GALAPAGOS WHALE SHARK PROJECT

FIELDWORK REPORT 2020

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PARTICIPATING ORGANISATIONS:

Parque Nacional Galápagos Ecuador

Galapagos Whaleshark Project

WWF Russell E. Train Education for Nature

save our seas foundation

Galapagos Conservation Trust

Galapagos Shark Diving

OCF Japan Okinawa Churashima Foundation

GSC Galapagos Science Center USFQ · UNC-Chapel Hill

Georgia Aquarium

Planeterra Foundation

Turtle Island Restoration Network — Fighting for a Blue-Green Planet

Marine Megafauna Foundation

Universidad San Francisco de Quito

Figure 1: Darwin Arch by Darwin Island, dive and study site. Photo ©Jonathan R. Green, 2018

THE GALAPAGOS MARINE RESERVE

The Galapagos Archipelago is a group of Islands found 1000 km off the coast of continental Ecuador. It is an archipelago where major currents converge and create the conditions for an abundance of life. The Panama current flows from the north, bringing in warm waters, and the Humboldt current originating in the Antarctic, bringing cold, nutrient rich waters. Together they form the South Equatorial Current which travels from the continental landmass North and then East towards the islands. A submarine current, the Cromwell flows from the West, bringing in more cold, nutrient rich waters which upwell on the islands' platform. These environmental conditions, along with its geographical location at the equator make Galapagos a place like no other on Earth, where a unique collection of flora and fauna can be found. It is the northernmost location on the planet where one can find a penguin, the Galapagos penguin, the only place in the world with a marine lizard , the Marine

Iguana, and where giant tortoises still roam. It is also a region of importance to highly migratory marine megafauna, such as the whale shark.

Whale sharks, Rhincodon typus, are amongst the most highly mobile both vertically when diving and horizontally throughout the Oceans. Although protected by CITES, (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), and listed on the IUCN Red List as Endangered (Pierce & Norman, 2016), their populations are still on decline as they are subject to incidental bycatch by net fishing vessels and are targeted by vessels from Asian regions, particularly China, for their fins and oil.

First described by Dr Andrew Smith in 1828 very little is known about the species. It is known that they are generally solitary and pelagic and have a broad distribution throughout the Oceans between 40°N to 45°S. They are filter feeders relying principally on plankton and spawning events of fish, coral, and marine invertebrates; times when massive aggregations of hundreds of whale sharks, usually juveniles, are known to occur (Heyman et al., 2001; Hoffmayer et al., 2007; Rohner et al., 2015). They are ovoviviparous, giving birth to live pups that as neonates are approximately 55-65cm in length (Schmidt et al. 2010). However, where they give birth and where the pups live for the first years of life is still a matter of discussion. Where they breed, how they navigate the world's oceans, and why the adult females are only spotted in very few particular places.

The population of whale sharks at the Galapagos are one of these unique areas, and the only site in the world where more than 50% are females (99% in the Galapagos, Acuña et al.2014). Adult female whale sharks, ranging between 9-15m length are sighted off the far northern islands of the archipelago, Darwin and Wolf, between June and

December. The sightings suggest that they do not travel there to feed since they have only been sighted with an open mouth twice (Green, J pers. ob. 2012 at Wolf Island and Green, S. pers. ob. 2020 at Darwin's Arch), so what attracts this unique group of whale sharks to pass through this site?

On the 11th August a team of scientists and researchers from the Galapagos Whale Shark Project, Galapagos National Park and Universidad San Francisco de Quito, (Galapagos Science Center), set off for the remote island of Darwin which lies at the northernmost point of the Galapagos Archipelago (Under research permit PC-64-20), to attempt to answer some of these questions.

Figure 2: Diver and whale shark side by side.
Photo ©Jonathan R. Green, 2020

Figure 3: Diver face to face with an adult female whale shark called Nemo.
Photo ©Jenny Waack, 2020

OBJECTIVES

Since 2011 a multi institutional and international team have been studying their natural history, movements and behaviour on a local and regional scale. They have also been carrying out a series of activities to better understand their natural and reproductive cycles and examine the role of the Galapagos Islands and other oceanic island ecosystems, using satellite tags, blood draw, ultrasound, tissue sampling and photo identification.

This season the team went with the purpose of answering further questions about their diving behaviour and navigational abilities, along with continuing blood draw for posterior analysis.

We aimed to deploy a total of 12 satellite tags on 10 individual whale sharks. 8 SPLASH10 tags and 2 double “hybrid” tags that combine a SPOT6 tag with a miniPAT on

the same clamp that is affixed to the dorsal fin. Blood samples would be drawn from as many individuals as possible and all whale sharks sighted would be photographed and / or videoed for photo ID.

Date	Location	Activities
11 August 2020	Itabaca Channel	Departure in the afternoon (16:20)
12 August 2020	Arrival-Darwin	Arriva and kit set up (17:30)
13 August 2020	Darwin	3 dives
14 August 2020	Darwin	3 dives
15 August 2020	Darwin	3 dives
16 August 2020	Darwin	3 dives
17 August 2020	Darwin	3 dives
18 August 2020	Darwin	3 dives
19 August 2020	Darwin	3 dives
20 August 2020	Darwin	3 dives
21 August 2020	Darwin	3 dives
22 August 2020	Darwin	3 dives
23 August 2020	Darwin (Morning)/ Wolf (Afternoon)	2 dives/ 1 dive
24 August 2020	Wolf and Departure	1 dive & departure (9:00AM)
25 August 2020	Puerto Ayora	Arrival to Port

Figure 4:
Expedition dates and activities of the field research trip 2020

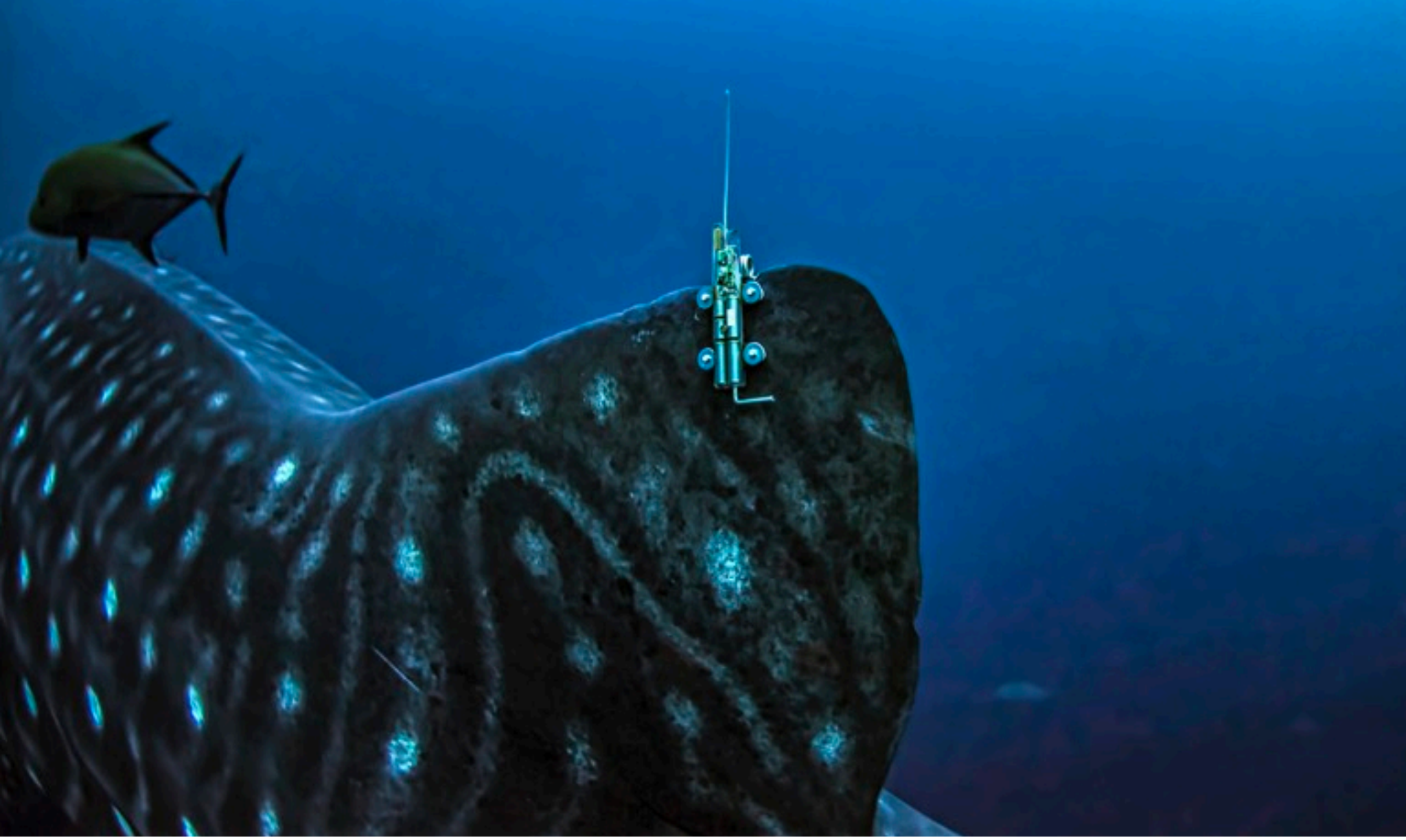


Figure 5: The SPLASH10 - 346B fin-mount tags sit high on the dorsal fin just fore of the apex. This ensures a strong position that will maximise transmissions and reduce risk of removal or loss. Photo © Jenny Waack, 2020

SATELLITE TAGS TYPES

SPLASH 10-346B and SPOT6-257 tags, previously covered with anti-fouling paint for longer duration, were attached to clamps with bolts and nylon pads. The miniPATS were attached to the opposite side of the SPOT6 clamps to create the hybrid fin-mount tag. SPLASH10-346B tags are made to record both vertical and horizontal movements, while SPOTs mainly record horizontal movements, and miniPATs mainly record vertical. By tagging the sharks with both the SPLASH (Figure 6) and the Hybrid tags (Figure 7), we could assure data that would describe a more complete image of the sharks' movements. The fin-mount methodology was first used in 2018 and since then has been selected over towed tags since it has proven to result in much higher levels of retention, longer tracking data and is a far less invasive method of tagging.

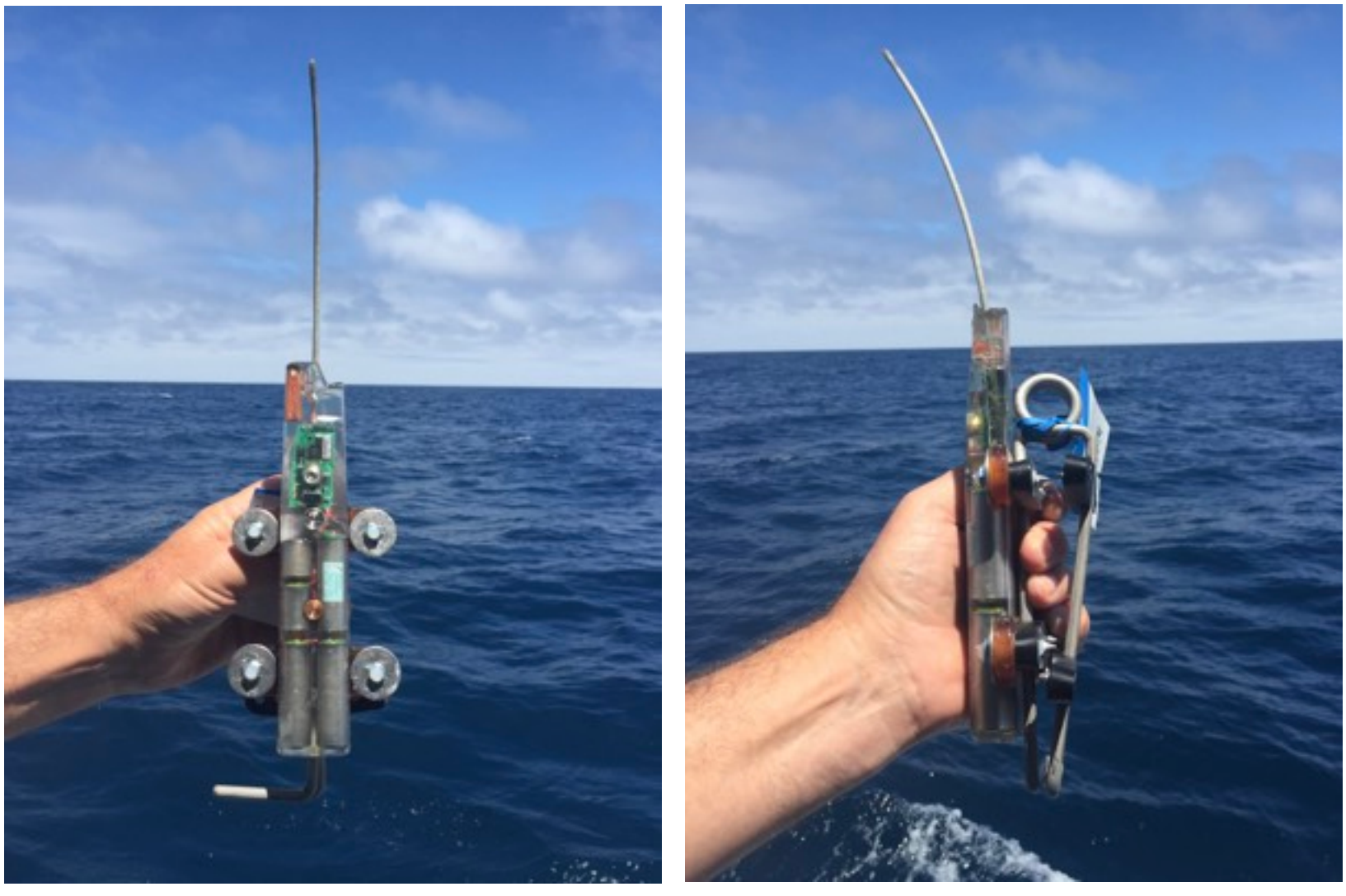


Figure 6: Tags mounted on fin clamps with nylon pads - SPLASH10-346B (Photos ©Sofia M Green, 2020)

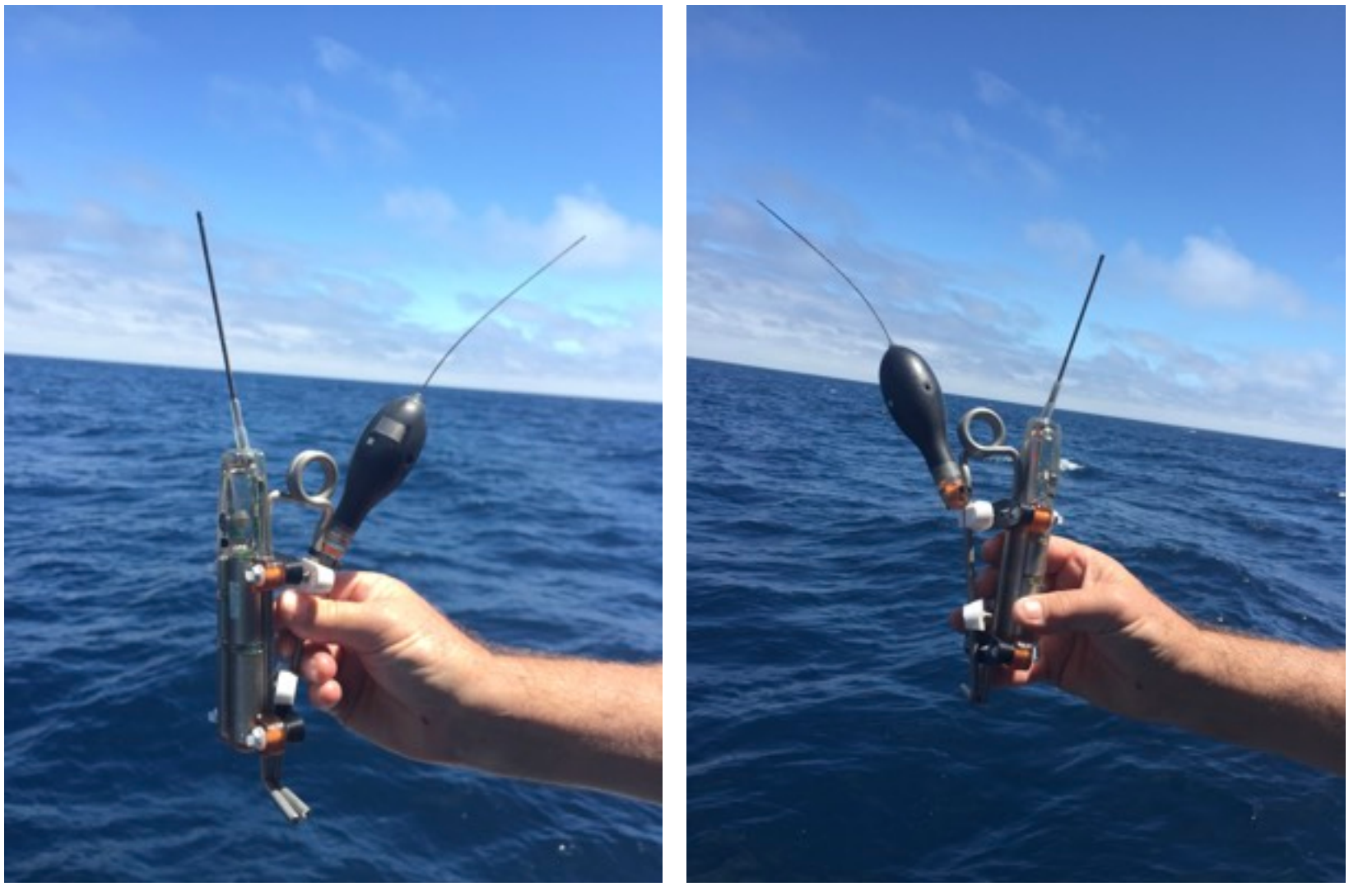


Figure 7: Tags mounted on fin clamps with nylon pads - SPOT6/MiniPAT hybrid tag (Photos ©Sofia M Green, 2020)

Figure 8: Researcher tagging a 13m female whale shark with a SPLASH 10-346B fin mount tag. Photo ©Jenny Waack, 2020

SATELLITE TAGS DEPLOYMENT

All the fieldwork is performed at Darwin's Arch dive site at Darwin Island, Galapagos. A team of ~4 divers undertake 3 daily SCUBA dives with 12 litre tanks of 20.9% oxygen and each dive is within recreational limits. No dive is carried out within less than an hour and a half from each other.

During the dive, the team scouts for whale sharks along the underwater platform. Each diver is separated from the others by the longest safe distance possible in order to improve the team's range of sight underwater. Once a diver spots a whale shark he/she alerts the others with a dive shaker for the team to approach the shark. One team member tags the shark, another takes photo ID, and another will attempt to biopsy the animal and/or take a blood sample. It is important to note that not all procedures may be carried out with every shark. This is dependent on the strength and direction of the currents, sharks' swimming speed, direction and depth, and the shark's reaction. Every

interaction is as un-invasive as possible. As the team is attempting to carry out these procedures, a pre-designated diver acts as the USO, (underwater safety officer), in order to supervise, coordinate and assist other team members, whenever necessary.

Tagging: The diver swims towards the top of the shark and place a SPLASH 10-346 tag bolted to a fin clamp with nylon pads at the top of the dorsal fin, making sure that the wet/dry sensory and antenna face directly upwards, for improved transmission rate and longer tracking time (Figure 8). This clamp will eventually corrode and fall free of the animal.

Figure 9: Researcher tagging a 4 m juvenile male whale shark with a SPOT6/MiniPAT hybrid fin mount tag. Photo ©Jenny Waack, 2020

Figure 10. A National Park Ranger draws blood from the pectoral fin of a ~13m adult female whale shark. Photo ©Jonathan R. Green, 2020

BLOOD DRAW

Materials:

Blood draws are performed using a double syringe with stopcock, a 30cm draw tube and a 16 gauge needle. The double syringe is used so that the initial blood drawn through the tube, which is contaminated with seawater can be separated in one syringe, and for the pure blood sample to be separated in the other. The 30cm tube attachment is used to give the needle more mobility, making the process a bit easier on free-swimming wild whale sharks (Figure 10). Both syringes contain Heparin Sodium solution which serves to prevent the blood from clotting.

The initial processing of the sample occurs directly after the dive, when back on board the vessel. The blood from the

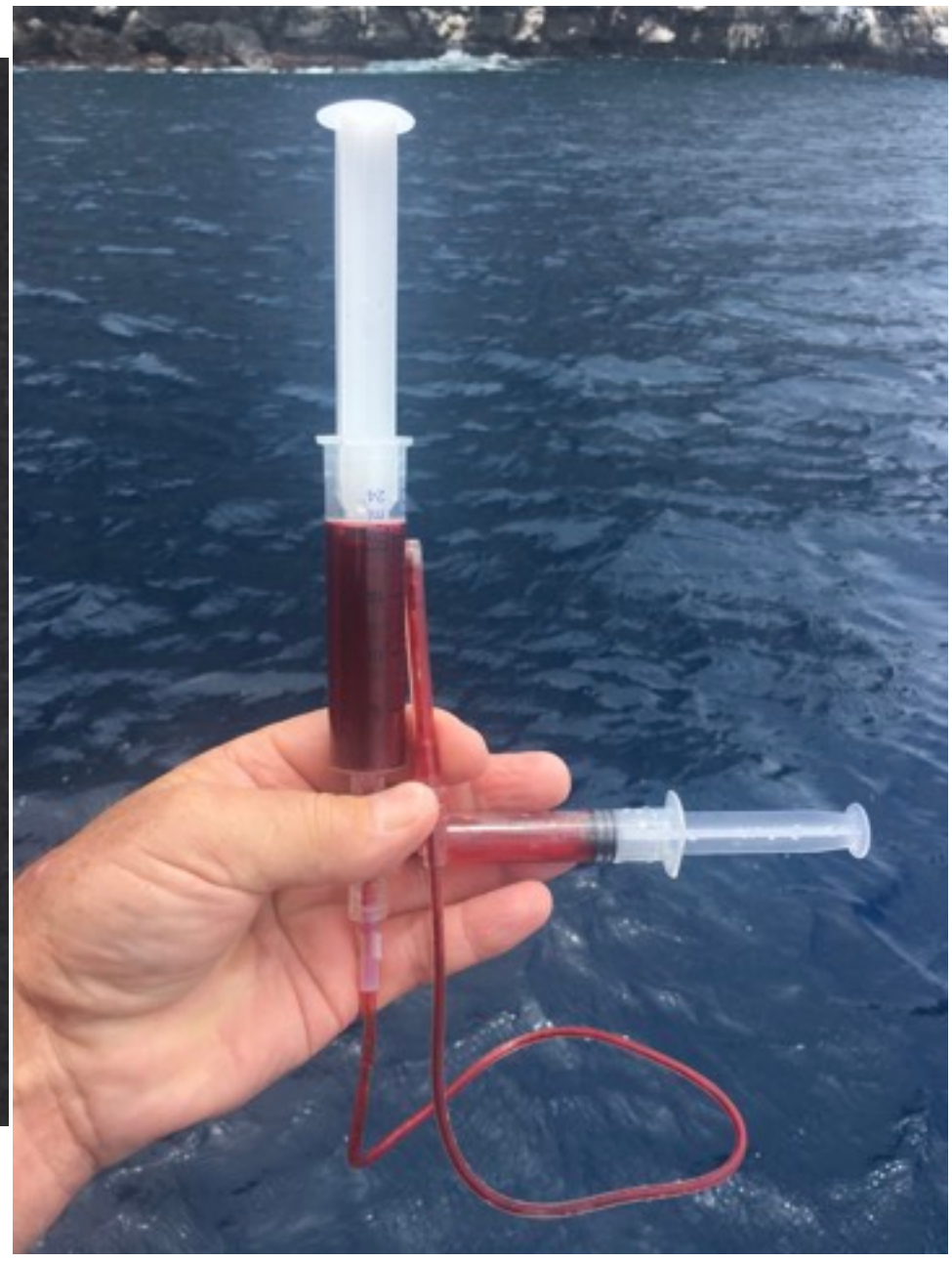


Figure 11 (above left &right):
Blood draw setup using a double syringe with dual stopcocks to allow contaminated blood to be drawn first into the lateral syringe and then by closing the first valve uncontaminated blood can be drawn into the principal syringe. The principal syringe is treated prior to diving with Heparin Sodium solution in order to prevent coagulation of the blood before the divers return to the vessel for centrifuging.

Figure 12 (below): Vials with whole blood, plasma and red blood cells. Placed in cold storage for later analysis.

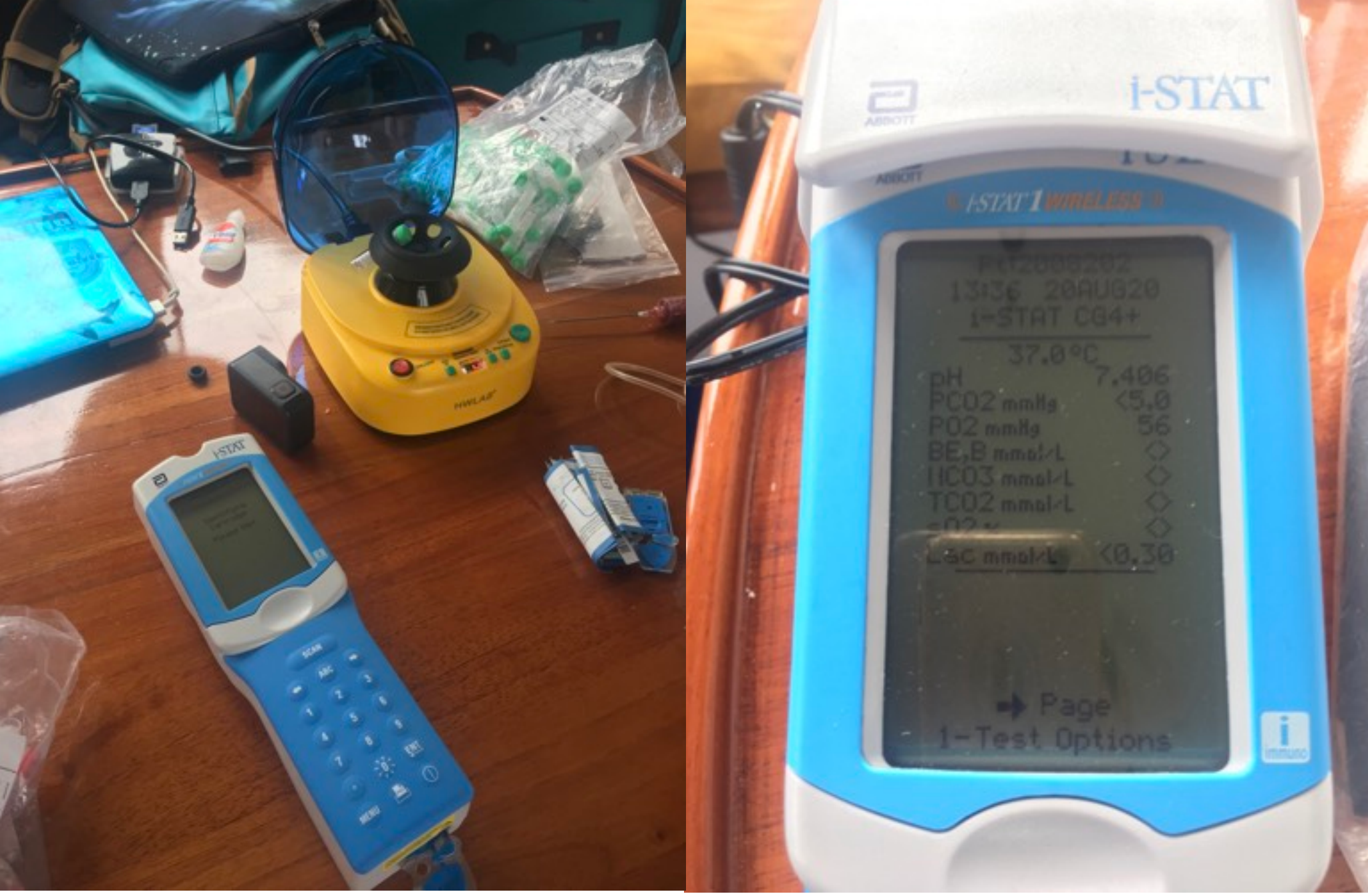


Figure 13: left: i-STAT 300 analyser (which gives blood gas concentrations and lactate acid level) and centrifuge for on board processing and analysis; right: i-STAT results of a female whale shark.

syringe is separated into vials which are then spun in a centrifuge at 4,000 RPMs for 10 minutes. The samples are then further separated into whole blood and plasma. One vial of whole blood is then used for blood chemistry analysis using a handheld iSTAT 300 analyser which gives blood gas concentrations and lactate acid levels. These will be used to determine basic health of the animal. The rest of the whole blood is stored with the plasma samples in the freezer for posterior analysis in the USFQ laboratory.

Blood draws are being undertaken by the team for various purposes. The samples will be analysed for hormone levels of Testosterone, Progesterone and Oestrogen to create baseline data of adult female whale shark levels and at a later time be used to determine reproductive state and the

possibility of pregnancy. Ideally blood must be drawn from as diverse a group as possible from multiple sites around the World. This would serve as a study group to better determine and understand baseline health and in the case of the big adult females, reproductive state and possible pregnancy. Lactate levels may also be used as an indicator of stress. This far none of the individuals that have been sampled show high or unusual levels of lactate which would indicate that the procedures do not have any negative effects on the sharks.

Figure 14: Diver draws blood from the pectoral fin of a adult female whale shark.
Photo ©Jonathan R. Green, 2020

Figure 15. Blood drawn from an 11m adult female whale shark that has been already tagged. A second diver observes and videos the procedure as a third diver takes images for photo ID. Photo ©Jenny Waack, 2020

FIELD WORK

The team attempts to draw blood from as many individuals as possible, by taking into account various factors. For this procedure to be safe, as it is being carried out in the wild, the environmental conditions, the depth at time of sighting, and the whale sharks' initial reaction are closely observed. Blood draws can only occur when the whale shark is swimming in the direction of the current, the current is at a low-medium speed, the initial depth of the encounter does not exceed 20 meters, and the whale shark does not react, (speeding up or visibly moving away from) during initial contact.

While one diver performs the blood draw, another diver will pair up and stay close by as a support diver in case of any eventuality. The safety diver keeps track of the depth and location, since the diver performing the blood draw is usually focused on the procedure. If the whale shark begins to descend into unsafe depths or moves too far away from the dive site, the safety diver will call the other diver off with the use of a dive shaker.

Figure 16. One diver tagges the female whale shark. A second diver observes and videos the procedure as a third diver takes images for photo ID.
Photo ©Jenny Waack, 2020

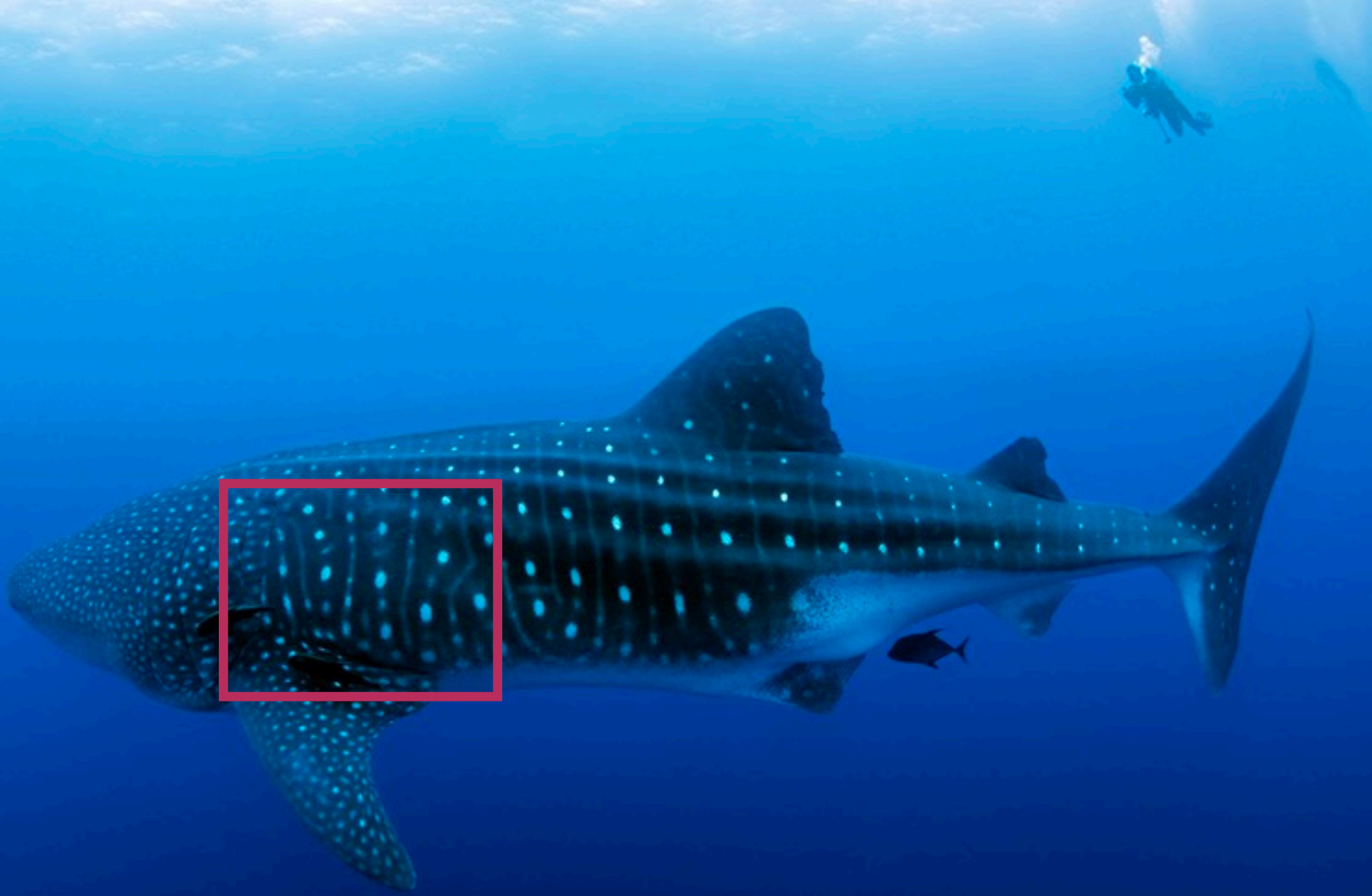


Figure 17: The area shown in red is used for mapping the unique spot patterns for identification. Photo ©Jonathan R. Green 2018

PHOTO IDENTIFICATION

Photo Identification is a passive tracking mechanism. From the 5th gill slit to the end of the pectoral fin, the whale shark's markings make up a unique pattern that serves to identify each shark as an individual. Throughout the 2020 field expedition, 25 different whale sharks were identified through photo ID. After the field work, these images were uploaded to the Wildbook For Whale Sharks (https://www.whaleshark.org), an online database with whale shark photo ID's from around the globe, uploaded by scientists and citizens alike. The database uploads the individual patterns and matches them to similar photos from

the same location and around the world. Besides passive tracking, photo ID allows for abundance and survival studies of whale shark groups around the globe. The whale sharks sighted in the Galapagos are not commonly seen elsewhere and are infrequently sighted again in the archipelago, showing a low lagged ID rate, low residency index (0.6d d.yr -1) , low apparent survival rate (measured though whale shark re-sightings), and low site fidelity (Araujo et al., in prep). However, a few sharks have been re-sighted in the

Figure 18. Spot pattern mapping on the global database for whale shark IDs, Wildbook for Whale Sharks (www.whaleshark.org)

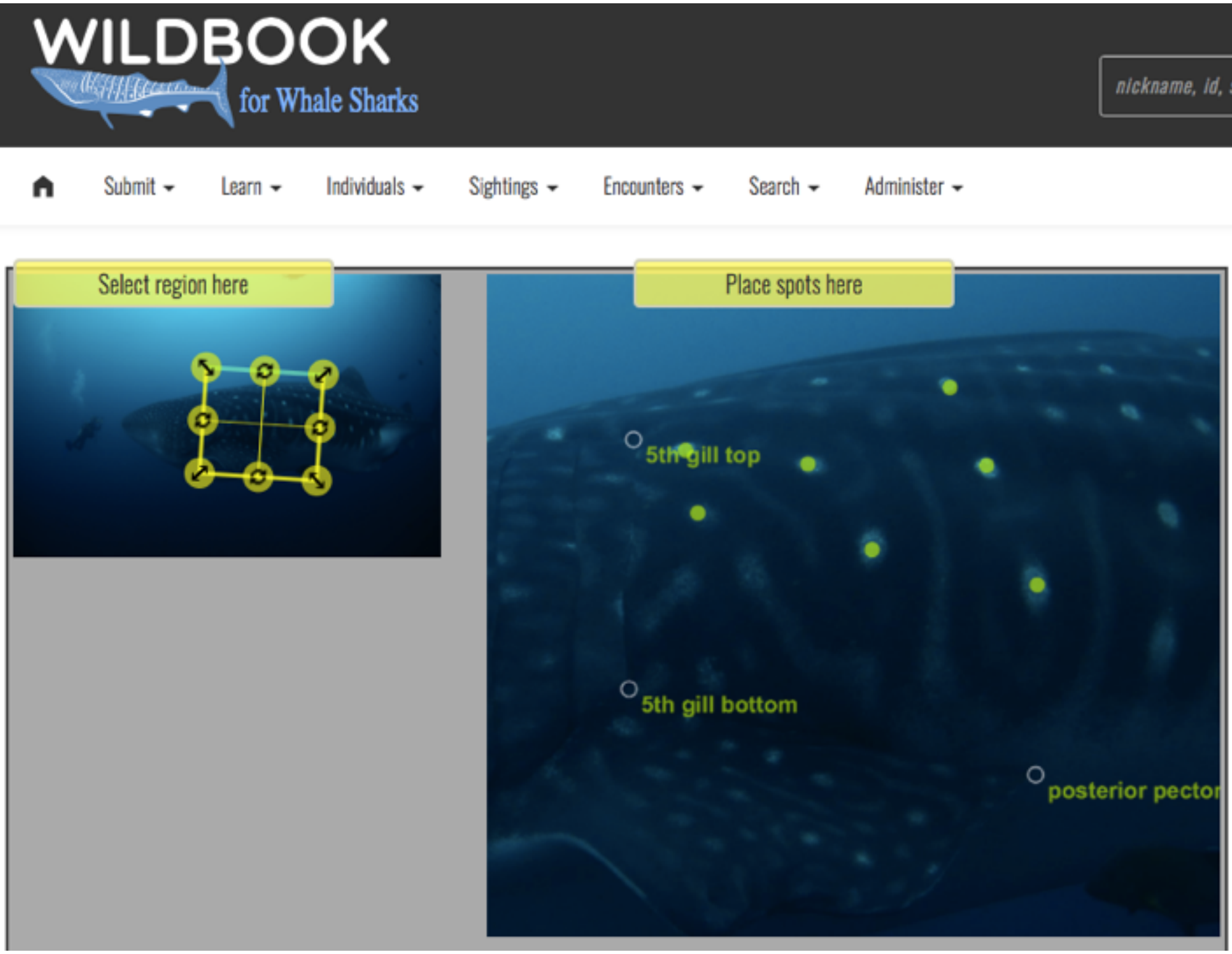


Figure 19: Whale Shark swimming over the platform. ©Jonathan R. Green,2020

archipelago, including a whale shark sighted 12 years after the first photo ID report between 2007 and 2019 and recently a 3 year re-sighting between 2017 and 2020. Over 600 individuals have now been identified in the Galapagos archipelago and as the database grows we will be able to create a better picture of this unique group of whale sharks.

Figure 20: Diver checking the sex of the whale shark which swims up towards the surface. Photo ©Jonathan R Green, 2020

PRELIMINARY RESULTS

1) SATELLITE TAGGING

The research trip, with a duration of 15 days was successful in all its goals. During the 12 days spent at the research site of Darwin Arch, where the vast majority of whale sharks are sighted in the Galapagos, a total of 10 individual sharks were tagged with satellite tags, 8 with SPLASH10 tags and 2 with a hybrid combination of miniPAT / SPOT6 tags and 4 blood samples obtained from 2 individuals.

Of the whale sharks tagged, 9 were adult females between the lengths of 10 – 14m and a single juvenile male of approximately 4.5m. Blood samples were taken from adult females.

6/10 sharks transmitted successfully for a period of time long enough to provide useful data. Four tags stopped transmitting 2-4 days after their tagging (SPLASH # 203637, 38, 39, 44). There are several reasons why this could occur.

Figure 21: Tracks of 10 whale sharks tagged at Darwin Island, Galápagos on August, 2020 expedition.

Whale sharks are deep diving animals and if the whale sharks surpass the ~2,000 meters of depth, the tag implodes under pressure and since the Galapagos Platform is highly oceanic, these depths are found adjacent to the tagging area, making this a likely reason. Tags are also removed by associated species. Other sharks such as Silkies and Galapagos have been seen rubbing against the whale shark's skin and could displace the tag from its position. We believe this most likely occurred to SPLASH # 203638 since three days after tagging this shark, we sighted her from our vessel in the morning, with her tag still on, and saw sharks rubbing on her from the surface. The next time we sighted her was during the midday dive that same day, and she was without tag.

The other six tags gave excellent transmissions which provided useful data to analyse their diving behaviour, their movement patterns, habitat preferences based on environmental variables, and more. Three of these are still transmitting regularly. Not only have they provided important data to further understand their behaviour, they are also contributing to conservation by providing us, and consequently local policy makers, with data about Marine Protected Area connectivity. This information can then be used to support the current projects to expand the Galapagos Marine Reserve and/or support the creation of new protected areas such as the proposed Marine Corridor or Swimway between the Galapagos, Ecuador and Cocos Island National Park, Costa Rica.

Figure 22: Whale shark swimming close to the research team. Photo ©Jonathan R Green, 2020

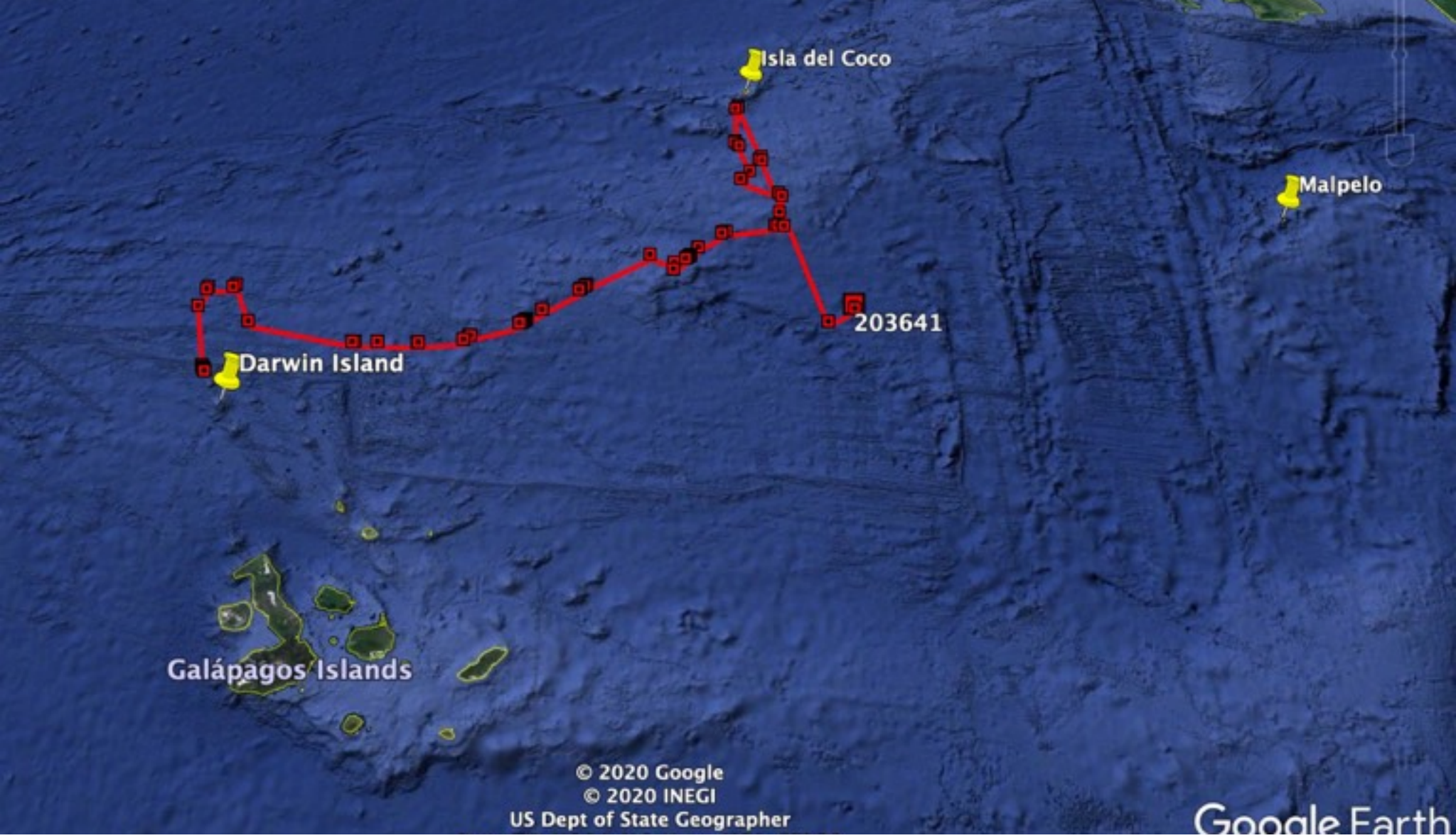


Figure 23: SPLASH #203641 recorded traveling between Galapagos Marine Reserve and Coco's Island, Costa Rica through the Galapagos-Cocos marine corridor.

SPLASH # 203641, also known as "Coco" travelled between these two marine protected areas, highlighting the importance of the Galapagos-Cocos marine corridor between them, used by several marine megafauna species such as Hammerhead sharks, Galapagos sharks, turtles, and others and recently named a Hope Spot by Mission Blue as a future area of conservation (May 12, 2020). Her track is the first record of a whale shark also making use of this corridor (see Figure 23) and will be used to support the creation of this MPA.

SPLASH # 203642, named “Nemo” because of her clipped left pectoral fin, is another whale shark contributing data to conservation. Her track is the first recorded track of a whale shark leaving the GMR and returning to the archipelago after 80 days and after a journey of around 1,600km. She was registered not only returning to the archipelago, but to the tagging site, providing a full migration track (Figure 24). Her use of the Galapagos platform highlights the importance of the protection of this area, and the need to expand it to protect its surrounding waters, also used by these species and other highly mobile marine megafauna.

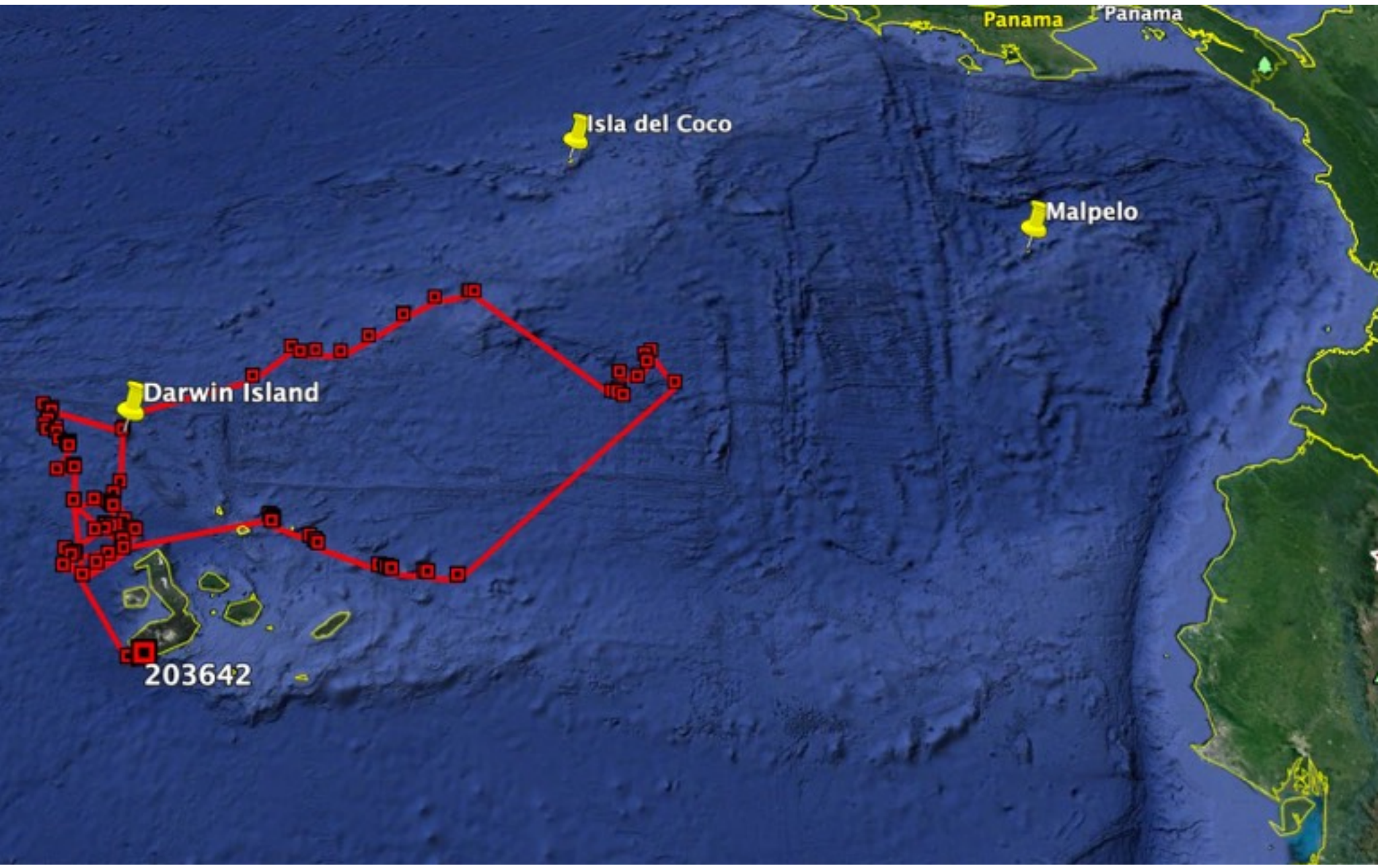


Figure 24: SPLASH # 203642’s track provides a full migration record back to the GMR.

Figure 25: SPLASH # 203643 "Johanita" during the three months since she was tagged.

SPLASH # 203643, named Johanita, headed north towards the Galapagos Rift Zone (Figure 25). This is the most common route following their tagging at the Arch of Darwin. Her track then went west until she looped back along the Cocos Ridge before heading south towards the Ecuador / Peru northern border. Her track also shows that she spent a considerable time in the marine corridor between Galapagos and Cocos. Her last transmission was on the 16th November but it is not uncommon for the adult female whale sharks to dive and remain undetected for weeks at a time as they head to the Peru / Chile trench area off the continental shelf of Northern Peru.

Of the tags that are still regularly pinging, SPOT #203645 is of special interest (Figure 26). This is the only juvenile whale shark and the only male tagged this season. He was tagged with a miniPAT/SPOT hybrid fin mount tag; his data serves to show how his movements, based on age and gender, might differ from the adult females. Unfortunately his miniPAT released on the 31st of August, only 13 days after being tagged, meaning that its diving behaviour can only be analysed up to that date. However, his horizontal movements are still highly relevant and the project will aim to tag more juveniles and hopefully more males in the future to analyse whether they follow a different pattern of movements than the adult females more commonly sighted at Darwin's Arch, Galapagos.

Figure 26: Track of the only male juvenile (SPOT #203645/ MiniPAT # 184033) tagged this season.

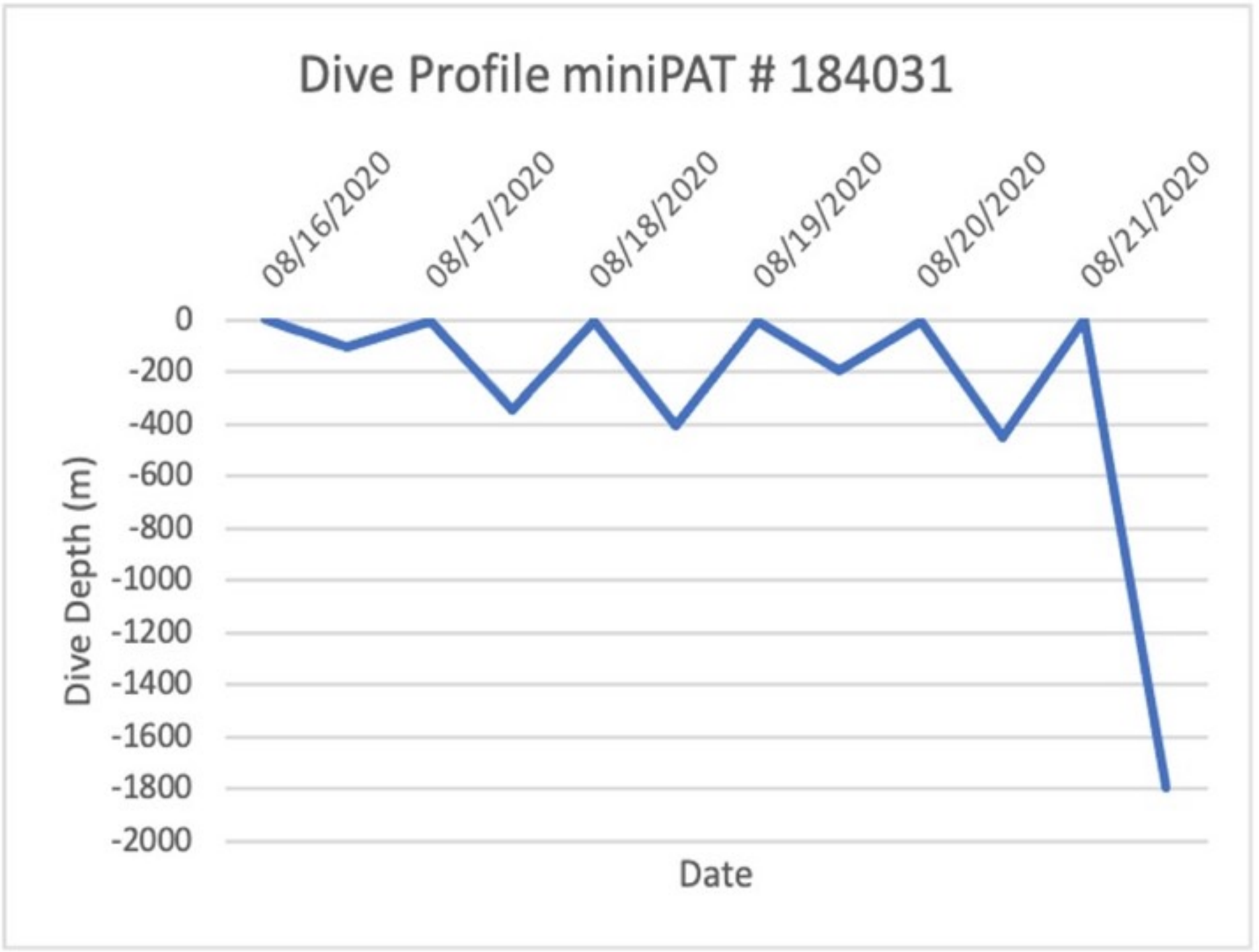


Figure 27: Dive profile for 10m female whale shark tagged with miniPAT #184031.

The two miniPATs deployed this season released soon after the tagging period (Figure 29). MiniPAT # 183031, which had been tagged alongside SPOT6 # 203646, released 5 days after the 10m female whale shark had been tagged. The tag was released due to a shark's deep dive to a depth of 1798 meters (Figure 27). Her SPOT tag stopped pinging at this time, mostly likely crushed by the pressure. On the other hand, miniPAT # 184033, deployed alongside SPOT6 # 203645, on the juvenile male mentioned above, seems to have released 12 days after the tagging occurred due to the shark spending a long period of time at the surface. Before having released, the tags data shows his deepest dive to a depth of 728m (Figure 28). His SPOT tag is still currently pinging 100+ days after tagging.

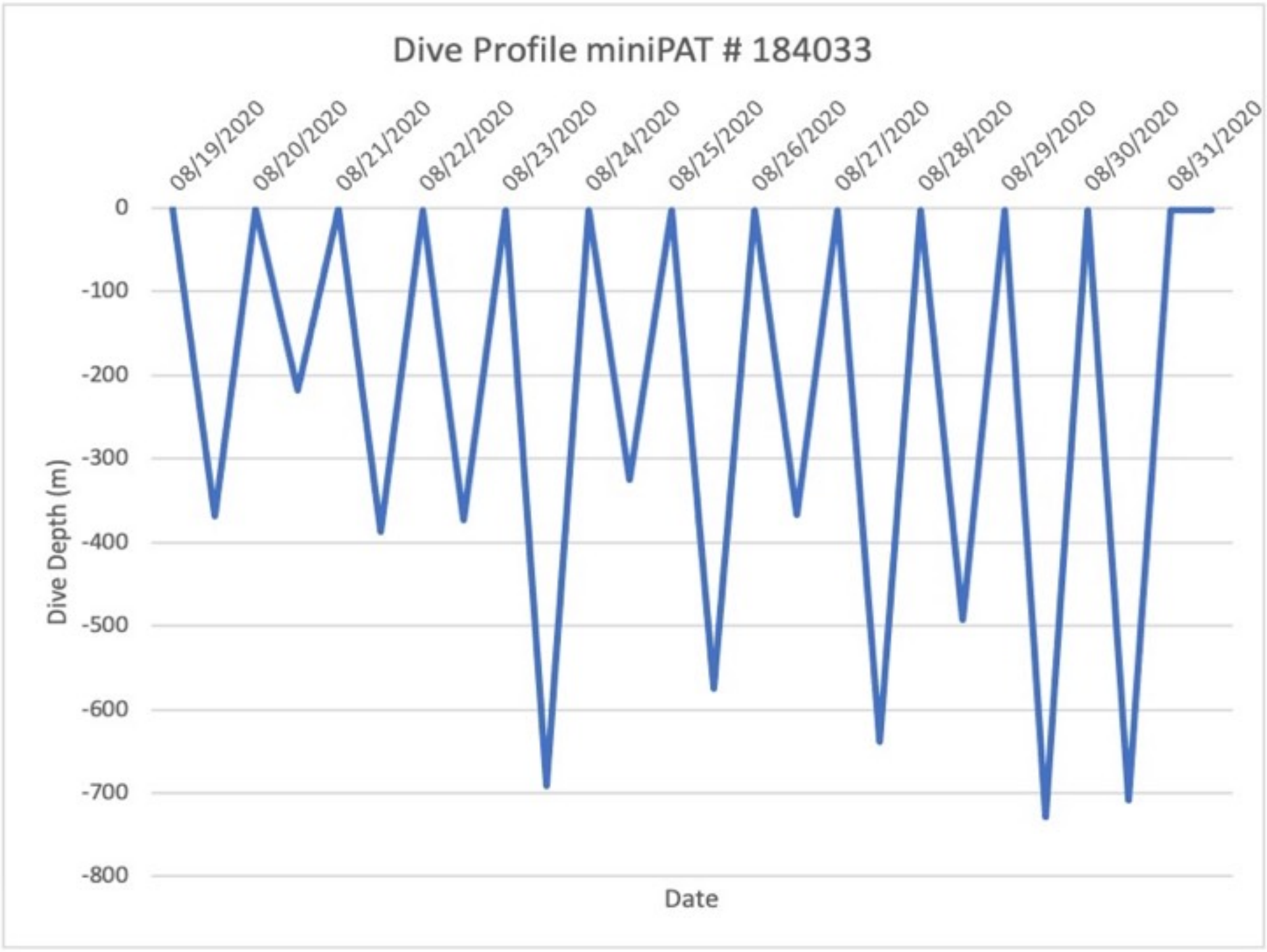


Figure 28: Dive profile for 4.5m male whale shark tagged with miniPAT #184033.

PTT	Serial	Decoded As	Last Decode	Voltage Range	Estimated Uplinks	Passes	Messages	Locations	Deploy Date	Release Date	Release Reason	Release Depth	First Data to Release	Fastloc Snapshots
184031	20P0758	MiniPAT	09-Sep-2020 19:42:55	3.48v to 3.22v	26,624 to 26,752	521	4,105	514	16-Aug-2020 13:16:00	21-Aug-2020 07:00:00	Too Deep. Pin was intact at the time of release	1688±8 meters	4d 19h	---
184033	20P0762	MiniPAT	22-Sep-2020 17:18:53	3.46v to 3.09v	30,848 to 30,976	608	4,860	600	19-Aug-2020 17:08:00	31-Aug-2020 05:00:00	Floater. Pin was intact at the time of release	0±8 meters	11d 13h	---

Figure 29: Summary of miniPAT results from the Wildlife Computers' Data Portal.

Figure 30: Two whale sharks sighted at the same time. Photo: ©Jonathan R Green, 2020

PRELIMINARY RESULTS

2) BLOOD DRAWS

During this year's field expedition, the team managed to undertake four individual blood draws, which were later noted to be from two shark individuals matched at the surface with their photo IDs. The iSTAT 300 results are noted in Figure 31. The 5th sample was used to test the iSTAT machine with "leftover" blood from a syringe with possible seawater contamination, which is why its results of partial oxygen are significantly different than that of the others.

The lactate levels were analysed for indicators of stress that might be caused by our research activities. This far none of the individuals that have been sampled show high or unusual levels of lactate which would indicate that the procedures do not have any negative effects on the sharks.

Sample ID	Trial #	Date & Time	Temp (°C)	pH	PCO2 (mmHg)	PO2 (mmHg)	BE,B mmol/L	HCO3 mmol/L	TCO2 mmol/L	sO2%	Lac mmol/L
GD200820-3	1	20/08/2020 13:16	37	7.424	<5.0	49	NULL	NULL	NULL	NULL	<0.30
GD200820-3	2	20/08/2020 13:23	37	7.435	<5.0	53	NULL	NULL	NULL	NULL	<0.30
GD200820-3	3	20/08/2020 13:36	37	7.406	<5.0	56	NULL	NULL	NULL	NULL	<0.30
GD170820-3	1	21/08/2020 13:30	37	7.391	<5.0	90	NULL	NULL	NULL	NULL	<0.30
GD170820-3*	2	21/08/2020 17:28	37	7.355	<5.0	22	NULL	NULL	NULL	NULL	<0.30

Figure 31: August 2020 iSTAT 300 results from 4 blood draws of 2 individual whale sharks.

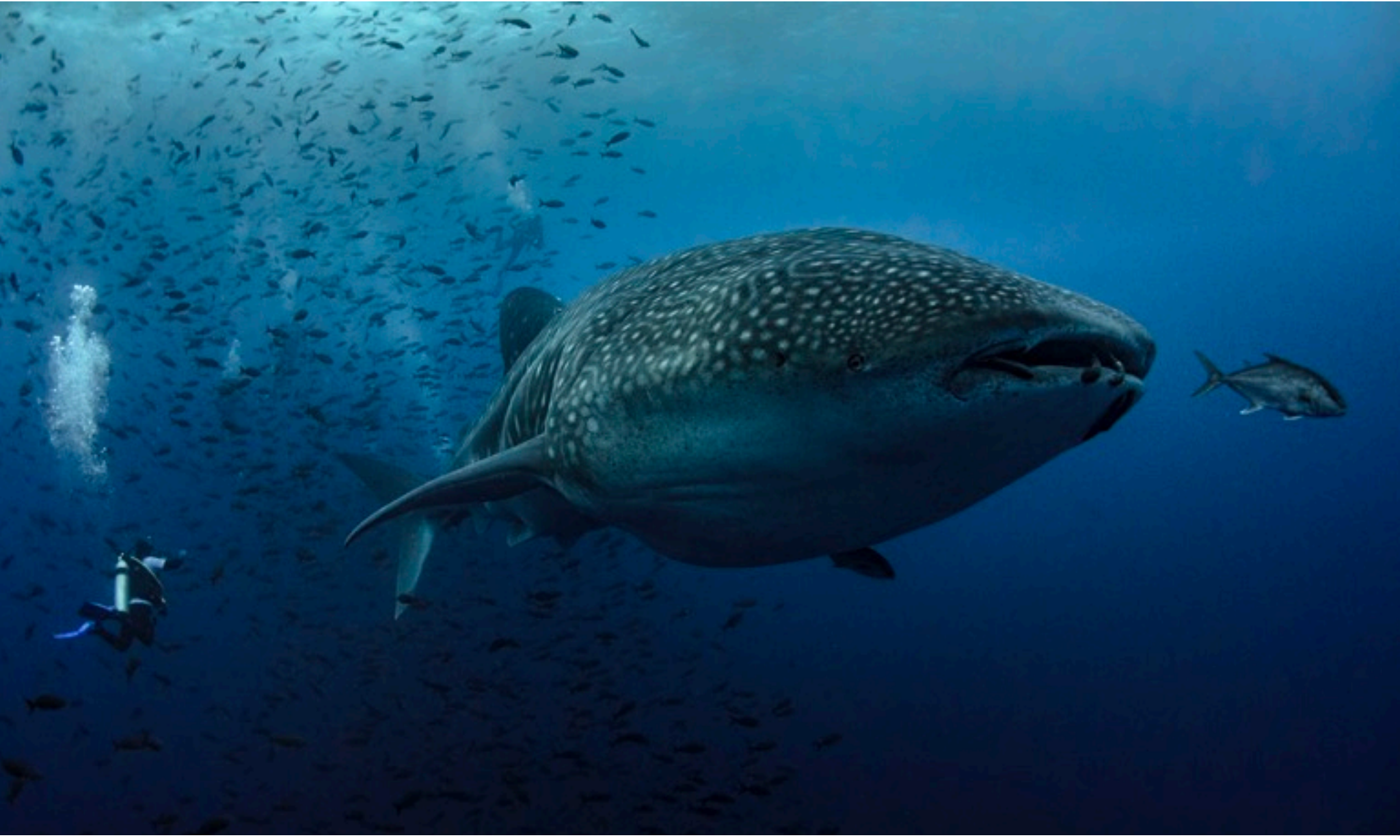


Figure 32: Whale shark swims straight towards the divers. Photo: ©Jenny Waack, 2020

CONCLUSIONS & OBSERVATIONS

Despite the challenges of carrying out field work during a global pandemic we achieved our goals and the overall data thus far from the satellite tags has proved invaluable in our endeavour to support proposals for the expansion of the Galapagos Marine Reserve and the proposed establishment of a marine protected corridor or Swimway between Galapagos and Cocos Island.

The track of “Coco” #203641 demonstrated irrefutably the connectivity between the two oceanic island ecosystems. Previous data such as acoustic tag records from both sites showed clearly that certain species were regularly travelling between the areas but the whale shark satellite track is a very graphic form of proof.

The round trip or return migration made by “Nemo” #202642 helps reinforce the importance of the Galapagos Marine Reserve in the regional movements

of whale sharks. In a period of 80 days she returned to Galapagos to pass by Darwin Arch. What still remains a mystery is the precise reason for the whale sharks to hone in on this particular point. Hypotheses include the geological formation as a way point between areas of high importance to natural cyclical needs such as feeding and breeding areas, a point of unique geomagnetic character which might be used for orientation or the destination, specific or general, for birthing. The latter would certainly seem supported by the fact that over 99% of the whale sharks sighted here are adult females, the dearth of males and the additional fact that the sharks do not appear to be feeding at the time of frequenting Darwin Island.

The very short deployment times of both of the miniPATs confirms the need to move completely away from this type of tag and the benefits of the SPLASH10 - 346 tag as the most efficacious for our needs and purposes until a tag that can withstand greater depths is developed.

SPOT6 #203645 which was kept back after we had deployed all the other tags with the intention of tagging a juvenile. This was achieved as a very small, (for the Galapagos), male ~4.5m, was the last tag deployed and has given a very extensive track up to the date of writing. Notable as the shark reached the northernmost point of any of the individuals we have tagged so far and is currently about to pass the southernmost point. It is easily conceivable that juveniles do not replicate the extreme deep dives of the adults and that unless the tag were to become fouled or the shark meet an untimely end then we might achieve one of the longest tracks both in time and distance. His last transmission was on the 9th December, 350nm west of the coast of Peru, South America. During the more than 115 days since leaving the relative safety of the Galapagos Marine Reserve this individual has been constantly in areas of high fishing pressure. Using Global

Fishing Watch at https://globalfishingwatch.org/map/ we are able to see in real time the potential threats as the whale sharks roam (See figure 33).

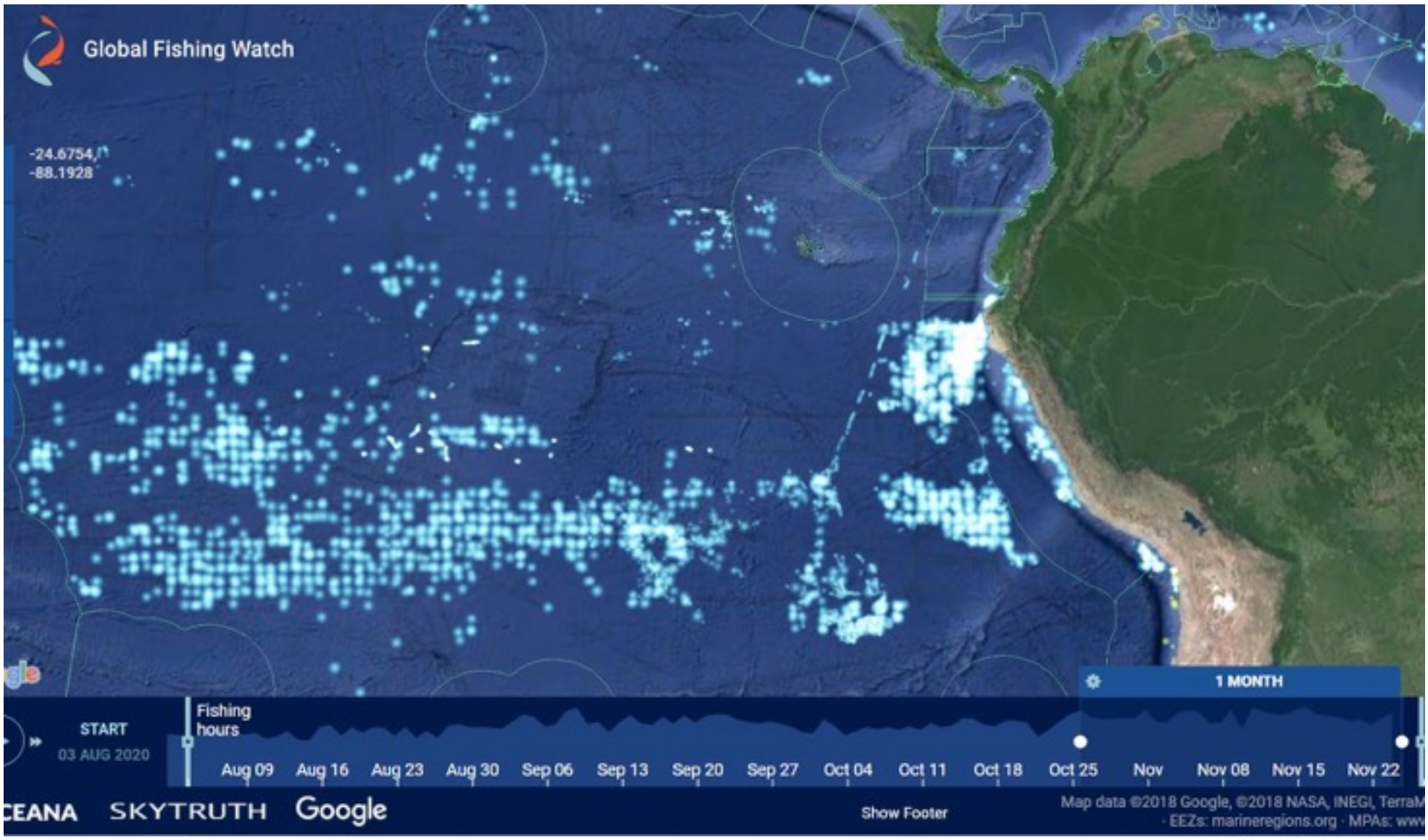


Figure 33: A screenshot of the fishing activities since the tagging trip in the Eastern Tropical Pacific. Each small point represents fishing activity and the larger spots are multiple vessels or activities. White patches show constant fishing activity. Courtesy ©2018 Google, ©2018 NASA, INEGI, TerraMetrics

The tracks this season were not altogether similar to previous years. The ranging further north of around 50% of the tagged sharks would seem to be related to the anomalous SSTs (Sea Surface Temperatures) associated with a Niña event. This occurs every few years when SSTs are generally lower than normal along the ITCZ and throughout the region of the Eastern Tropical Pacific. La Niña events are considered the “flip side” of El Niño Southern Oscillation, (ENSO) when superheated surface waters subject the Galapagos and the entire region to much hotter temperatures than usual and the cold currents of

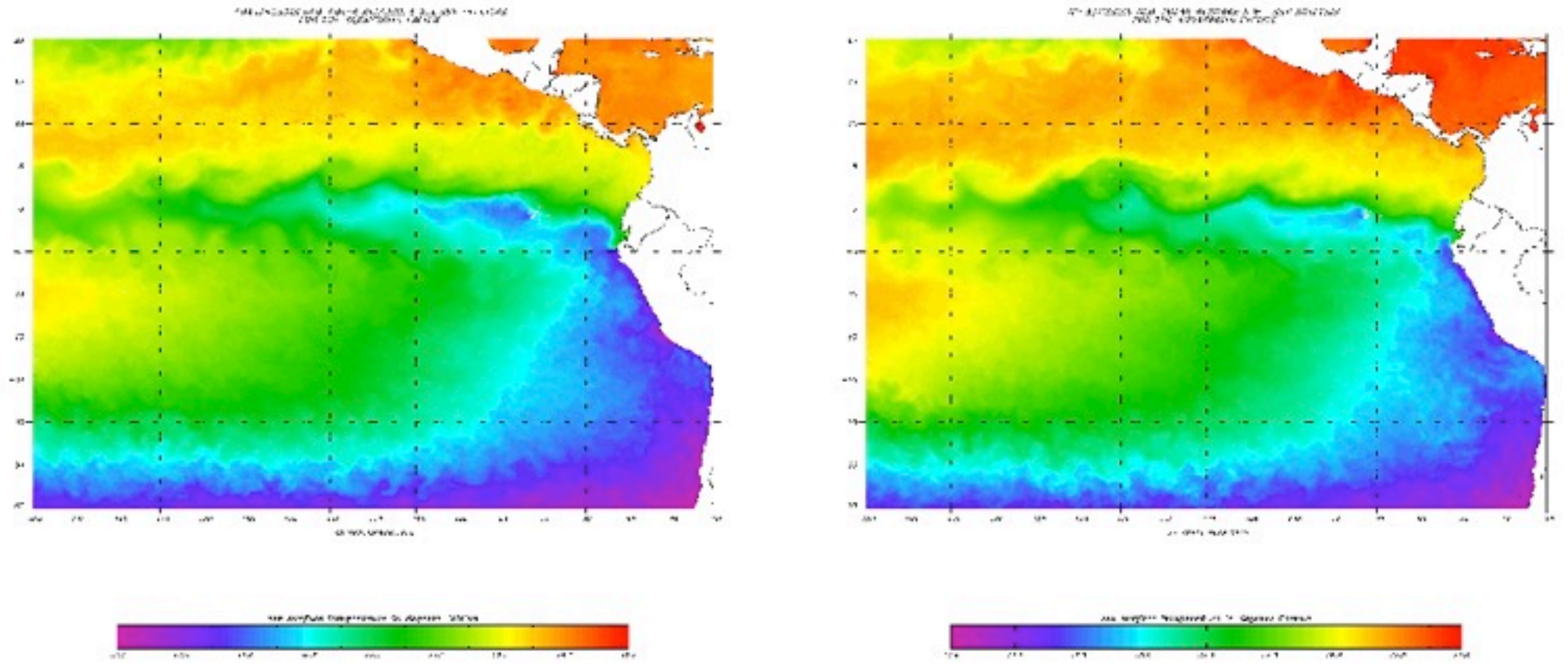


Figure 34: Sea Surface Temperature charts NOAA / NESDIS from August to November 2020 showing strong cool season with marked Cromwell and Humboldt current upwelling that persists in the Eastern Tropical Pacific area.

nutrient rich waters that originate in the Southern Ocean, the Humboldt and Cromwell currents cease to up well. This produces a die out of many species starting with the uni and multicellular flora and fauna, plankton, that are the basis of the food chain and with resulting die outs all the way up to the apex predators and pelagic filter feeders such as whales and whale sharks. Those species that can do so move, migrate and relocate temporarily or permanently if open niches are available. The reverse might happen if species then return or arrive to the Galapagos, with such arrivals being temporary or permanent if they are able to establish and survive. Species displacement often occurs at this time, again temporary or permanent and an equilibrium is reached within the community, habitat and ecosystem, until a similar event might occur.

Following the success of our field trip last year 2019 with the highest level of tag retention yet recorded, 100%, we had hoped that at least one of the whale sharks might give us either a year of data or a round trip returning to the GMR. The SPOT6 / miniPAT #184027 which was a juvenile female whale shark appeared to be headed back towards Galapagos in April of 2020 when suddenly she did an about turn back west. She had been called “Hope” or “Esperanza” in Spanish due to her adoption by donors to the Planeterra Foundation. We followed her satellite movements with great interest until she stopped transmitting on the 22nd May, 2020 (Figure 35). Although this is not unusual, her transmission indicated she was regularly at the surface. Whale sharks that we have tagged have often spent extended periods of time without transmitting so initially we were not overly concerned. After a number of weeks since her disappearance and with growing concern that she might have deep dived and crushed the tag or somehow the tag had been dislodged we looked more closely at her last

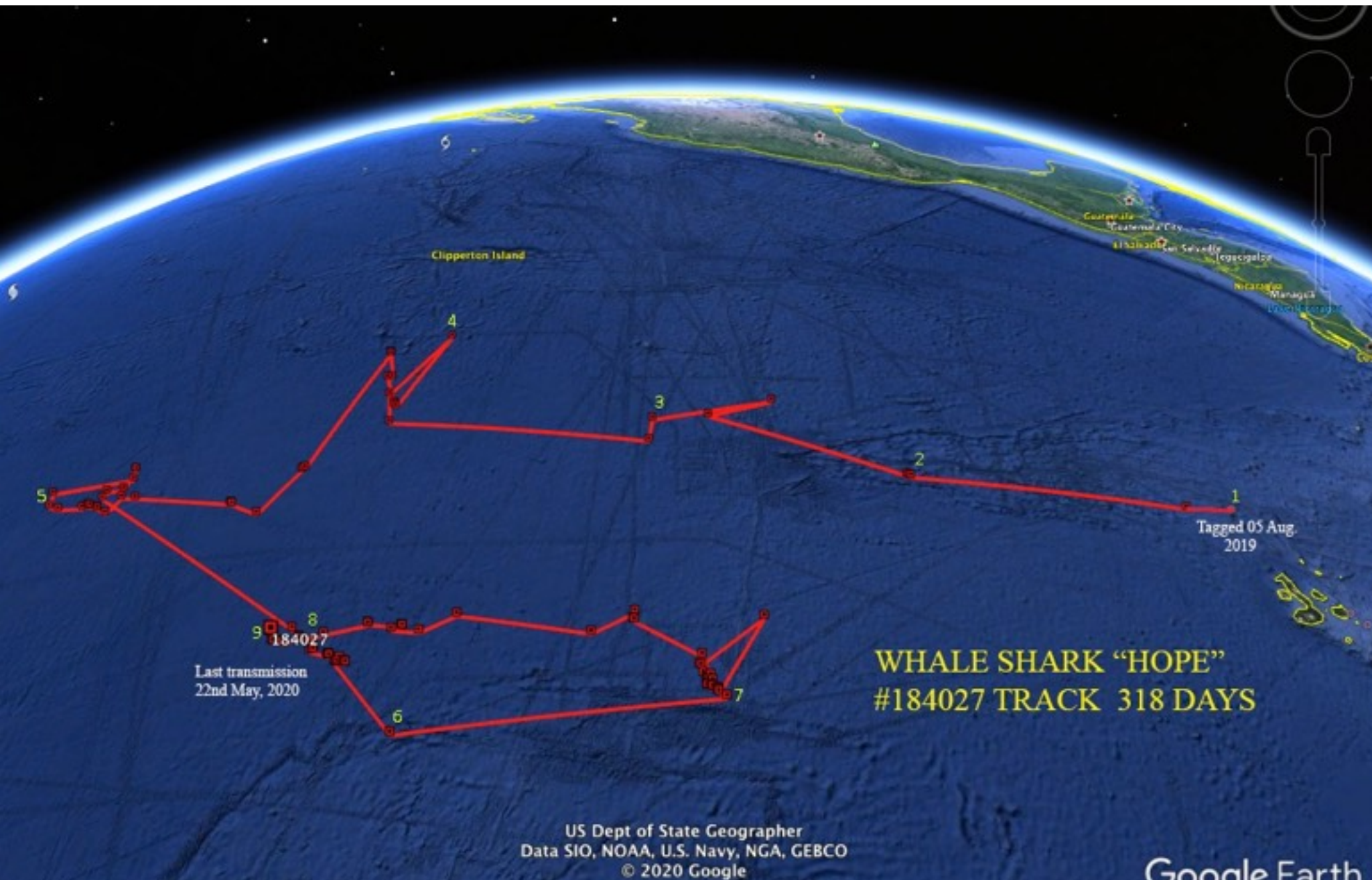


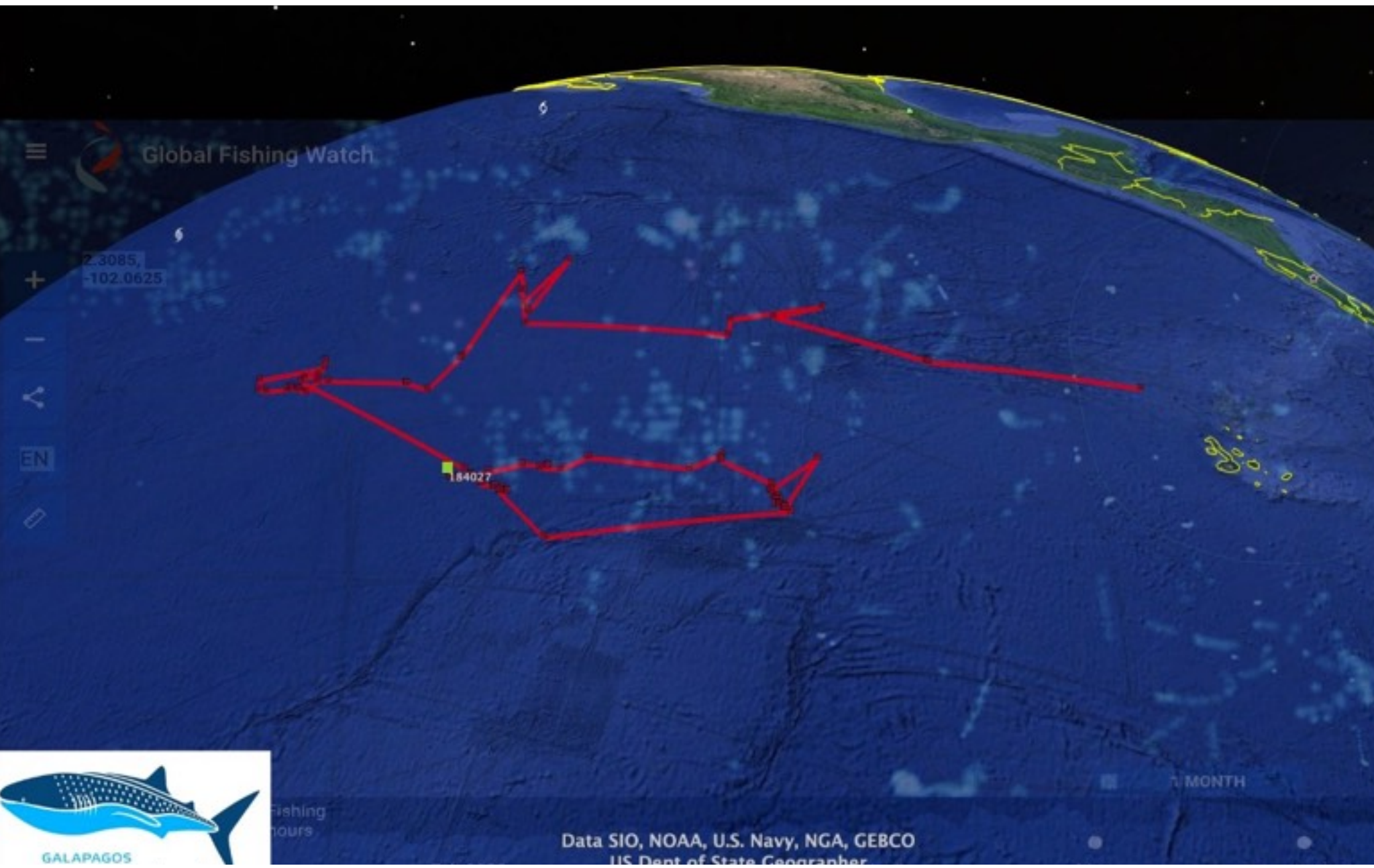
Figure 35: The track of "Hope" #184027 until her last transmission on May 22nd, 2020 in an area of intense fishing activity

movements. Her last two transmissions were just 32 minutes apart and during this time she had travelled a distance of approximately 3.8nm. This could be satellite error but if true her speed would be between 6-8 knots per hour, a figure far too high to be a swimming whale shark that might average 1.5 knots per hour with a maximum speed of around 3 knots. Her position was then compared with fishing activities in the area at the time of her disappearance using Global Fishing Watch and we were able to see that she had been constantly swimming through areas of extremely intense fishing for much of the time she was in international waters and at the time of her last reported position (Figure 36). Although we will never know for certain it would appear likely that she fell victim of the netting vessels that are year round harvesting all and any species of sharks for the, mainly Asian, markets for shark fin

soup. A juvenile whale shark of a few tones would not be a difficult catch for these vessels.

The subsequent news resulting from a reTweet by the Governor of the Galapagos Islands, Norman Wray, was a viral worldwide demand to know more about “Hope” and her species. Whilst her potential loss to this industry is of huge concern the media reaction has perhaps opened up much discussion about IUUF, (Illegal, unreported and unregulated fishing) that is depleting the Oceans of life, and hopefully raised global awareness of this dire situation that must be addressed if we are not to witness the extinction of the vast majority of marine species in the next decades.

Figure 36: “Hope’s” track overlaid on fishing efforts of May 2020 as reported by the Global Fishing Watch.



We did see evidence of fishing activities in the form of three shark species, Galapagos, Silkies and Hammerheads all with hooks in the mouth or even the eye, (see Figure 37) resulting from Long Line fishing. Although illegal in the GMR this activity is increasing both with the local fishing groups and those from mainland Ecuador. Artisanal long lines are frequently found and taken out of the ocean by dive boats operating in Galapagos: https://www.msn.com/en-us/weather/video/galapagos-guides-work-tirelessly-to-free-sharks-from-illegal-fishing-gear/vp-BB19RznP

Figure 37 (above & below): Hammerhead shark swims past with a hook and line attached to his eye. (Screenshot captures ©GWSP)

Figure 38 (right & below): Screenshots courtesy of video- Galapagos Sky Dive Vessel and Dive Masters.

We also found Fish Aggregation Devices, (FADs) that are composed of a net with a bamboo raft which has a barrel usually full of decomposing bones from a cow or similar hanging underneath the raft and attached to a radio buoy so its position is known. This is then set to drift through the Reserve, attracting primarily sharks that are then caught by longlines that are set nearby. These often become entangled in coastal areas such as the one the GWSP team found in Shark Bay on the 23rd August, 2020, whilst retrieving an acoustic receiver (See figure 39).

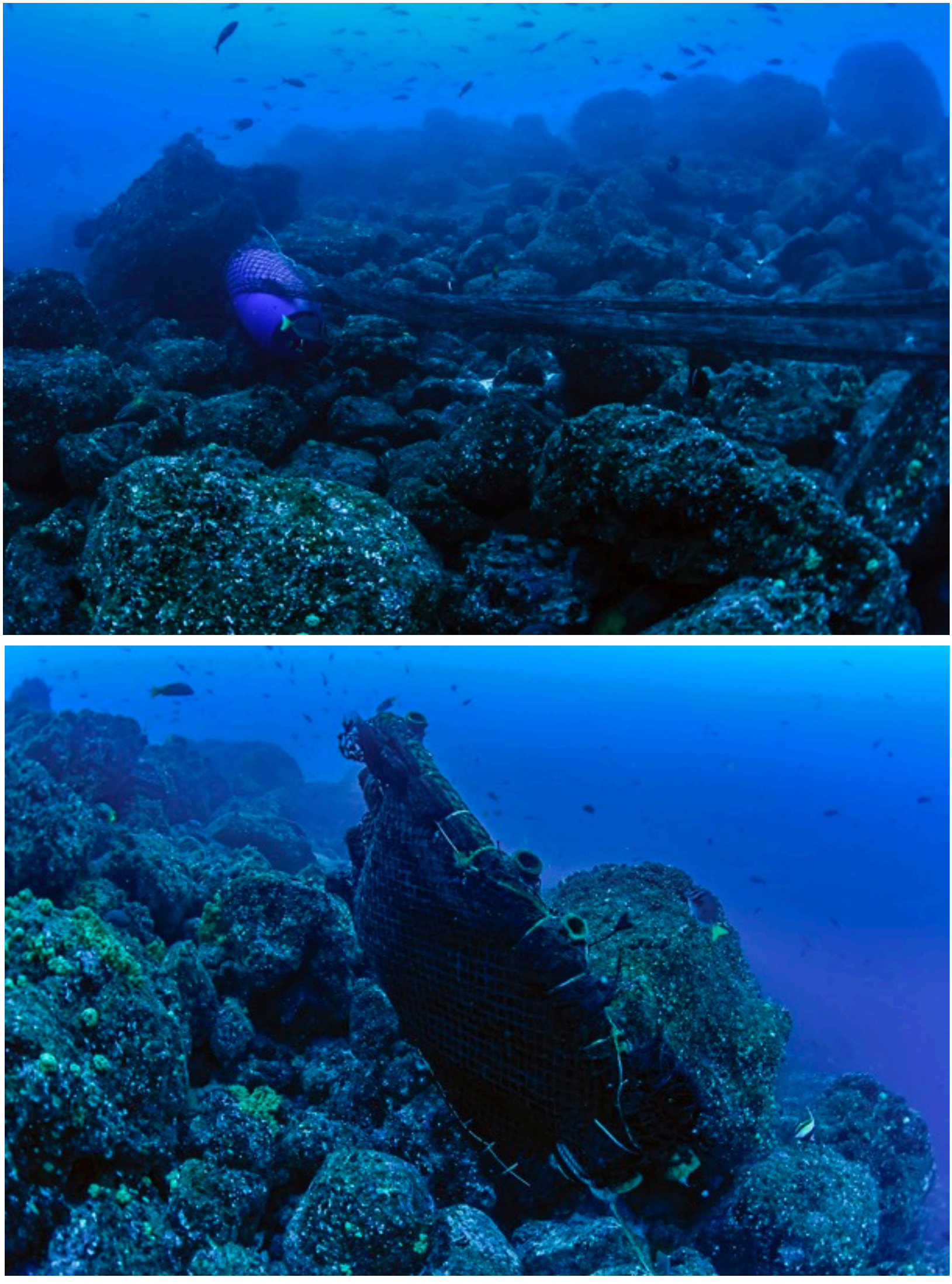


Figure 39 (above & below): FAD found entangled on rock and coral slope, Shark Bay, Wolf Island. Photo: © Sofia M Green, 2020

Figure 40: Divers recording the whale shark swimming by and taking photo identification images. Photo: ©Jenny Waack, 2020

Since we began the tagging program we have become increasingly aware of the associated species and relationships that exist between whale sharks and other shark species. With the towed tag deployment we suffered huge losses of up to 60% of our tags that we assume were removed by other shark species either as part of a cleaning behaviour or simply mistaking the tag for prey. Particularly evident is the association between whale sharks, Silkies, Galapagos and Black tip sharks. The latter three seem to use the whale shark as a “rubbing” or cleaning station, presumably to remove parasites from the skin of the smaller shark. Whether any benefits from this for the whale shark exist is not known (See figure 41).

Galapagos sharks have also been observed at times in considerable numbers, 5 - 10 but displaying different behaviour to the other associated sharks. On various occasions when team members approach the whale shark they accompany, they react in a “territorial / aggressive”

Figure 41 (above): Silky shark rubbing against the head of an adult female whale shark. Screenshot from video GWSP

Figure 42 (below): Black tip shark accompanying an adult female whale shark. Screenshot from video GWSP

posturing, approaching divers with dipped pectoral fins and very directly. They also appear to be in tight formation close to the cloacal area of the whale shark (see figure 42 & 43). We will continue to observe this behaviour and hopefully note any indications that this could be prompted as an olfactory / chemical reaction to a female whale shark that might be at a particular stage of reproductive cycle such as post birthing. The question we would like to answer is whether the Galapagos sharks are detecting cloacal secretions from the oviducal gland related to recent birthing or mating? Or whether this association has another reason for being.

This season was with a much reduced team given the pandemic and travel restrictions for many countries. We are optimistic that next year at the end of June we will be able to reincorporate more of our partners and team members to carry out further ultrasound and blood work. We will

Figure 43: Two Galapagos sharks following a whale shark. Screenshot from video GWSP.

Figure 44: Diver is taking photo identification of a whale shark.
Photo: ©Jenny Waack, 2020

continue to analyse movements this season and in January begin to look at depth and diving data from the SPLASH 10-346B tags deployed this year. We are still in discussion with engineers to see how we can achieve a tag which will work at even more extreme depths to discover how deep whale sharks are diving and for how long they can remain at these depths. So far all attempts have failed to record maximum depth. Whilst we will continue to tag each season at Darwin Island we are aiming to begin tagging during the months of February - March to the south of Isabela Island where a second aggregation has been observed. This will require the use of aerial surveying by a small plane or ultralight in order to find the whale sharks and coordinate with a boat based team.

Figure 45: Whale Shark over the rocky area at Darwin's Arch after it was tagged with a SPLASH10 - 346 satellite tag. Photo: ©Jenny Waack 2020

ETHICAL DISCLAIMER

All tagging, biopsy work and blood sampling is conducted under and approved by the Galapagos National Park Permit PC-64-20 under the project "The role of oceanic islets for the protection of marine migratory species".

The ethical approval allowed for:

- Fin mounted and/or towed satellite tagging through procedures pre-approved by the GNP and a maximum of 30 tags per species per expedition.
- Blood samples of a maximum of 10 CC per sample and for the following purposes: gases, hormonal analysis to determine reproductive state and nutrition/general health.
- Tissue samples of a maximum of 100x5mm for fatty acids and stable isotope analysis taken with a biopsy tip on a Cressi pressure gun.
-

Figure 46: Juvenile male whale shark after he was tagged with a SPOT6/miniPAT hybrid tag. Photo: ©Jenny Waack 2020

OUTREACH

As part of our work, we believe that it is of essence to make time for public outreach, to share what is being done with our research and the importance behind it, to as many different audiences as possible. This year we participated in interviews, webinars, and press stories.

With the return of the Chinese fishing fleet to the outsides of the Galapagos Marine Reserve and the loss of Hope's transmission, our project received high attention from the press and other media.

These are the news stories shared about the whale sharks that have been collaborating directly to conservation:

https://docs.google.com/document/d/1X3QMVC3WYNADUi7U-VqWFLbGBYECajerupthNtYTxE4/edit?usp=sharing

Webinars this year:

- “Por que ampliar la zona de protección del mar que rodea a Galápagos?” (“Why is it important to extend the area of protection of the ocean waters that surround Galapagos”)- Más Galápagos & Kuna Ecuador

- “Whale Sharks in the Galapagos- Oceans Greatest Mystery” - Natural Habitat Adventures

- “Real Time Crisis: Ecuadorian Marine Violation”- Sustainable Ocean Alliance

- “The Galapagos Whale Shark Project”- Pacifico Libre

- “Galapagos Day” - Galapagos Conservation Trust 2020 https://galapagosconservation.org.uk/galapagos-day-2020/

The GWSP also participated in the making of the following videos, alongside “Caja Negra”, a group of young Galapagos citizens who felt like spreading the message:

- https://www.youtube.com/watch?v=YNYOpNy94rQ

- https://www.youtube.com/watch?v=bkLyZeVEOko

ACKNOWLEDGMENTS & THANKS

Photo: ©Jonathan R Green, 2020

Figure 47: Female adult whale shark swims straight towards the researchers. Photo: ©Jonathan R Green, 2020

THANKS

This year we would like to especially thank The Galapagos Conservation Trust, Save Our Seas Foundation, the Russell E. Train Fund For Nature, and Planeterra Foundation for their support and funding and believing that even under the current global circumstance the expedition would take place. Thanks too, to Johannes Schoeter and Xiaoyang Yu, and Galapagos Shark Diving for their generous help and to Gloria and David Asencio, owners of the Queen Karen Yacht, with the entire crew for preparing for the expedition on short notice and helping make a success of it. In addition thanks to Manolo Yepez for his help on the field trip and for a rapid pickup when the currents swept us away.

Finally we would also like to thank all our donors, including those not named at the beginning of this report for their continuing support of this project. Without this help and the faith you put in our ability to carry out the work, even under difficult circumstances, we would not be able to continue with these discoveries that we sincerely hope will help us protect these waters, the species that live in them, and the general health of our Oceans.

Figure 48: Whale shark swimming away. Photo ©Jonathan R Green, 2020

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APPENDIX

Photo: ©Jonathan R Green 2020

# R. typus	Gender	SPOT #	miniPAT #	SPLASH #	Date # Dive of the day	Photo ID & WB ID	Blood Samples	Total Length (meters)	Observations (scars, depth of sighting, etc)	Tagger ID
1	F	0	0	203637	13/08/2020 # 1	GD 130820-1	0	11,5	Scratched peduncle. Clipped off of back of dorsal and clipped top caudal. Sighted ~17m	SMG
2	F	0	0	203642	14/08/2020 #1 15/08/20 #1	GD 140820-1	0	12	Nemo-No left pectoral fin (only small stump left). Sighted 4 times (1,8,12,32min). Last time she was trailed by Galapagos Sharks. Tagged at 10m depth, placed right in front of the dorsal tip. Sighted again one day later on the first dive at min 39.	SMG
3	F	0	0	203641	14/08/2020 #1, #2, #3	GD 140820-2	0	11	Tagged at 17 m depth, 28min into dive. Scratches on dorsal and in front of right eye. Remora's in right "armpit". Tag placed almost at tip of dorsal. Adjusted later by JRG. Sighted during the 2nd (min43) and 3rd dives again.	SMG
4	F	0	0	203643	14/08/2020 #3	GD140820-3	0	10,5	Tagged at 5m depth ~32min into dive. Had a notch/dip on the head at the same line as the end of the pectoral fins.	SMG
5	F	0	0	203639	15/08/2020 #1	GD 150820-1	0	12	Sighted at 15m depth and tagged around 17m depth at ~9 min. Faded markings on head, deformed 5th gill right.	JRG
6	F	0	0	203640	15/08/2020 #1	GD 150820-2	0	11	Sighted at 15m depth and tagged around 20m depth at ~13 min. No visible scarring, very pointy dorsal.	JRG
7	F	0	0	0	15/08/2020 #1	GD 150820-3	0	5,5	23min into dive. Female juvenile spotted almost at surface around 7m.	

# *R. typus*	Gender	SPOT #	miniPAT #	SPLASH #	Date # Dive of the day	Photo ID & WB ID	Blood Samples	Total Length (meters)	Observations (scars, depth of sighting, etc)	Tagger ID
8	F	0	0	203638	15/08/2020 #1, #3 16/08/2020 #3 18/08/2020 #3	GD 150820-4	0	11,5	32min into dive spotted at 20m depth. Back of dorsal is ragged. Couple of clips. Scarring along the left side. Tagged in second sighting (3rd dive of the day), not during 1st dive of day, during min 1 at 23m depth. Had a full 7 minutes with her during the first 7min of 3rd dive. Spotted again one day.	SMG
9	F	0	0	203644	15/08/2020 #2, #3	GD 150820-5	0	10,5	Sighted 29 min into dive and tagged at 23m depth. Deformed 5th, left gill slit with remoras. Back of dorsal had c-shaped bite missing. Re- sighted at 3rd dive of day. Tag looked good. Sighted at min17, 17m depth.	SMG
10	F	203646	184031	0	16/08/2020 #1, #2	GD 160820-1	0	10	Sighted and tagged at 12m depth, 1st min of the dive. No obvious markings.	JRG
11	F	0	0	0	17/08/2020 #2, #3	GD 170820-1	0	11	Sighted a 17m depth at 25 min into dive. Attempted blood. Not successful. Has a wavy top caudal fin. Resighted on 3rd dive.	
12	F	0	0	0	17/08/2020 #2	GD 170820-2	0	9,5	Sighted at 7m depth, 38min into dive. Attempted blood. Not successful.	
13	F	0	0	0	17/08/2020 #3 21/08/2020 #2, #3	GD 170820-3	2	10,5	Sighted at 21m deep and heading down. Has scar on her head and down her left side (like an indent). Has some clips off her dorsal. Sighted again at end of dive ~40min in scratching on the rock platform at 7-10m depth. Sighted again on the 21st of Aug: Sighted 2 min into dive at 7m and then again throughout dive. “Zig zag" dorsal fin. Little clips out of both pectoral fins. Remora inside 4th gill slit on left. SMG and JP attempted blood in pelvic fin during 1st sighting. Then on 2nd dive of day JRG managed to draw blood. Sighted again 3rd dive 21st, JP managed to draw blood.	

# *R. typus*	Gender	SPOT #	miniPAT #	SPLASH #	Date # Dive of the day	Photo ID & WB ID	Blood Samples	Total Length (meters)	Observations (scars, depth of sighting, etc)	Tagger ID
14	F	0	0	0	18/08/2020 #2	GD 180820-1	0	10	Sighted at 20m depth, ~21min into dive on the North sandy area. Attempted blood draw. Almost successful.	
15	U	0	0	0	18/08/2020 #3	No ID	0	5	Juvenile. Attempted tagging. Not successful.	
16	F	0	0	0	18/08/2020 #3	GD 180820-2	0	10?	Sighted in 3rd dive. Not really ID. Have a video.	
17	M	203645	184033	0	19/08/2020 Breakfast, #2	GD 190820-1	0	4.5-5	Sighted by the boat, after the 1st dive of the morning (we think it is this one). Had small clipping on the caudal, which the juvenile on the 18th did not have. Then sighted and tagged at end of 2nd dive ~45min in at 7m. Clipped top caudal and scratch (white marking) on "nose" on left side.	SMG/ JRG
18	F	0	0	0	19/01/2020 #3	GD 190820-2	0	9	Sighted ~53 min into dive. Heading to safety stop. She rose from ~20m to 10m at fast speed and went right past us.	
19	F	0	0	0	20/08/2020 #1	GD 200820-1	0	10	Sighted first at 3 min into dive ~15m depth. Turned around and sighted again ~20min into dive at 10m depth. Has a scarred caudal fin and a little clip of the middle of the dorsal on the back.	
20	F	0	0	0	20/08/2020 #1	GD 200820-2	0	13	Sighted around 10min into dive at 17 m depth. Does not have any particular scarring and has very straight back of dorsal fin.	

# *R. typus*	Gender	SPOT #	miniPAT #	SPLASH #	Date # Dive of the day	Photo ID & WB ID	Blood Samples	Total Length (meters)	Observations (scars, depth of sighting, etc)	Tagger ID
21	F	0	0	0	20/08/2020 #2	GD 200820-3	2	12	Sighted 3 times in dive. 5min into dive, 10m depth (JRG got blood from pelvic, SMG attempted pectoral blood draw). Then sighted again around 25min into dive and again on safety stop at 45min into dive.	
22	F	0	0	0	20/08/2020 # 3	GD 200820-4	0	11	Sighted 4 min into dive at ~16m. She then swam down to 24 as we attempted to draw blood. She has white scars on top of 4th & 5th gill. Little c-shaped bit missing out of dorsal. Caudal has scars and bits missing.	
23	F	0	0	0	21/08/2020 #1, #2, #3	GD 210820-1	0	13	Sighted first time at 6min into dive also ~7m. Then sighted again throughout dive. Very straight dorsal and no clips off of pectoral. Line down left pectoral. She had remoras besides and inside cloaca. SMG attempted blood draw in pelvic 1st sighting and then pectoral in seconds sighting. JW attempted blood in pelvic during 2nd sighting. Sighted simultaneously with GD 210820-3 at one point. Then sighted once again and JRG attempted BD from pelvic.	
24	F	0	0	0	21/08/2020 #1, #2, #3 22/08/2020 #1, #2, #3	GD 210820-2	0	11	Sighted several times throughout the dive, 1st time around 20min into dive. Has scarring all down her left side and small clippings off of her caudal fin. Scar on her little back top fin. Sighted one more time almost at safety stop simultaneously with GD 210820-1.	

# *R. typus*	Gender	SPOT #	miniPAT #	SPLASH #	Date # Dive of the day	Photo ID & WB ID	Blood Samples	Total Length (meters)	Observations (scars, depth of sighting, etc)	Tagger ID
25	F	0	0	0	22/08/2020 # 1	GD 220820-1	0	12	Sighted at 20m depth, 10min into dive. AH attempted BD from Pectoral and SMG attempted BD from pelvic. Not successful.	
26	F	0	0	0	22/08/2020 # 1	GD 220820-2 (No Good ID)	0	12	Sighted 45 min into dive on the surface, dorsal fin breaking the surface.	
27	F	0	0	0	22/08/2020 #2	GD 220820-3	0	4,5	Sighted after dive by Queen Karen. She came up to the panga several times. Managed to check gender.	
TOTAL	1M/15F/ 1U	2	2	8		25	4	12		

Photos by Jonathan R. Green, Sofia M. Green, Jenny Waack

Design & layout Jenny Waack

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