

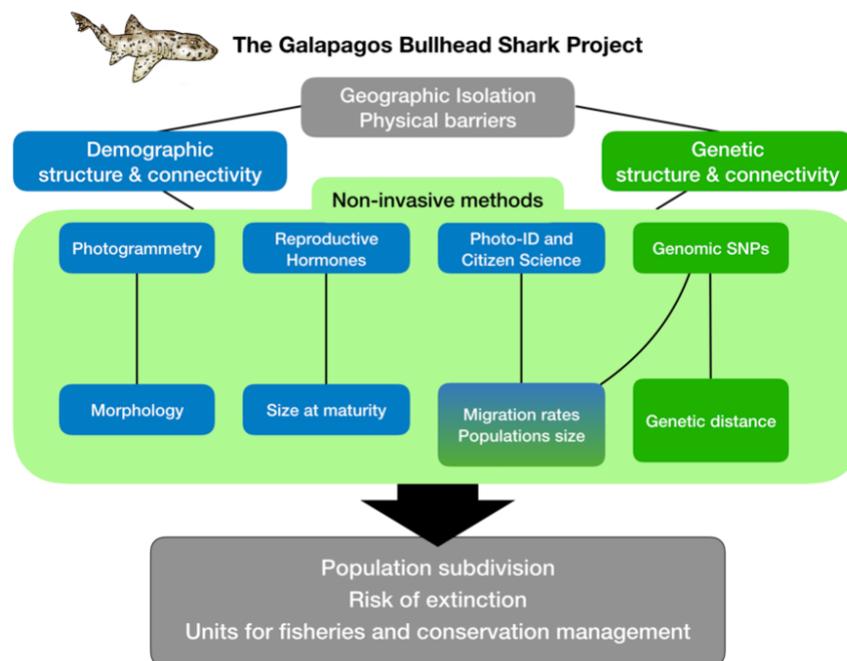
Interim Report February 2020

Project title: Population connectivity of Galapagos Bullhead Sharks and the identification of key habitats for conservation in the Galápagos Archipelago

Project ID: 25628-B (Maximilian Hirschfeld)

Balancing scientific discovery and conservation of an elusive marine species

Galapagos bullhead sharks have limited dispersal capacity because of their adaptations to living on the sea floor. Paradoxically, this shallow-water demersal species has managed to thrive at geographically remote locations, including the oceanic Galapagos islands. Here they lack population connectivity. The extreme geographic isolation and limited amount of suitable habitat may lead to low levels of genetic diversity and a lack of replenishment from adjacent areas. Consequently, these isolated populations are more susceptible to man-made threats including direct exploitation through fisheries and habitat reduction through climate change.



The Galápagos bullhead shark (*Heterodontus quoyi*) was described as early as 1840, but until now little scientific information existed about this species. The small bottom-living shark is thought to have a small geographic range limited to the coast of Perú and the Galápagos Archipelago. Since 2015, the Galápagos bullhead shark project (graphic above) integrates a suite of **non-invasive sampling methods** to shed light on the **geographic distribution, life history, demographic and genetic structure and connectivity** of the elusive species to assess population subdivision in the eastern Pacific. The integrative approach ultimately aims to define ecologically and genetically distinct units of the Galápagos bullhead shark covering its entire geographic range to develop effective strategies for local and regional **fisheries and conservation management**.

To achieve these goals the project is divided into four focal points:

I. Generating scientific knowledge
III. Education and awareness

II. Building local capacity
IV. Communicating the results

What we have achieved so far

What Darwin couldn't see

Since Darwin, the Galapagos Islands have been a hotspot for scientific discovery in the wake of the theory of evolution. However, to date most research has focused on the evolution, population dynamics and conservation of the charismatic fauna on land. The Galapagos bullhead shark project is a new window into the Galapagos underwater world. At the start, we knew close to nothing about Galapagos bullhead sharks but through the continuous support of the Rufford Foundation we have come a far way, continue to discover and create essential knowledge for the long-term conservation of the Galapagos marine environments.

To date a total of 198 sharks were sampled from seven locations on five islands and citizen scientist observations were reported throughout the archipelago. A graphical overview of the project methods, sampling effort and a geographic summary of the information obtained through research expeditions and citizen science was presented at the Rufford Conference ***Science for the conservation of the Eastern Tropical Pacific Region*** in January/February 2019 (poster presentation attached). Below is a summary of the project achievements and results to date for each focal point and a time line with activities until the end of the grant period.

I. Generating scientific knowledge

1. Geographic distribution (see poster)

Citizen Science and research expeditions have resulted in the an archipelago-wide data set of geographic positions of bullhead sharks and their egg cases. Galapagos bullhead sharks were previously unknown to inhabit the islands of Floreana, Española, San Cristóbal. Our results indicate that all three islands harbour important habitats for this species but we could not yet confirm locations that are used to deposit eggs or are used as nurseries for juveniles on these islands. The West coast of Isabela Island and Fernandina island form a hotspot for the bullhead shark population. Most sightings have been reported here and egg cases indicate important reproductive habitats.

What's next: Generating detailed distribution models to identify the most important habitats.

2. Life history, demography and demographic connectivity

When and where do bullhead sharks mature?

On our research expeditions we have collected 188 blood samples from 79 from females and 109 from males on five different islands (see poster). These samples were processed to extract plasma hormones and were exported to Australia to determine plasma hormones levels. The demographic structure of locations on different islands was assessed using photogrammetry (See figure 2 and 3 below). To date it appears that there is no separation of juvenile and adult habitats and that males and females also use the same areas. This information will be combined with measurements of plasma hormone levels to estimate the size at which female and male bullheads mature.

Figure 2. demographic distribution of male and female bullhead sharks.

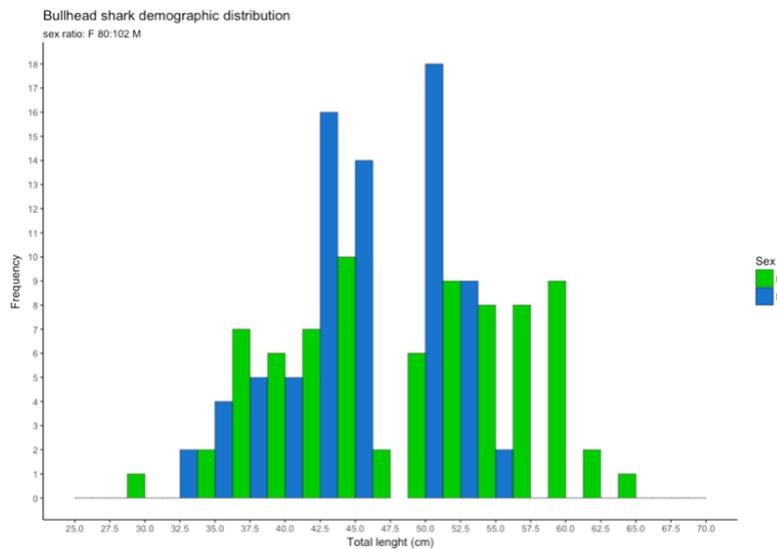
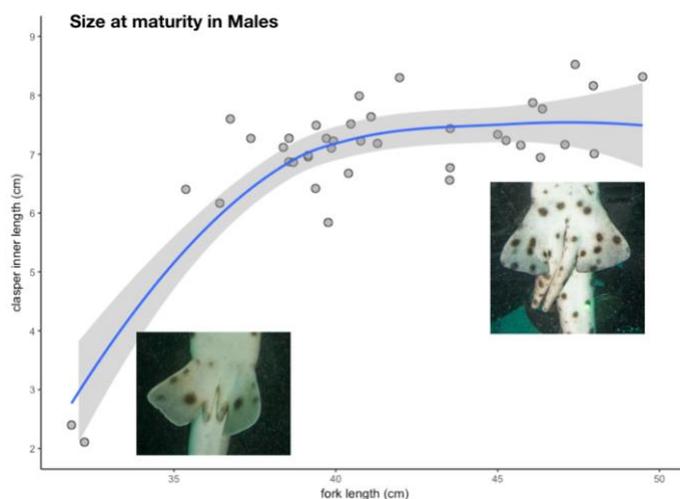


Figure 3. Male reproductive organs, so called claspers can be used to gauge sexual maturity in male sharks. However, the determination of plasma hormone levels will provide much more precise evaluation of maturity in male and female bullheads.



Do bullheads travel? (Demographic connectivity):

Photo-identification of the spot-pattern on bullhead sharks has resulted in the mark-and-recapture of several individuals. For example, one male *Hq17/09/17PE8* (recapture code: *Hq01/08/18PE2*) was captured at the same location on Española Island and one female *Hq23/08/16PVR8* (recapture code *Hq16/09/17PVR2*) at the same location on Isabela Island, both after one year. The use of the unique spot pattern to identify bullhead sharks was also confirmed using genomic methods. To date no recapture was found to migrate between locations on the same islands or even between islands. This indicates that bullheads are either highly resident or return to the same locations over long time periods.

What's next: Accurate hormone levels to determine size at maturity have not been determined yet. This is due to a flooding of the research institute of the collaborator Cynthia Awruch in Australia delaying the lab work and because the common methods used in sharks have resulted in lower levels of hormone detections in bullhead sharks at the beginning, requiring the development of finer methods.

3. Genomic connectivity and effective population size

The project was able to collect 198 tissue samples from five islands representing the Western and Central-south-eastern bioregions of the Galapagos (see poster). Genomic analyses has resulted in the identification of at least four genetically distinct units (figure 4) with low migration rates among them. We estimated that these units have low genetic diversity and small population sizes (table 1).

Figure 4: Principal component analysis (top) and Admixture Analysis (bottom) of thousands of genomic markers clearly identify four genetically distinct units: The western archipelago and Santiago Island (West, SAN), Floreana island (FL), Española Island (ES) and San Cristóbal island (SCY).

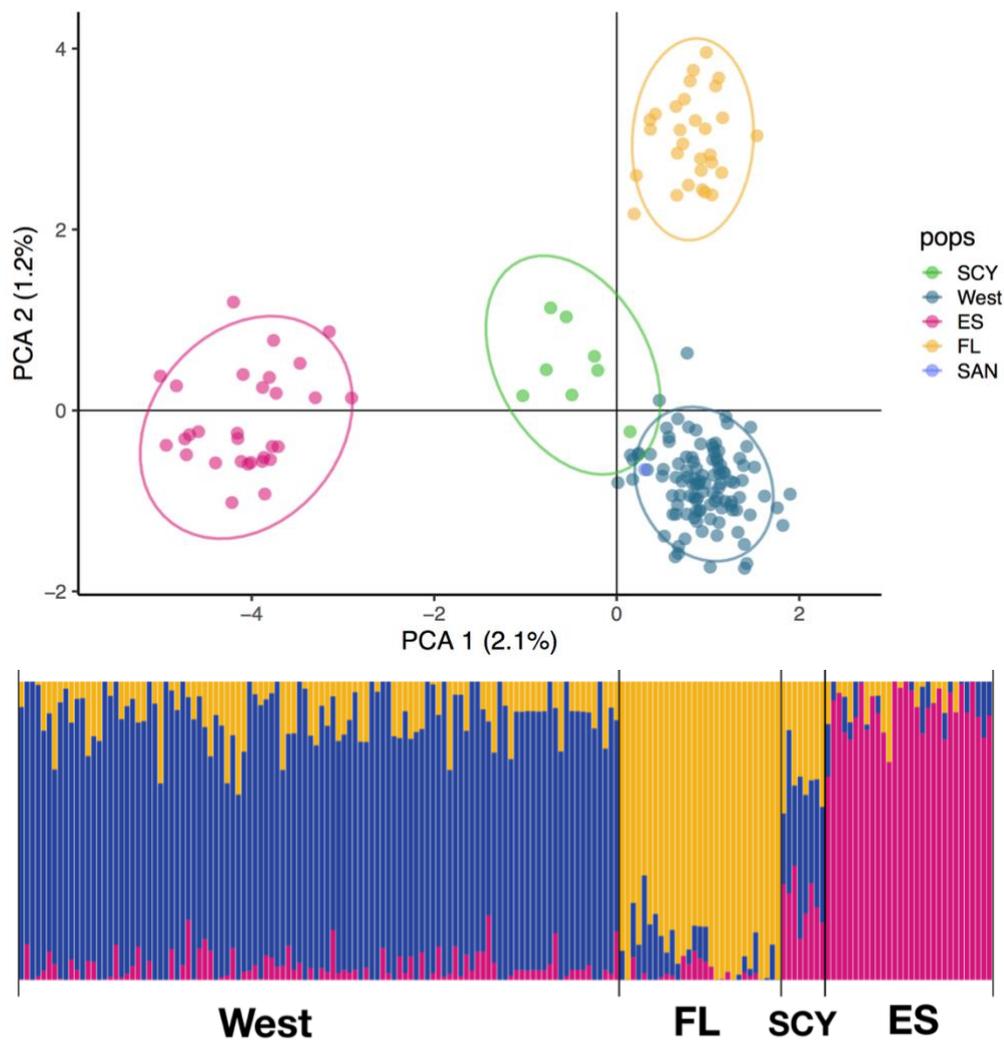


Table 1. Genetic effective population size (N_e) for genetically isolated groups (the sample size of San Cristóbal island was insufficient to accurately determine this statistic).

| Islands | N_e (confidence intervals) |
|----------|------------------------------|
| Española | 343 (334 - 352) |
| Floreana | 1641 (1464-1866) |
| West | 7415 (6854-8077) |

II. Building local capacity

Building local capacity was achieved through **research participation, workshops** and **citizen science campaigns**.

Participation: Many Galapagueño and Ecuadorian students and volunteers, as well as Galapagos National Park Rangers and local Fishermen have participated in the field and laboratory, as well as outreach and educational campaigns. Through participating in these activities they gained hands on experience in field and laboratory methods including photo-identification and population demographic analyses and most importantly learned about the importance of shark conservation in the Galapagos and how to scientifically approach conservation issues.



Citizen Science Campaigns:

To improve local participation in GCT supported citizen science projects we designed and implemented The Galapagos Shark Hero campaign in 2019 (images below). A total of 51 locals participated in the campaign and 11 winners (1 first, 5 second and 5 third price) were publicly announced for their dedication to shark conservation projects and received prizes and certificates during the Galapagos Research and Conservation conference in San Cristóbal (June 2019).



Workshops:

Together with two colleagues (Javier Oña and Robert Lamb) I organised two workshops oriented towards improving collaborative science to study the connectivity of marine species in the Eastern Tropical Pacific and how to translate scientific knowledge into conservation actions. The workshops were held as part of the **2nd Rufford Conference South America - Science for the conservation of the Eastern Tropical Pacific Region** I organized together with Javier and Robert in January/February 2019. As part of this workshop series we organized a round table with researchers from the Galapagos Science Center and Charles Darwin Station, and key Galapagos National Park staff (see photo below).



III. Conservation education and raising awareness

Shark Day and Shark Experience:

In 2018 and 2019 we again organized the annual Galapagos Shark Day with much success. The participation in these two years exceeded 100 registered participants between the age of 3 to 15 years. In both years 12 overall winners were drawn to participate in an excursion called the Shark Experience (professional video can be viewed on the Rufford website for this project).

Children's book:

Together with a team of science communicators at the University of San Francisco de Quito we created an educational story about the Galapagos Bullhead shark as part of a children's book about animals and conservation in the Galapagos. The book is in the last round of revision and due to be published soon.



IV. Scientific publication and media coverage.

Scientific publications:

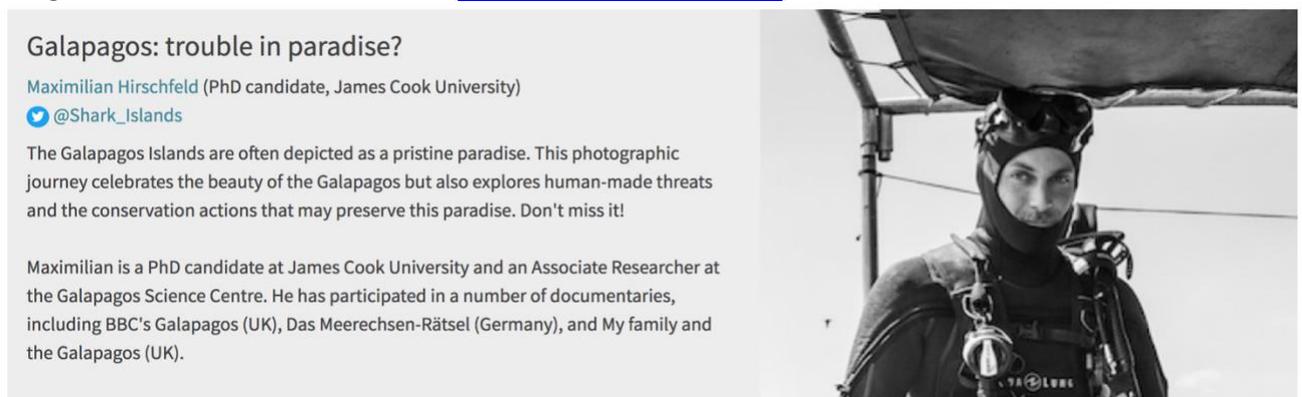
Presentations: Project aims, results and conservation significance was presented at the 1st, 2nd and 3rd Galapagos Research and Conservation Conference in Galapagos, at the Oceania Chondrichthyan Society conference in Australia, at the Shark International Conference in Brazil and at the *Science for the conservation of the Eastern Tropical Pacific Region in the Galapagos*.

Journal articles: A draft of the results of the genetic population connectivity (shown in section I.3.) is being drafted for publication in the Journal **Heredity** or **Conservation Genetics**.

Media coverage:

Besides the project website (www.bullheads.org), the project info on the GCT **Discovering Galapagos** website and several other blogs, the bullhead shark project was featured in Monty Halls **My Family and the Galapagos** (SeaDog Productions Inc., UK).

In June 2019 I presented about sharks and conservation issues in the Galapagos at a public event of the global **Pint of Science** movement (<https://pintofscience.com/>):



Galapagos: trouble in paradise?

Maximilian Hirschfeld (PhD candidate, James Cook University)
@Shark_Islands

The Galapagos Islands are often depicted as a pristine paradise. This photographic journey celebrates the beauty of the Galapagos but also explores human-made threats and the conservation actions that may preserve this paradise. Don't miss it!

Maximilian is a PhD candidate at James Cook University and an Associate Researcher at the Galapagos Science Centre. He has participated in a number of documentaries, including BBC's Galapagos (UK), Das Meerechsen-Rätsel (Germany), and My family and the Galapagos (UK).

Conclusions:

Overall, the Galapagos Bullhead Shark project has made giant strides towards the rediscovery of this formerly forgotten species. From knowing nothing about this unique species we have come to have a good idea about where the species occurs, what habitats they like, where they reproduce and how genetically different the populations on different islands are. From a scientific perspective we can say that the geographic isolation has led to small populations on isolated islands such as Española and Fernandina that are likely threatened by future habitat loss through climate change.

In early 2019, an IUCN review of coastal shark species in South America was undertaken. In many cases, the scientific data available is insufficient for solid evaluation of IUCN Red List status. Since then we have gained new knowledge about the bullhead sharks and can pinpoint the gaps in knowledge we still need to fill.

Progress evaluation and Budget

I consider that the project has made satisfying progress during the first half of the funding period with important scientific findings and new and continuous outreach campaigns. Fortunately, I was able to secure additional funding from another external grant to cover some of the cost of sequencing the first round of samples for this project (see budget below). This means some additional funds are available to cover sequencing of samples from Perú and additional samples from Galapagos in the next project phase.

In the next project phase we aim to sample Bullhead sharks in Perú to be able to identify how different these populations are to the ones in the Galapagos. This will eventually enable us to delineate discrete groups of the species within the Galapagos and between the archipelago and the South American mainland. This information may then be combined with morphological data, life history parameters

and species distribution data to evaluate the species' risk of extinction, update IUCN red list status and inform management.

Table 2. Current budget. Additional external funds used for part of the sequencing costs are highlighted in green.

| Item description | RSGF | Spent | Spent (other funds) | Remainder |
|--|---------------|-------|---------------------|-------------|
| Genetic analyses (sample processing, DNA extraction and sequencing) | 3450 | 1405 | 1880 | 2045 |
| Field work in Perú (Chartered ship, includes dive tanks, room and board) | 3500 | 882 | | 2618 |
| Field work Galapagos (Chartered ship, includes dive tanks, room and board) | 2400 | 0 | | 2400 |
| Shark Day (Promotional material, games, prizes, communication) | 250 | 440 | 190 | 0 |
| Dive gear and field equipment | 200 | 126 | 0 | 74 |
| Educational material, prints, posters | 200 | 440 | 240 | 0 |
| Total | 10.000 | | | 7137 |

Updated Time line:

Funding requested for October 2018 – December 2020, below an updated overview of activities.

July 2016 - October 2017: Establishment phase (2nd RSG)

February-June 2018: Presentation at international conferences (see .

June-October 2018: Presentation of results to the Galapagos community and the National Park. Field campaigns, outreach campaigns and building local capacity.

August 2018-June 2019: First year of the Galapagos Shark Conservation Hero campaign.

October 2018 – February 2019: Field work in Perú.

November 2018 - June 2019: Sample processing, data analysis and writing publications.

21-26 January 2019: Hosting the *IV South American Rufford Small Grant Conference* in the Galapagos. Presentation of results to the Galapagos community and the National Park.

June/July 2019: Galapagos Shark Day

March – December 2019: Outreach campaigns (Shark Hero) and building local capacity for long-term continuation of the project.

January - December 2020 (and onwards):

- Continuation of outreach and citizen science programmes.
- **Field work in Perú** with local collaborators
- Additional field work in the Galapagos
- data analysis and publication of the current results

- Exportation of new samples, data analysis and further publication from 2021 onwards

Additional information:

Project Videos:

Shark Day:

https://www.youtube.com/watch?v=vl_E0REDWg8

Shark Experience:

<https://www.youtube.com/watch?v=abxsaQnjm64>

Attached files:

1. Project images
2. Poster presentation presented at the 2nd Rufford Conference South America - *Science for the conservation of the Eastern Tropical Pacific Region*.