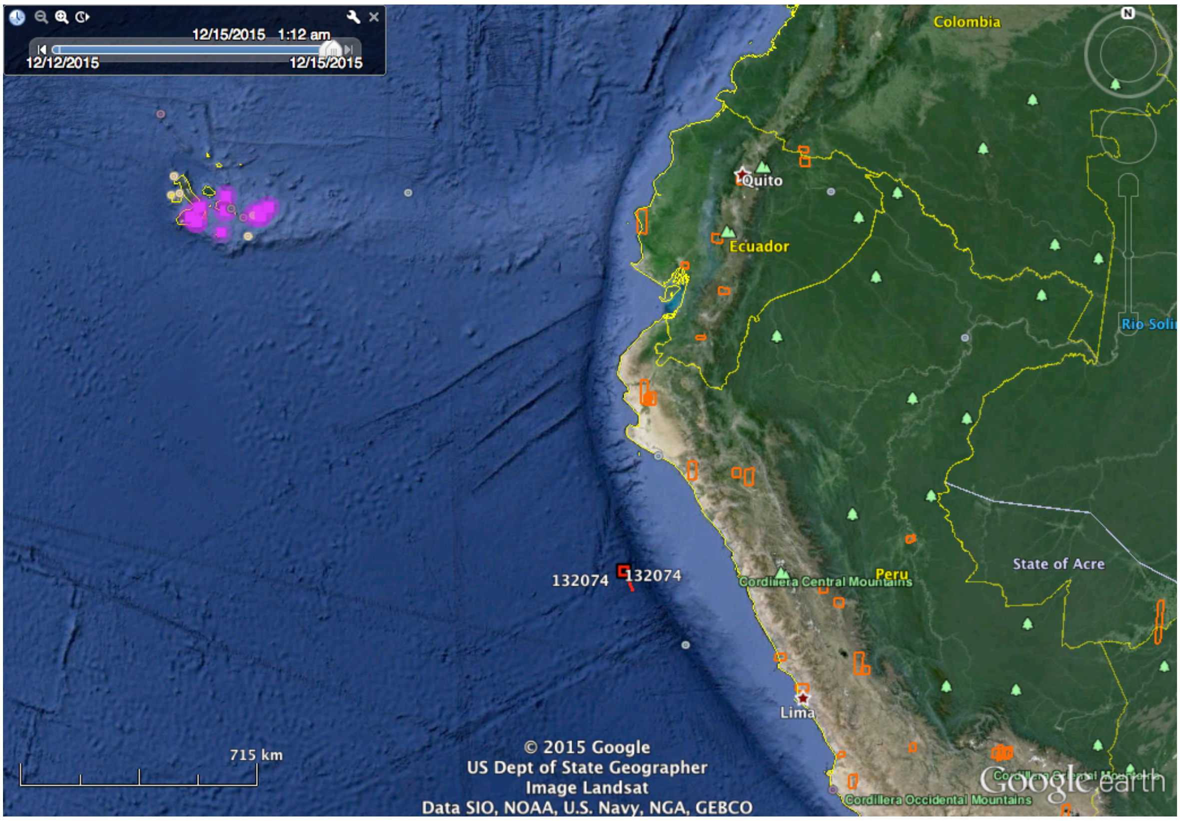

Figure 9. SPOT5 Tag #132072 at its last known position approximately 130nm off the coast of Southern Peru. (December 15th 2015 06:12 GMT)

1 SPLASH which detached or was removed by another shark species within 24 hours.
4 x miniPAT Mk 10. 1 detached after 5 weeks deployment. 3 are believed still active with 4 month and 8 months release date respectively, including the 2nd ever male tagged.
1 CATSCam which was programmed for a 12 – 15 hour deployment was successfully retrieved approximately 12 nm west of Darwin Island. Although we were unable to download the 59gb of data this was subsequently downloaded by Dr. Nikolai Liebsch one the the designers and programmers of the CATS tag. Never before recorded behaviour of Galapagos sharks "cleaning" against the whale shark was recorded but as this data is BBC copyright, this will not be for general viewing until 2017. (This material and other material filmed in the Galapagos with the Umbra and Alucia will be used for a 6k giant screen production for Alucia Productions and for a documentary series, "Oceans" by the BBC due for launching in 2017.
1 Sea Tag GEO/PSAT tags. This was deployed by the GA. After the previous season when we deployed 6 Sea Tags with no results either from opportunistic upload or programmed release we have opted not to continue using these tags. The tag detached or was removed in less under 24 hours from the time of tagging.
4 PAT tags 2x4 month release and 2x8 month release were deployed. One of the 120 day tags released or was removed by associated shark species after 5 weeks. The track will be analysed by Brent Steward and included in the next report. Three of the sharks tagged were adult females, all apparently pregnant. One of the 8 month miniPATs was a juvenile male. The tagging took place on the 10th September so expected release date will be around the 10th May 2016.

Tissue samples and plankton tows: Four tissue samples were collected from pregnant female sharks. One of these sharks was also tagged. We prioritised tagging over biopsy collection on this trip, so we consider this to be reasonably successful. Some adaptation of equipment will improve our collection rate on these large sharks, as we made several attempts where tissue was not extracted. We are redesigning our biopsy tips for improved performance on adult whale sharks. Following post-trip discussions with the Galapagos National Park authority, we have been granted provisional permission to use archival whale shark samples collected in previous years. That work will be added to the 2016 permit for the Galapagos Whale Shark Project team. 10 plankton tows were undertaken using a Neuston towed net and the analysis is being carried out by the USFQ and the GSC. Results will be published in the next report. As only one whale shark has been observed actively feeding in the Galapagos, near Wolf Island, this data may help determine if any feeding is occurring within the GMR.

Blood Draw: The main goal of this season was to determine the reality of this work. The first attempt we spent 4 minutes and 30 seconds with a shark trying to locate the pectoral sinus vessel which the GA team have found most successful when drawing blood from captive sharks at the aquarium. This procedure has only ever been successful in highly controlled conditions for which reason it was considered impossible in the natural environment, particularly Galapagos where the whale sharks swim by and strong currents are the norm. Despite several attempts at this, no blood was collected as the needle was too small. We will be attempting this again next season as this experience showed that with a larger gauge needle this technique should proove successful. The hope is to determine the reproductive state ie. pregnancy of the adult females by analysng hormonal levels but the blood chemistry should also give indicators of general health.

OBSERVATIONS

The last three seasons 2013/14/15 have all been "abnormal" year with an extended warm season lasting well into the cool "garua" season with anomalous warm Sea Surface Temperatures lasting into July and this year August. We have observed that when SST are generally greater than 26˚C the frequency in whale shark sightings decreases dramatically. This year we carried out field work in June, July and August and only found sharks in the latter part of August, despite carrying out aerial surveys by helicopter and underwater surveys down to depths of 400m by submersible.

Given the initial results of the CATSCam tagging we hope to include this as a component of future field trips. This may help reveal aspects of behaviour that other tagging techniques cannot record.

Also dependent upon results we are considering moving towards miniPAT instead of SPOT tagging. The tag loss rate would offset the greater cost of the miniPATs. Generally we had much higher success rates of retention this year as all tags with the exception of the SeaMod are now made of dark coloured resin or are painted dark before deployment. The longer tether also seems to increase retention but more work with this needs to be done.

If this period during 2015-16 does develop into a major climate event such as an E.N.S.O. the tag data will provide information that may be critical to how behaviour may change during such events. In order to perceive such trends it is imperative that this data collection is continued and takes place over a considerable period of time.

ACKNOWLEDGEMENTS

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