SHARK INVESTIGATION IN THE GALAPAGOS MARINE RESERVE

WHALE SHARK PROJECT

Photo: ©Simon J. Pierce 2017

FIELDWORK REPORT
2017 SEASON

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Participating organisations:

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.*

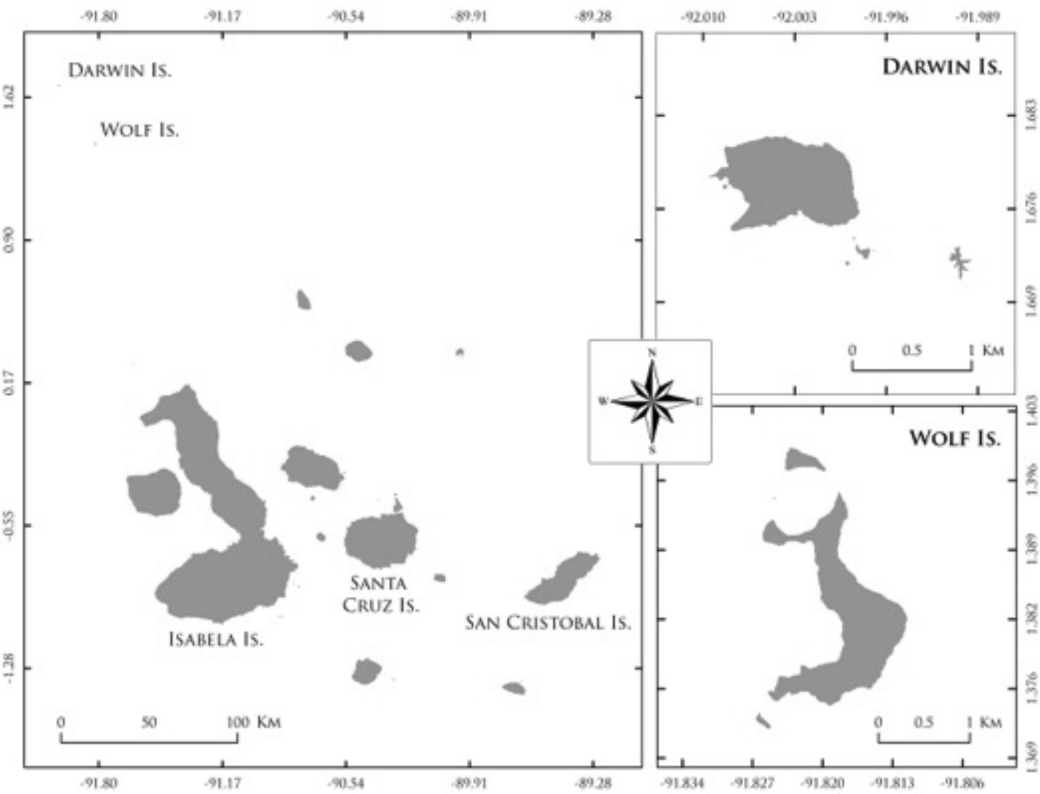


Figure 1. The Galapagos Archipelago with outlying islands Wolf and Darwin.

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 in 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. Apparently pregnant whale shark female of 14 m total length found at Darwin Island in September 2014. (Note distended abdomen). Photo: ©Jonathan R. Green 2014

Listed as Vulnerable on the IUCN Red List in 2003 its status changed to "Endangered" in 2016, 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 six shark species are studied, Whale sharks (*Rhincodon typus*), Tigers (*Galeocerdo cuvier),* Hammerhead (*Sphyrna lewini*), Galapagos (*Carcharhinus galapagensis*), Silkies (*C. falciformis*) and Black tip (*C. limbatus*). In 2011 with funding from the Rapier Family Trust, one to two annual field trips have been carried out between the months of July and October. In the ensuing years partnerships with a number of institutions have been formed broadening the scope of both fieldwork and data analysis strengthening the Galapagos Whale Shark Project and making it one of the most innovative and ambitious of its kind.

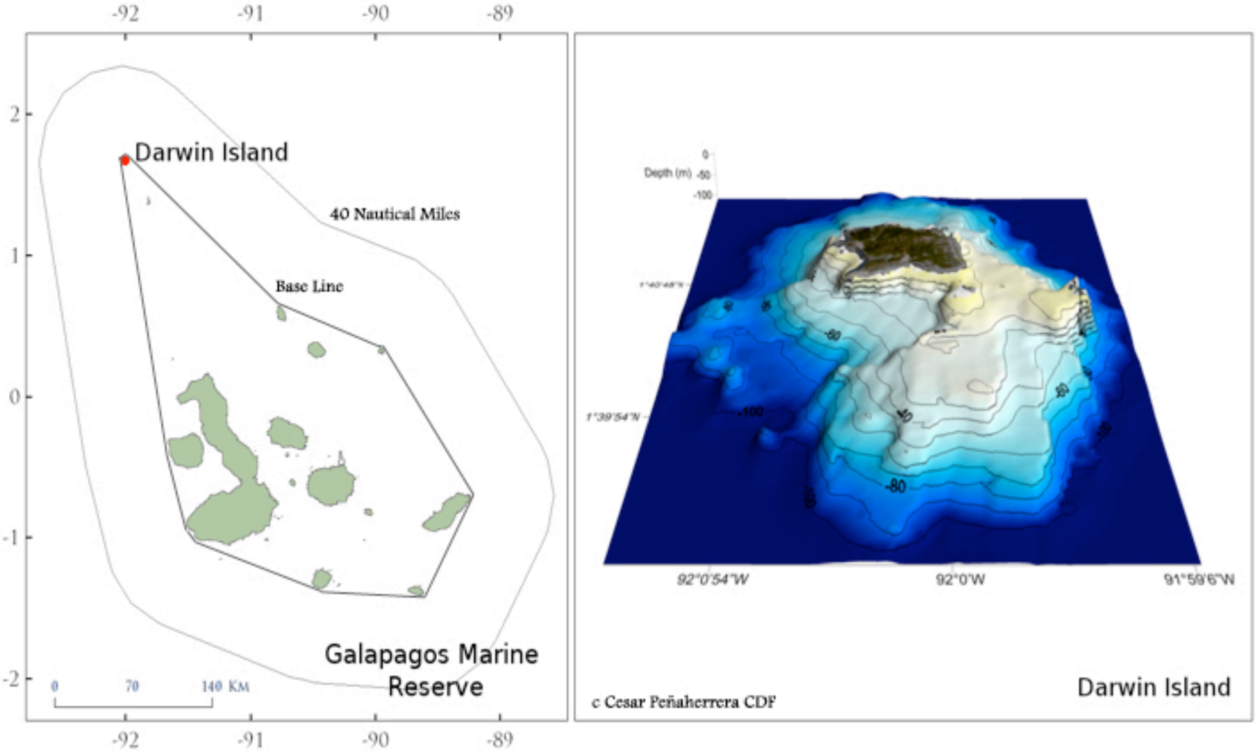


Figure 4 Map of Galapagos Marine Reserve with baseline and 40 nm limit and Bathymetric map of Darwin Island. (Cesar Peñaherrera P. CDF).

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 movements, 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 15-20 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.
- Continue to upload photo for ID to www.whaleshark.org for global database comparison
- Collect tissue samples for DNA and/or Stable Isotope/Fatty Acids analysis.
- Carry out Neuston net tows to ascertain presence of micro plastics in mid oceanic areas
- 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:

  5-x SPOT6 – towed and fin mount. (Wildlife Computers. Figure #5 & 6)
  1 SPLASH, (Wildlife Computers. Figure #7)
  14-x miniPAT, (Wildlife Computers. Figure #8)

  The SPOT6 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. Given the deployment success and detachment history with the towed tags we are now deploying a prototype fin-mount that has proved successful with juvenile sharks in other study areas.

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, Haul out 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 MiniPATS record vertical depth movement. Environmental temperature. Tracking Data: Light-based Geo-location. 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.

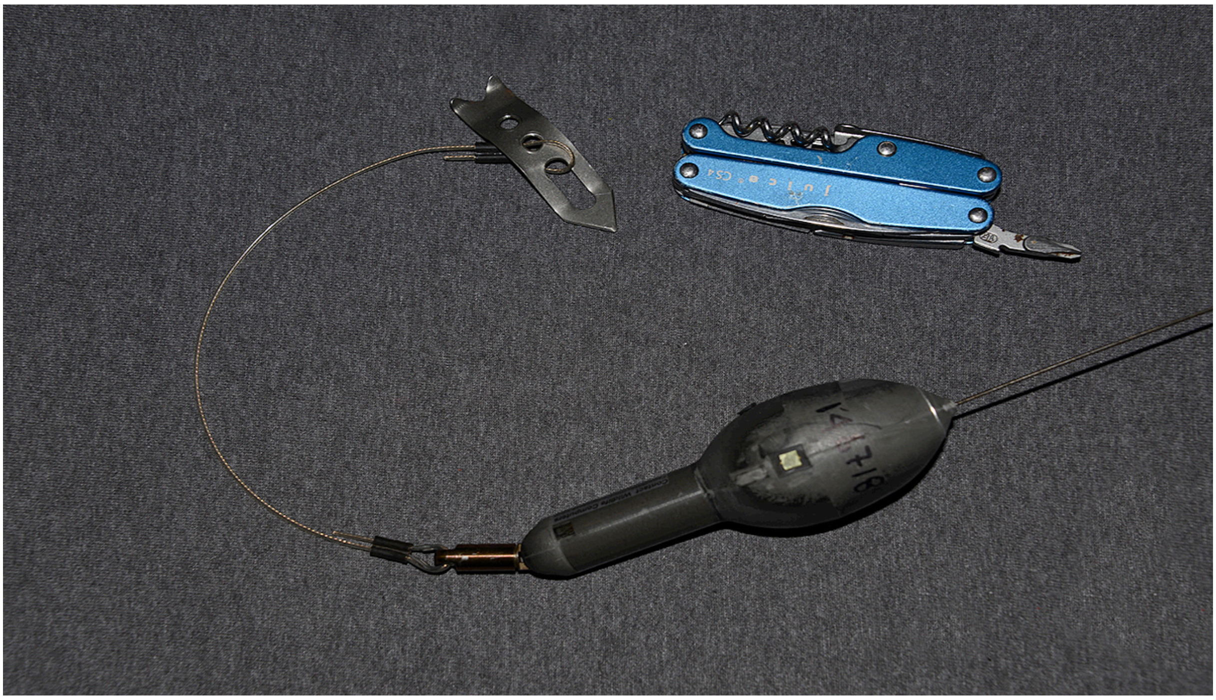


Figure 5. MiniPAT tag with modified anchor dart and short, (12cm approx.) tether. (Wildlife Computers http://wildlifecomputers.com/our-tags/minipat/) (Photo:©Jonathan R. Green 2016).

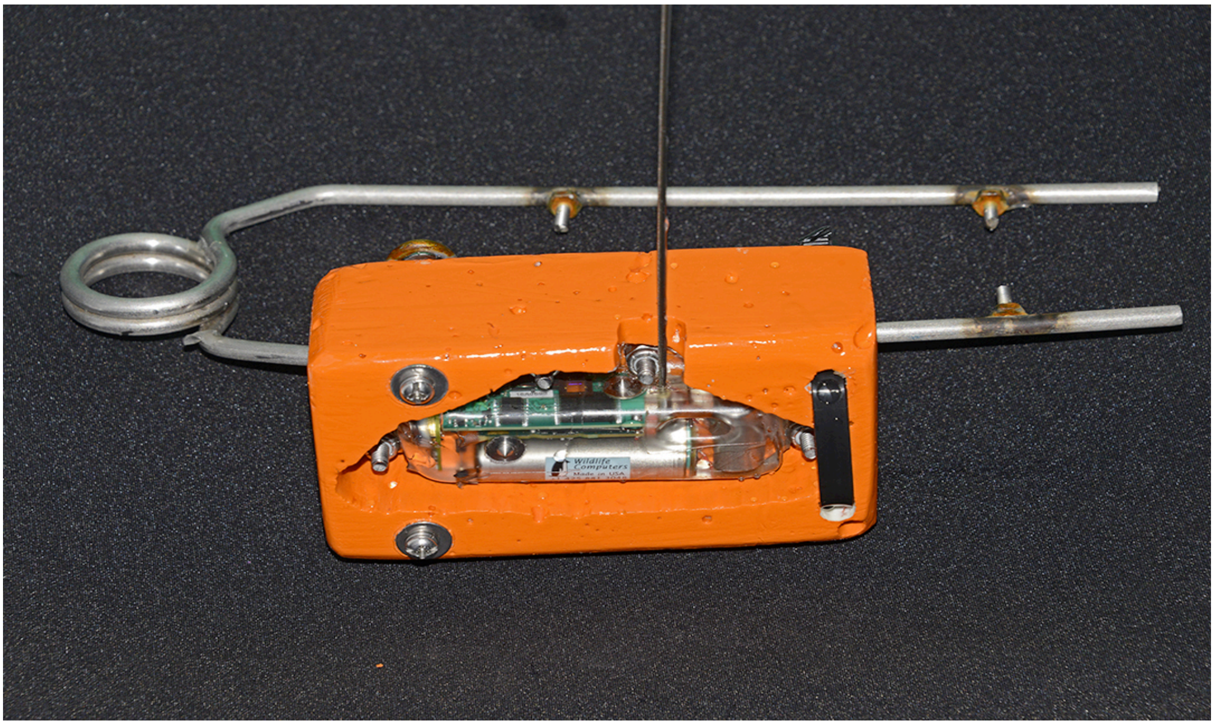


Figure 6. Fin mount SPOT6 prototype previously deployed on juveniles. (Photo:©Jonathan R. Green 2017).

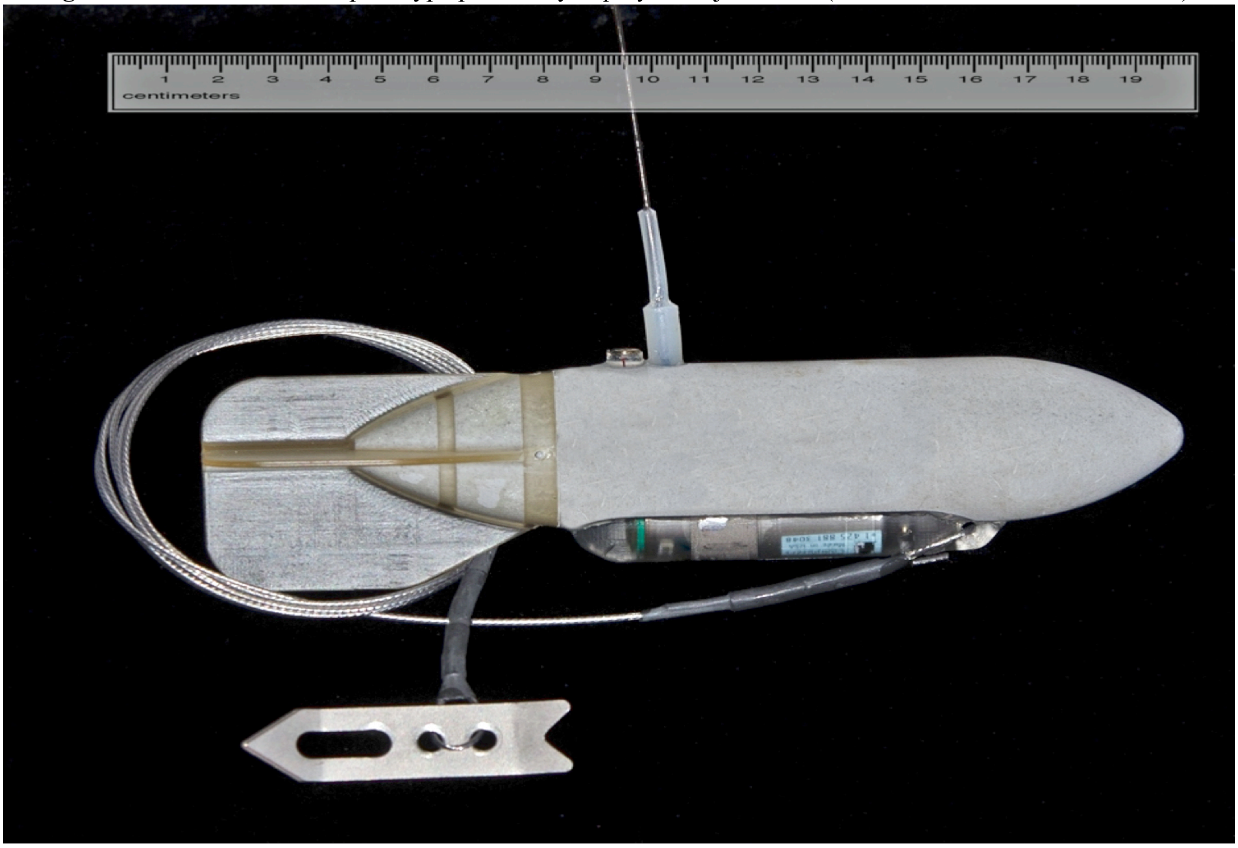


Figure 7. Towed SPOT6 tag (©Jonathan R. Green 2017).

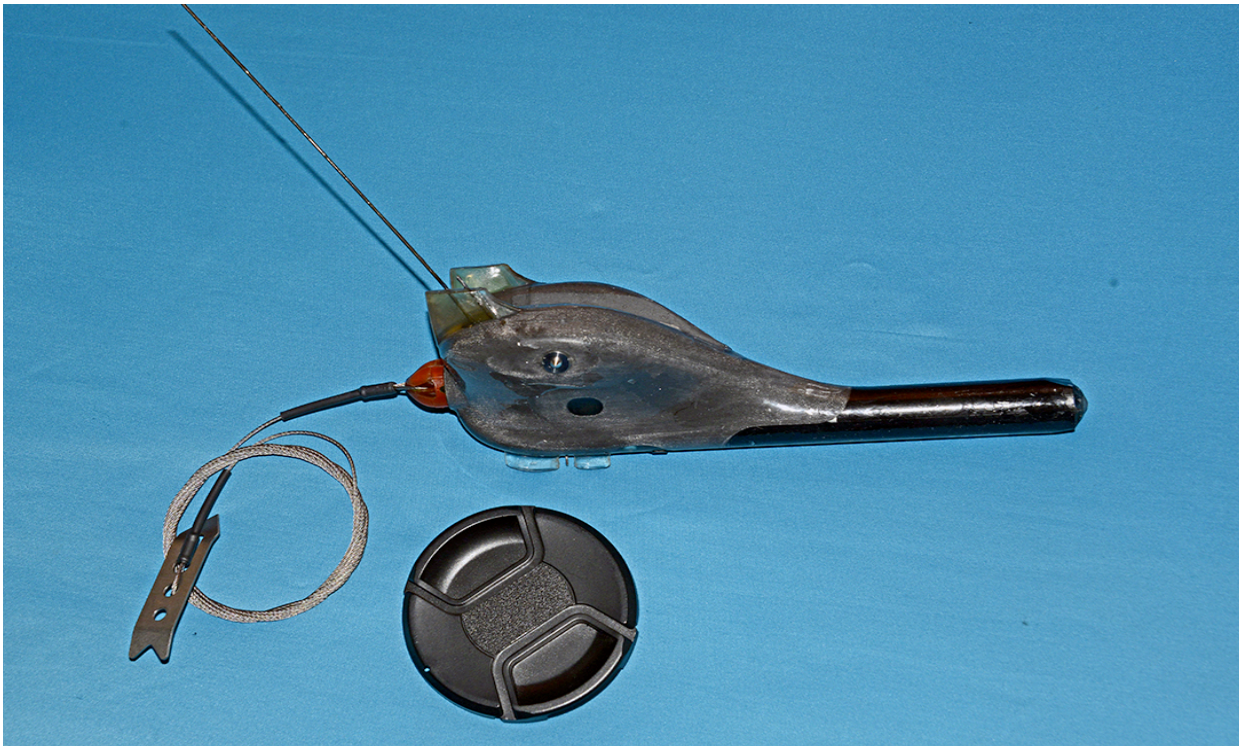


Figure 8. Towed SPLASH tag – first deployment in Galapagos. (©Jonathan R. Green 2017).

The towed satellite tags were deployed using a stainless steel multi filament cable and dyneema. 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.

- *Blood Draw*. Until this season this technique had only been successful thus far in controlled conditions with whale sharks in aquariums using the pectoral sinus. The blood draw equipment, (Figure #7), uses a two-way stopcock to prevent salt-water contamination. The needle gauge is #14 and syringe 25cl. Once the blood vessel has been located the blood is drawn into the lateral syringe first, then in to the principal syringe. During the GWSP July field trip with Okinawa Aquarium the team managed to draw blood from two adult females that were both apparently in an advanced stage of pregnancy. They drew the blood from vessels at the base of the dorsal fin saddle. The samples are currently in storage awaiting CITES permits for export and laboratory analysis.

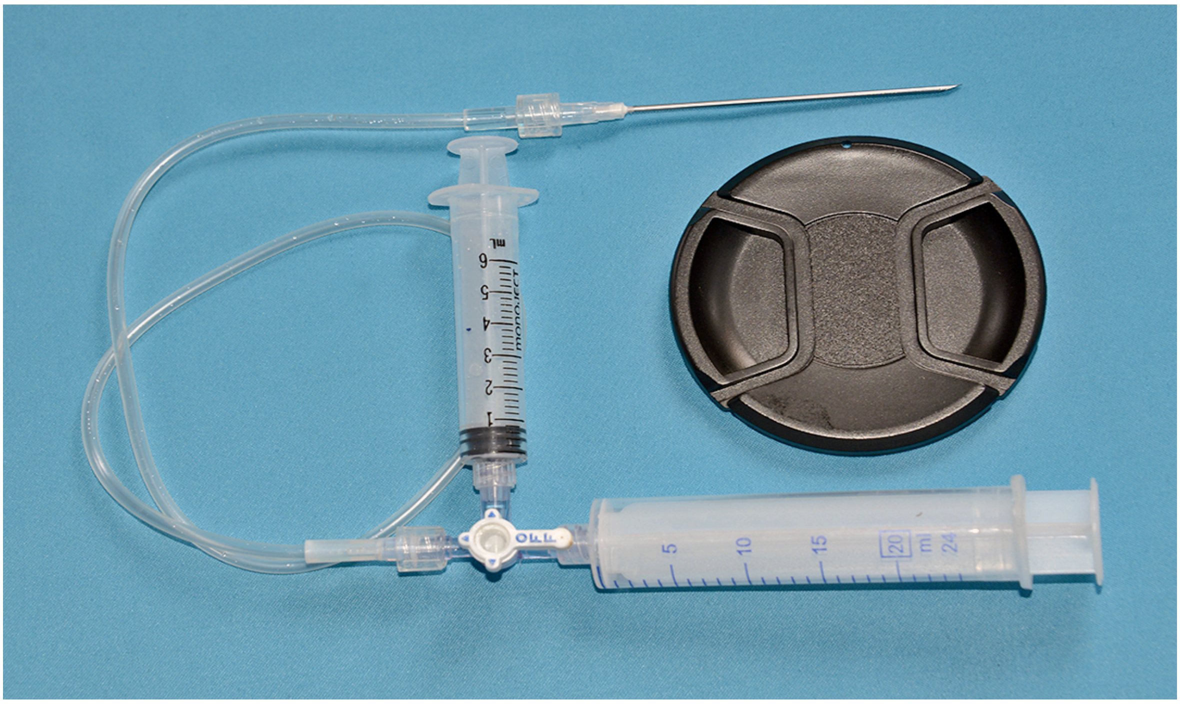


Figure 9. Blood Draw setup with 16 gauge needle, 2 way stopcock, lateral syringe for contaminated blood and principal 24ml syringe for sample. (Photo:©Jonathan R. Green/Blood Draw Kit Al Dove, Georgia Aquarium)

– *Tissue biopsy*

Whale sharks are a highly mobile pelagic species that exhibit complex movement patterns seemingly influenced by life-stage, reproduction and feeding. While we have photographic evidence that immature individuals remain in a single regional aggregation, genetic evidence suggests that breeding individuals perform long-range migrations. Their elusive nature beyond the juvenile life-stage makes the determination of their movement patterns beyond this extremely difficult, and so we would like to characterise their individual, aggregational and ocean basin connectivity using genetic techniques. The unique demographic of individuals present at Darwin Arch in the Galapagos presents a unique opportunity to collect samples from mature whale sharks, which - combined with samples from juveniles worldwide - will help us to put their connectivity into context.

To collect the samples, we usually use a modified Hawaiian sling (an elasticated pole) which allows us to take a small (~6mm diameter) sample of skin from the shark. We take these biopsies from the area immediately under the dorsal fin on the left side of the shark to ensure that we are taking it from the thickest part of the skin (the sub-dermal layer here is likely at least ~ 10cm thick) and so that we can identify when a shark has been sampled before to avoid duplicate sampling. This technique works well with the whale sharks we see in coastal aggregations, the vast majority of which are immature sharks typically between 5 and 8 metres in length. We found however that using this technique with mature whale sharks, whose size maybe between 9 – 15 metres, was more problematic. We found that the biopsy tip would not penetrate the tough outer skin layer of the mature sharks in the same area using the hand pole, and it was not often effective in other areas of the shark where the skin may be thinner, i.e. in the area below the second dorsal fin. We decided to attempt the biopsies using a pressurised spear gun to give us the extra power we needed to penetrate the upper skin layer. This resulted in the biopsy tip successfully penetrating the skin layer, and we were able to collect samples in this way. The sharks meanwhile, do not physically react to either technique. Another problem encountered was that the tissue would not remain inside the sampling tip as it was withdrawn from the skin. Altogether, of the 5 sharks we attempted to sample from, we gained 3 samples. We will be looking at ways to improve upon the technique for next year so that we can guarantee more successful sampling attempts.

Once we have the tissue, it needs to be preserved either by freezing or storing in >90% ethanol. The amount of tissue from one sample can be used in several different analyses, so the tissue is separated into several different sampling tubes. This means we can store it using both preservation techniques and we have back-up tissue sections of the same animal in case the samples are somehow rendered unusable or lost etc. Once relevant permits are obtained, i.e. CITES import and export, and local fisheries/ park permits, the samples will be processed. We will use a combination of genetic (microsatellites and mitochondrial DNA) and genomic (SNP) markers which will enable us more specifically to study parameters such as:

- Demographic history; Historical population size reductions and expansions;
- Genetic structure and the presence of gene flow across and between oceans;
- Breeding behaviour and relatedness of individuals within and between oceans and aggregations;
- Regional comparisons of genetic diversity of the species.

Once the samples have been sequenced, we can answer questions such as those above using a variety of software to analyse genetic distances between individuals and sub-populations, to analyse the partitioning of genetic diversity to infer connectivity, and even characterise the relatedness between individuals in terms of siblings, parents and tertiary relations. The results will give us greater insights into how the species has been and is now connected on temporal and spatial scales, will allow us to assess genetic health of sub- and meta-populations, and to understand their habitat use throughout their life-stages. The collaboration of various regional organisations, together with the variety of genetic markers and software, will allow this study to develop in both fine- (i.e. national) and large- (i.e. international) scales, resulting in comprehensive characterisation of the species both across and within oceans. To effectively fulfil this project and those beyond it, continued sampling of relevant sites year after year will be necessary to yield robust data. This information will be used to formulate more effective conservation management plans and to guide resource management for this endangered species.

FIELD WORK ITINERARY

Date	Place	Activities
9/13/17	Puerto Ayora	Left in the afternoon (15:00)
9/14/17	Roca Redonda	2 dives
9/15/17	Darwin	3 dives
9/16/17	Darwin	3 dives
9/17/17	Darwin	3 dives
9/18/17	Darwin	3 dives
9/19/17	Darwin	3 dives
9/20/17	Darwin	3 dives
9/21/17	Darwin	3 dives
9/22/17	Darwin	3 dives, 1 plankton tow
9/23/17	Darwin	3 dives
9/24/17	Darwin	3 dives
9/25/17	Darwin	3 dives, 1 plankton tow
9/26/17	Darwin	3 dives, start navigation after lunch (14:30)
9/27/17	Puerto Ayora	Arrival to port

ACTIVITIES CHRONOGRAM

Date	No. dive	Start time	Duration	T° surface °C	T° below surface °C	Depth of thermo-cline (m)	Visibility (m)	Sightings Whale Sharks
9/14/17	1	10:00	0:30	17	17	No	15	0
9/14/17	2	13:00	0:30	20	20	No	15	0
9/15/17	3	7:50	0:53	23	23	No	30	0
9/15/17	4	11:40	0:51	24	24	No	30	0
9/15/17	5	15:40	1:03	24	24	No	30	0
9/16/17	6	7:23	0:50	23	23	No	20	0
9/16/17	7	11:10	0:56	23	23	No	25	0
9/16/17	8	15:13	0:51	23	23	No	25	0
9/17/17	9	7:07	0:50	23	23	No	15	0
9/17/17	10	11:05	0:54	23	23	No	20	0
9/17/17	11	14:41	0:49	23	23	No	8	1
9/18/17	12	7:17	0:49	23	23	No	10	2
9/18/17	13	11:04	0:53	23	23	No	12	0
9/18/17	14	14:45	0:51	23	23	No	12	0
9/19/17	15	7:11	0:50	23	23	No	15	0
9/19/17	16	11:09	0:58	23	23	No	20	0
9/19/17	17	15:18	0:58	23	23	No	15	0
9/20/17	18	7:17	1:00	23	23	No	20	0
9/20/17	19	11:23	0:52	24	24	No	25	0
9/20/17	20	15:15	0:42	24	24	No	25	2
9/21/17	21	7:07	0:51	23	23	No	15	2
9/21/17	22	11:07	0:55	24	24	No	20	1
9/21/17	23	14:55	0:49	24	24	No	15	2
9/22/17	24	7:14	0:56	22	22	No	12	0
9/22/17	25	11:13	0:48	22	22	No	10	2
9/22/17	26	14:55	0:39	22	22	No	8	0
9/23/17	27	7:10	0:57	22	22	No	8	0
9/23/17	28	11:16	0:54	22	22	No	8	0
9/23/17	29	15:05	0:53	22	22	No	5	0
9/24/17	30	7:15	0:49	22	22	No	12	1
9/24/17	31	11:04	0:56	22	22	No	12	0
9/24/17	32	14:51	0:57	22	22	No	10	0
9/25/17	33	7:30	0:54	23	23	No	18	0
9/25/17	34	11:06	0:59	23	23	No	25	0
9/25/17	35	15:10	0:53	23	23	No	15	0
9/26/17	36	6:59	0:42	23	23	No	25	3
9/26/17	37	10:01	0:52	23	23	No	25	2
9/26/17	38	12:28	0:43	23	23	No	20	2

PRELIMINARY RESULTS

Satellite tagging:
A total of seven individual whale sharks were tagged, (see figure #**10**), with a combination of ten tags:

1x SPLASH

4x SPOT6

5x MiniPAT

Three sharks were double tagged with both SPOT6 and MiniPAT tags to compare locational data after the release of the MiniPATs.

Photo identification:
We identified 7 sharks that were new to the global database, raising the total number recorded from Galapagos to 178. Although these have yet to be uploaded and processed by the global image data system we found no matches with any previously sighted at Darwin.

Tissue biopsy:
Three samples were collected from three individual sharks. These will be sent for local and overseas analysis as part of a global comparative study. No funds are available for their analysis at present.

Plankton / micro plastic tows:
Two tows were carried out using a Neuston net, (see figure #11) on the 22nd September PM and 25th September AM. The samples were frozen and be delivered to the GSC for analysis.

Blood draw:
Without access to a centrifuge and adequate storage facilities no further blood draw was attempted during this field trip. This work will be continued next season at which point we hope to have the results from the July GWSP trip. The samples taken with the Okinawa Aquarium team and the GWSP in July are stored at the GSC for future analysis. These samples may be key to determining reproductive state. No funds are available for their analysis at present.

SPOT6 #	miniPAT #	Splash #	Date of tagging	Foto ID	Sex	Preg-nant	Size	Observations
172176	172241		9/17/17	GD 170917-3	F	yes	9.0m (est.)	SPOT "fin mount" doble tagging
	172245		9/20/17	GD 170920-3	F	yes	12.0m (est.)	Possible Orca bite on her left flank between abdomen
172175			9/21/17	GD 170920-3	F	yes	12.0m (est.)	SPOT "fin mount" double tagging with miniPAT #172245 Biopsy
164565			9/21/17	GD 170921-3	F	yes	13.5m (est.)	SPOT "fin mount"
	172240		9/22/17	GD 170922-2	F	yes	12.5m (est.)	
	172239		9/24/17	GD 170924-1	F	?	11.0m (est.)	Biopsy
		172174	9/26/17	GD 170926-1/1	F	yes	12.0m (est.)	Dorsal fin 3/4 missing
	172246		9/26/17	GD 170926-1/2	F	yes	13.0m (est.)	White patch at the head
151674			9/26/17	GD 170926-1/2	F	yes	13.0m (est.)	Double tagging with miniPAT #172246 SPOT tag removed by asociated species Biopsy (2nd dive)
157789			9/26/17	GD 170926-1/2	F	yes	13.0m (est.)	Double tagging with miniPAT #172246

Figure 190. Table of taggings showing deployment of ten tags on seven individual sharks.

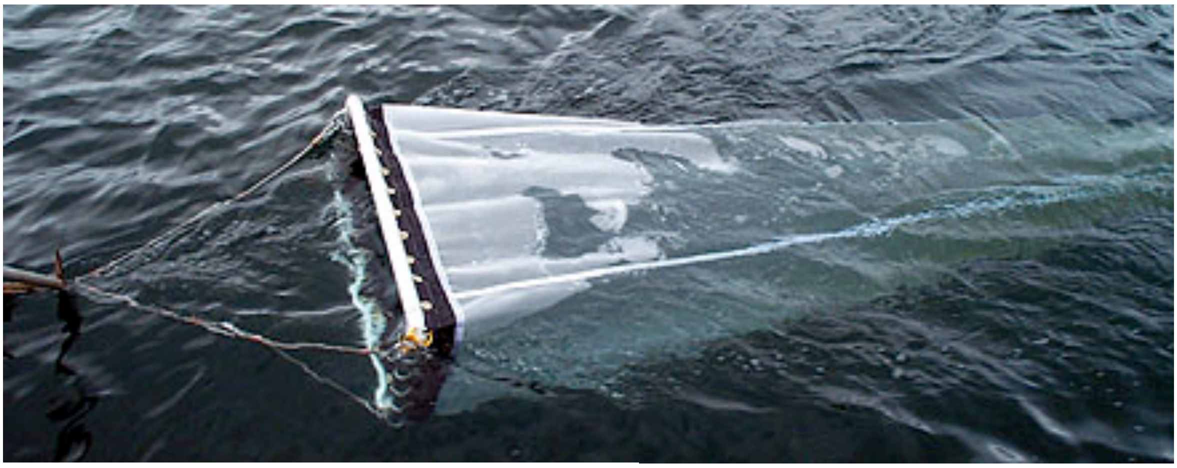


Figure 11. Neuston net for plankton and micro plastic tows

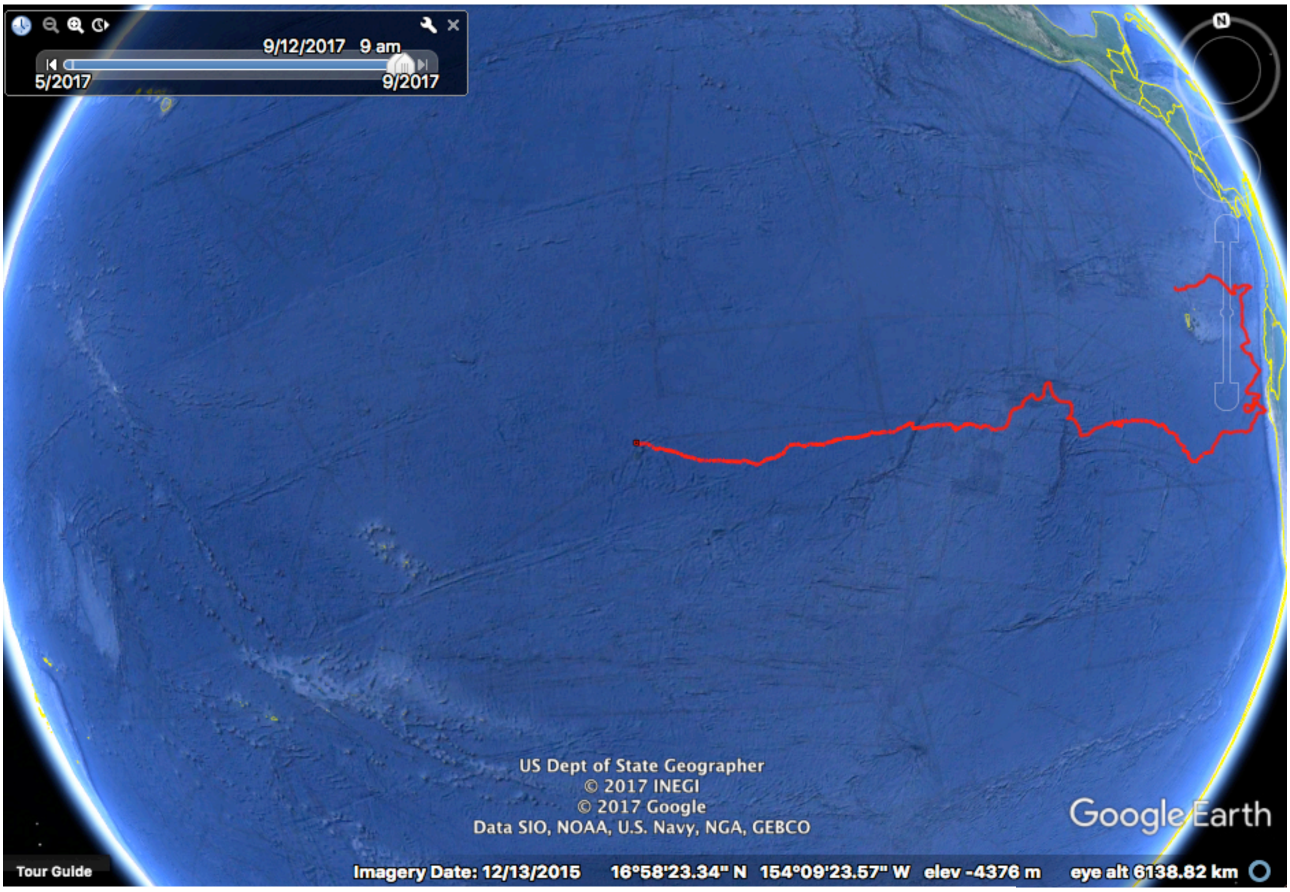


Figure 12. "Nazca" SPOT6 tag #151676 tagged 20th September, 2016 after a year of tracking.

The last transmission from this tag came on the 12th September just one week short of a calendar year. The full track is the longest in terms of time and distance from any of the SPOT tracks to date. The reasons for the tag to stop transmitting are unknown but the most likely is that the battery no longer has sufficient power. The battery life for a SPOT6 is estimated at around 300 days. This highlights the need for a longer lasting battery pack for the long term tracking needs of whale sharks. Needless to say this data supports the theory that whale sharks are indeed ocean travellers that may well move from one part of the planet to another over a period of years. With time we hope that photo ID data will confirm this even if satellite telemetry does not. Perhaps surprising though is that we still do not have a single recapture from another region. Given that we are now in the seventh field season this indicates that the numbers of whale sharks passing through Darwin Arch are probably much higher than original estimates confirming that this "population" is the largest concentration of adult female whale sharks of all known aggregations.

OBSERVATIONS

On consecutive nights 20th-21st and 21st-22nd September vessels with high-powered lights were observed at a distance of 2nm from the anchorage at Darwin Island. They both appeared to be around 100m or over in length. Without the possibility to approach the vessels it appeared they were involved in fishing activities. Given the position of the vessels they were definitely not tourist boats from Galapagos. This continues to highlight the necessity for effective patrolling of the waters around Wolf and Darwin Islands and the entire Galapagos Marine Reserve. We again observed sharks with fishhooks in their mouths and trailing nylon long line.

PUBLICATIONS

Two further publications have resulted from data collected directly from the GWSP with a third that will be ready for submission in December of this year.

Hearn AR, JR Green, MH Román, D Acuña-Marrero, E Espinoza, AP Klimley (2016) Adult female Whale sharks male long-distance movements past Darwin Island (Galapagos, Ecuador) in the Eastern Tropical Pacific. Mar Biol 163:214

Ryan JP, Green JR, Espinoza E, Hearn AR (2017) Association of whale sharks (*Rhincodon typus*) with thermo-biological frontal systems of the eastern tropical Pacific. PLoS ONE 12(8): e0182599. https://doi.org/10.1371/journal.pone.0182599

AMBIENTAL CONDITIONS

This season has been characterised by colder sea surface temperatures, (SST) than previous years. This combined with a pronounced "garua" season is typical of post "El Nino" or "La Nina" years. This are the expected climate conditions after the 2015 "Nino" event. The following NOAA SST charts are from the same period for last three years.

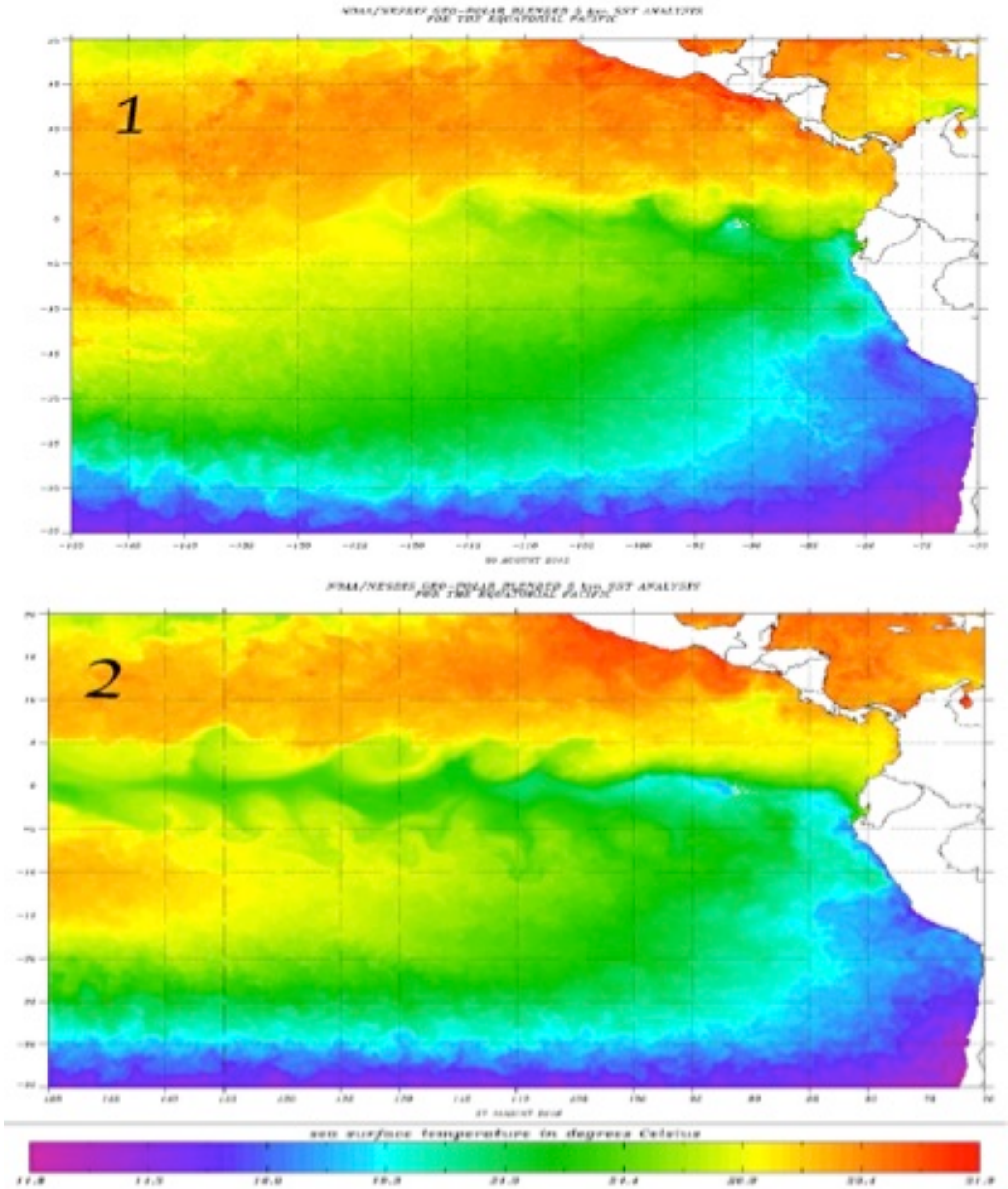
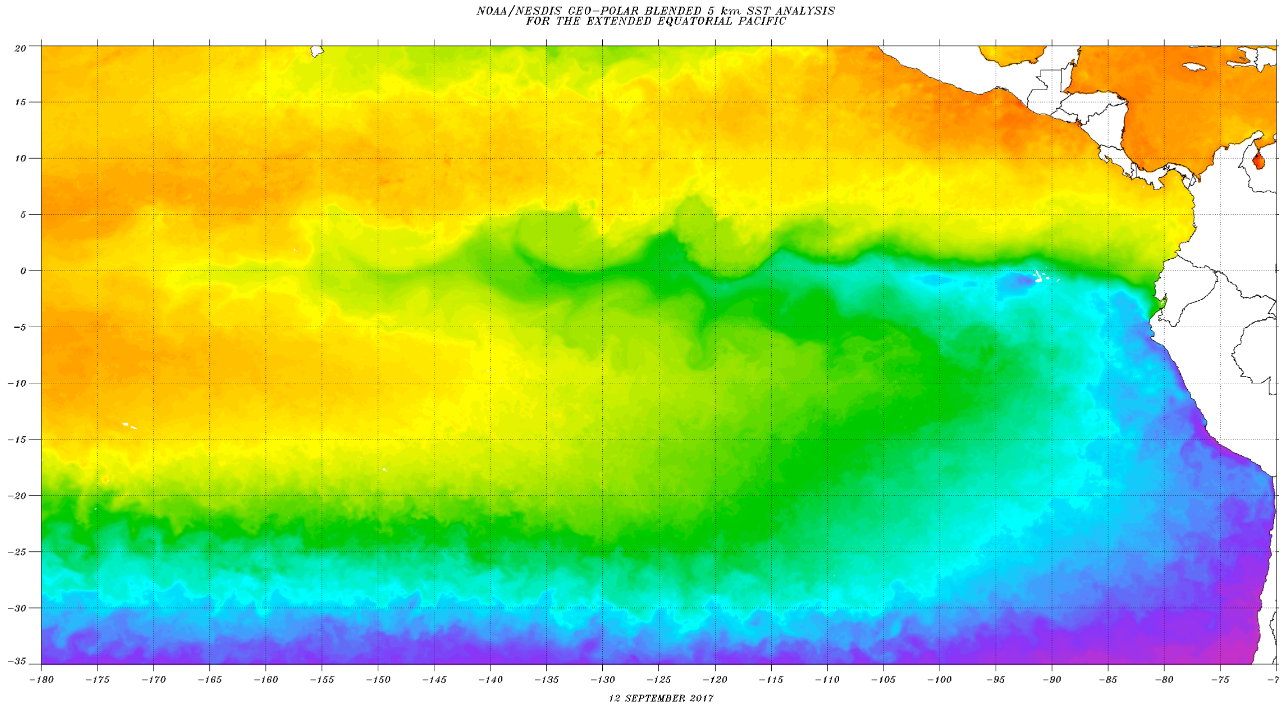


Figure #12 Sea Surface Temperatures for late August 2015 and 2016 (http://www.ospo.noaa.gov/Products/ocean/sst/contour/)



Much cooler conditions led to a decrease in visibility and frequency of sightings of whale sharks around the study area of Darwin Arch. Temperature appears to play an important role in the regional and local movements of the species with the highest frequency of sharks observed when temperatures are between 24-26C.

DISCUSSION AND FUTURE WORK

As we continue to add to the data collected in past field seasons we are looking forward to see how we can maximise our time in the field and improve on the methods of data collection.

Implementing photo ID with the dive operators of the GMR would hugely improve our chances of recapture, not only with animals from Galapagos but globally. Furthermore this data will help ascertain with greater accuracy frequency and total numbers of whale sharks transiting Darwin Arch.

Further blood draw, biopsy sampling and ultrasound will establish reproductive state as well as baseline health and population data such as connectivity / genetic isolation.

A move from towed satellite tags to close to the body or fin mount certainly would improve the deployment success rates but we need to examine the possibility of designing a prototype fin mount tag with increased battery life and more effective transmission power.

Underwater drone surveys will help determine whether the sharks are present at depth when not seen during daily diving activities. Particularly around the full moon and new moon phase when sightings of whale sharks decrease.

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