SAVE OUR SEAS FOUNDATION

ANNUAL REPORT 2018

save our seas
foundation

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save our seas
foundation
15th anniversary

“AS LONG AS THERE ARE PEOPLE WHO CARE, WE CAN AND WILL MAKE A DIFFERENCE.”

THE FOUNDER I SAVE OUR SEAS FOUNDATION

Photo by Byron Okes

Photo by Michael Scholl

CEO'S NOTE

Bimini, Bahamas – Nothing makes me happier than to take my five-year-old son Elliot snorkelling, especially with sharks. Seeing his smile and lack of nervousness demonstrates to me how our ideas and behaviour are modelled by our family, social and cultural environments. Elliot respects sharks and understands that they are an essential part of a healthy ocean ecosystem. He certainly is not unafraid, but he admires and appreciates them, and I could not ask more of anyone.

On 23 September 2018 the Save Our Seas Foundation celebrated its 15th anniversary and we decided to dedicate this keystone year to reflection and an analysis of our activities, commitments, strategies and achievements over the past decade and a half. That we have attained such a level of maturity is thanks in no small measure to a number of factors: the continued dedication and commitment of the Founder; the enthusiasm and passion of our various team members, both past and present; the development of committed strategies that target specific groups of endangered species; our ability to adapt and evolve these strategies rapidly as we learn from our failures and successes; the contribution made by energetic, extensive and lively communication to a broad audience; and investment in both early-career professionals and innovative, and sometimes risky, projects that go beyond the norm.

The Save Our Seas Foundation has grown into a well-established philanthropic organisation that is recognised and respected worldwide. In scientific and conservation circles it is acknowledged as a key element in the advancement of our understanding of sharks, rays, skates and chimaeras, as well as their habitats – and thus in efforts to conserve these endangered species. And so, in the year of reflection that was 2018 we concentrated on analysing and developing our strategies, and while we maintained our commitment to ongoing projects, we did not expand into new projects that might have diverted our attention elsewhere.

In 2018, the Save Our Seas Foundation continued its dedicated support for its three centres: the Shark Education Centre in South Africa, the Shark Research Center in the USA and the D'Arros Research Centre in the Seychelles. There was no field activity at the D'Arros Research Centre, where the focus was on analysis and completing the multiple projects that had been initiated during the previous decade. The Save Our Seas Foundation also supported five Partner projects (long-term Keystone Grants): the Bimini Biological Field Station Foundation (BBFSF) in The Bahamas, Shark Spotters and the Acoustic Tracking Array Platform (ATAP) in South Africa, the North Coast Cetacean Society (NCCS) in British Columbia, Canada, and the Manta Trust, which is based in the United Kingdom but operates worldwide.

Nineteen individual projects benefited from continuations of Keystone Grants and the foundation also sponsored the Eugénie Clark Award of the American Elasmobranch Society (AES) meeting, which took place in Brazil at Sharks International in João Pessoa in June, and student and keynote speaker travel awards at the European Elasmobranch Association (EEA) in Peniche, Portugal, in October. In addition, it continued its support of the Environmental Sciences Laboratory of the University of Seychelles. 2018 also marked the second year of our four-year Sawfish Strategy (2017–2020), which supports nine projects worldwide on the five Endangered or Critically Endangered sawfish species.

We published one issue of the *Save Our Seas* magazine in three editions (print, digital and web) and are distributing these worldwide for free. Knowledge comes from research, and in this issue our contributors investigated some lesser known but Critically Endangered species (angel sharks in the Canary Islands and sawfishes in Senegal and Papua New Guinea), discussed the very nature of marine science, delved into the ocean depths around the Galápagos and explored how recent advances in elasmobranch genomics could one day benefit medical research, and thus humankind.

Our commitment to communication in science and conservation is a long-term priority. In 2018 we invested in a thorough, extensive and successful communication strategy on our website and social networks by translating scientific peer-reviewed publications into articles dedicated to a wider non-scientific audience. To build on our 2012–2016 funding strategy commitment on Mobulidae, we supported the publication of both the *Guide to Mobulid Rays of the World* by Dr Guy Stevens and Daniel Fernando and the conservation strategy report entitled *Global Strategy and Action Plan for Mobulids* published by the Manta Trust.

Remaining true to the nature of the foundation since its inception in 2003, and inspired by our Founder's passion, we continue to support research, conservation and education projects on charismatic marine megafauna worldwide, with a significant emphasis on endangered elasmobranchs and their habitats. This support ranges from our primary role as a grant-making foundation to helping projects and events from a logistical perspective and endorsing more effective and far-reaching communication to the public. The passionate synergy between our team and our project leaders has enabled the Save Our Seas Foundation to grow further and mature, as well as to act as a leader in elasmobranch science and conservation.

Michael Scholl | Chief Executive Officer

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Photo by Fred Bavendam
Minden Pictures | National Geographic Creative

WHERE WE WORK 2018

The Save Our Seas Foundation was established in 2003 with a mission to protect our oceans by funding and supporting research, conservation and education projects around the world, focusing primarily on charismatic threatened wildlife and their habitats.
In that time, the foundation has sponsored over 300 projects in more than 50 countries, proudly supporting outstanding researchers, educators and conservationists who have contributed to the continued existence of more than 60 of our planet's precious marine species.

To find out more about our funded projects visit:
saveourseas.com/projects

SOSF SAWFISH

CONSERVATION STRATEGY 2017-2020

Photo by Michael Scholl | The subject image was taken under the authority of NMFS ESA Permit N° 22078

FOUR YEARS ON, ARE WE SAVING SAWFISH?

RUTH H. LEENEY

Photo by Oliver Renn. The subject image was taken under the authority of a NMFS ESA Permit No 22078

Dr Andrea Kroetz (NOAA Southeast Fisheries Science Center | National Marine Fisheries Service) and Michael Scholl (Save Our Seas Foundation) tagging a juvenile smalltooth sawfish in the Everglades National Park in Florida, USA.

Four years after the first sawfish conservation strategy was released, what have its impacts been so far? SOSF project leader Ruth H. Leeney of Protect Africa's Sawfishes provides an overview of the many sawfish projects supported by the Save Our Seas Foundation since the strategy's release and assesses how far we have come.

The first Global Strategy for Sawfish Conservation, the result of a collaborative workshop involving many shark researchers and policy-makers in 2012, shone a spotlight on the critical state of the world's sawfish populations. Published in 2014, it called for national and regional actions to prohibit the intentional killing of sawfish, minimise mortality in accidental catches, protect sawfish habitats, and ensure the effective enforcement of such safeguards, strategic research and responsible care in captivity. The Save Our Seas Foundation (SOSF) supported the development of this strategy and, inspired by its compelling message, decided to make sawfish a priority for funding. Since then, the SOSF has invested more than US$650,000 in 13 research and conservation projects to gather data and educate the world about this critically endangered family of fish. The SOSF's tribe of sawfish researchers and advocates have a truly global distribution, with dedicated efforts taking place in Mexico, USA, West Africa, Madagascar, Indonesia, Australia and Papua New Guinea, and several projects have a global scope.

In light of the IUCN Shark Specialist Group's recent release of 'Saving Sawfish – Progress and Priorities' – an update to its strategy – we celebrate the efforts made by all of the SOSF grantees focusing on sawfishes and highlight some of their achievements in the past four years.

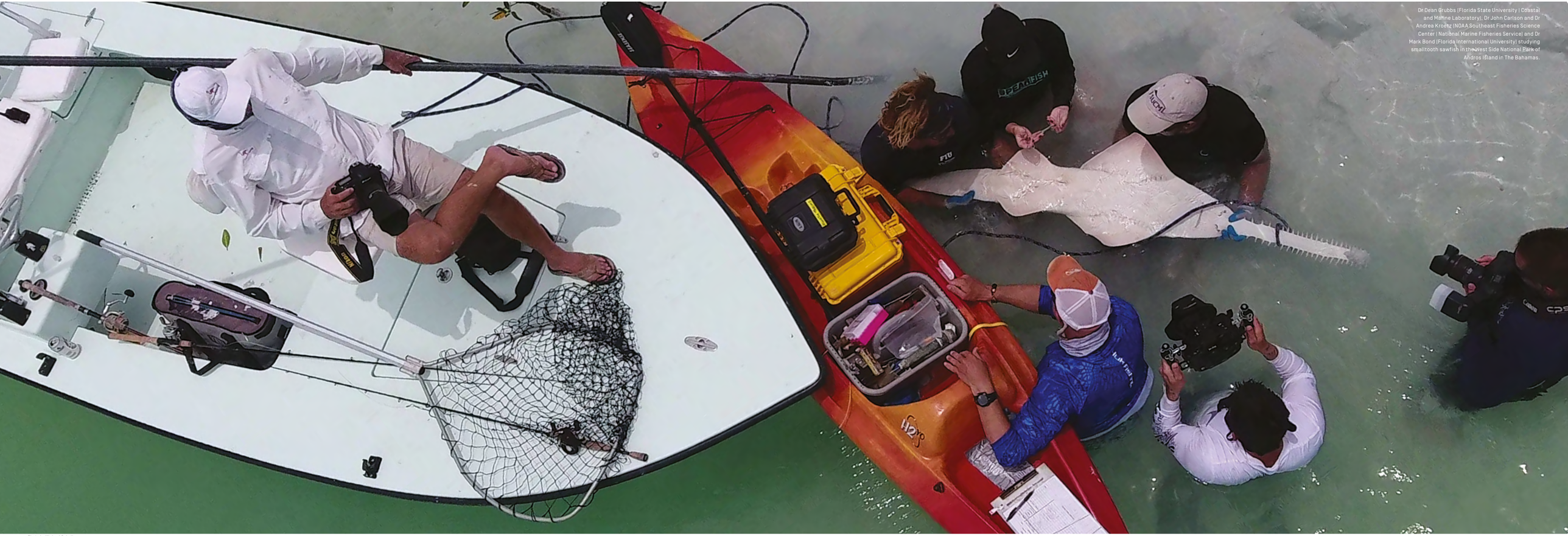
SAWFISH STRONGHOLDS

Back in 2014, researchers had already established that sawfish populations were present in Florida, The Bahamas and Australia. These have been termed 'lifeboats' for sawfishes – areas where researchers and conservationists hope sawfish populations have the best chance of recovery. Research in these regions has been able to focus on more detailed questions about sawfish ecology, population structure and conservation status. Gregg Poulakis and his research team have been collecting water samples in Florida, from which they extract environmental DNA (eDNA) to learn which habitats are used by smalltooth sawfish. Dean Grubbs and his colleagues have been studying sawfish habitat use in Florida and The Bahamas for eight years, aiming to determine where adult sawfish mate, where the females give birth and where important nurseries are. When they caught an adult female sawfish in 2016, off the remote island of Andros, they documented on film the live birth of sawfish pups in the wild – a world first that proved that, in addition to south-western Florida, The Bahamas is also a pupping area for smalltooth sawfish. The adult female sawfish was satellite tagged and travelled at least 385 kilometres (240 miles) over the course of the following year, providing the first evidence of long-distance migrations by smalltooth sawfish in The Bahamas. James Kilfoil is also working in The Bahamas, assessing whether drones can be used as a non-invasive way to conduct aerial surveys for sawfish. Off Australia's Cape York Peninsula, Barbara Wueringer works with citizen scientists to investigate the role of sawfishes in the region's coastal and estuarine ecosystems.

THE GROUNDBREAKERS

In contrast to Florida, The Bahamas and northern Australia, even as recently as 2012, next to nothing was known about sawfish abundance and distribution in many parts of Africa, Asia and Central and South America. Thanks to SOSF support, numerous research teams have been venturing out into the field and, for the first time, describing previously undocumented sawfish populations and habitats that may be in need of protection, as well as those where, more soberingly, sawfishes are now seldom seen. This less-than-glamorous work in remote areas with challenging conditions, and sometimes without any sightings of sawfishes at all, takes a special kind of commitment.

In Mexico, Ramón Bonfil and the Proyecto Pristis México team have been conducting drone surveys of potential sawfish habitats, as well as collecting water samples that will be analysed for eDNA. Ramón aims to identify areas still used by sawfish – information critical in the development of local conservation strategies. The team's education and outreach work with fishing communities meant that when a fisherman caught a smalltooth sawfish in January 2016, it was reported to Ramón. This was the first known capture of a sawfish in Mexican waters for several decades, suggesting that there may still be a remnant



Dr Dean Grubbs (Florida State University | Coastal and Marine Laboratory), Dr John Carlson and Dr Andrea Kroetz (NOAA Southeast Fisheries Science Center | National Marine Fisheries Service) and Dr Mark Bond (Florida International University) studying smalltooth sawfish in the West Side National Park of Andros Island in The Bahamas.

Photo by Michael Scholl

Photo by Matthew Potenski

population using Mexico's Caribbean coast. Armelle Jung and I have both conducted baseline assessments for sawfishes on the African continent. Armelle's work has been focused in West Africa, where the AfricaSaw team has developed reporting networks in coastal communities, encouraging them to report sawfish catches. She has conducted interviews to better understand whether sawfishes are still encountered by fisherfolk. My research in Madagascar has likewise used interviews and searches for sawfish rostra (saws) to reveal that sawfish are still present in at least two river systems and are at serious risk from gillnet fisheries. I also developed an educational book, *The King of the Fishes*, with SOSF support and more than 4,000 copies have been distributed to fishing communities throughout Madagascar and Mozambique. Nigel Downing is assessing whether sawfishes are still present in southern Senegal, while William White is documenting the presence of and fisheries for sawfishes around Papua New Guinea. In Indonesia, Dharmadi and the 'IndoneSaw' team are likewise collecting baseline data to establish whether sawfishes are still present and are encouraging fishing communities to release alive any accidentally caught sawfishes.

GLOBAL SCOPE

In addition to these site-specific projects, several others have a broader reach. At the University of Southern Mississippi, Nicole Phillips and her research group are analysing samples of sawfish tissue from around the world, often taken from rostra in museum collections, to estimate how much genetic diversity has been lost during the declines sustained by sawfish populations. Colin Simpfendorfer aims to answer questions about the current global distribution of sawfishes using eDNA survey techniques. The SOSF has also supported Sonja Fordham's work to advance sound national, regional and international policies for sawfishes (and other sharks and rays) by advocating for science-based limits on shark fishing and trade, protection for endangered species and stronger bans on finning.

Photo by Ruth H. Leeney

The distribution of the illustrated book on sawfish *The King of the Fishes* by Dr Ruth Leeney was welcomed by children in Madagascar and Mozambique. The educational book was published in English, French, Malagasy and Portuguese.

Photo by Leah Glass

The first screening of *Saving Madagascar's Sawfish*, under the stars in the village of Antsahampano, northern Madagascar.

Photos by Michael Scholl | The subject image was taken under the authority of NMFS ESA Permit No 22078

Dr Andrea Kroetz (NOAA Southeast Fisheries Science Center | National Marine Fisheries Service) releasing a juvenile smalltooth sawfish after tagging in the Ten Thousand Islands National Wildlife Refuge in Florida, USA.

WHAT'S NEXT FOR SAWFISHES?

Since the publication of the first Global Strategy for Sawfish Conservation in 2014, sawfish research and conservation activities have spread rapidly to cover new parts of the globe and have uncovered important information that gives hope in some places and in others paints a clearer picture of demise. A lot remains to be learnt about sawfish biology and ecology but, in many countries, we will never have the opportunity to do so if we do not first protect the remaining sawfishes from any further decline. While sawfishes are already well protected in Florida, The Bahamas and Australia, many developing countries do not have any legislation pertaining to sawfishes and of those that do, most lack the resources or capacity to enforce those laws. Simply put, conservation of sawfishes in the developing world will require a different tack. A multi-pronged approach is more likely to be successful, and this would comprise educating communities on why the protection of sawfishes is important and how it will benefit them; assessing the socio-economic importance of sawfishes and the willingness of fishing communities to change their behaviour; developing viable alternative livelihoods for communities; and encouraging community-led strategies for managing sawfish catches.

WHY ARE THESE CONSERVATION STRATEGIES IMPORTANT?

The Global Strategy for Sawfish Conservation raised awareness of the precarious state of sawfish populations globally among not only the research community, but also the broader conservation community and the public. The impressive collation of historical reports to generate a basic understanding of past sawfish distribution revealed huge holes in our collective knowledge of sawfishes, which is astounding given these fishes' huge size, their coastal habitats and their importance in traditional cultures around the world. This catalysed the development of many new research projects, and funding bodies found more than ample justification for the many applications they received.

While the surge in sawfish-focused research has been remarkable, some baseline assessments (such as those I conducted in The Gambia and Guinea-Bissau) have indicated that sawfishes may now be too rare for any recovery attempts to be successful. Given how many other marine species are in need of research and conservation efforts, and our constant battles as researchers, conservationists, advocates and educators to fund our work, it is important that we identify places where further resources and research efforts will be likely to have a positive outcome for sawfishes, as well as those areas where sawfishes realistically have little chance of recovery, and set priorities accordingly. At the same time, it is essential not to write off areas in the developing world that face significant challenges for conservation but are, after all, the areas where much of our planet's remaining biodiversity is found.

The Save Our Seas Foundation is proud to have supported a number of projects that have added many previously missing pieces to the jigsaw, providing novel information that contributes to a far better understanding than we have ever had before of where sawfishes exist, the threats they face and how we can address those threats. Armed with that knowledge, let's continue to empower researchers, educators, advocates and communities to celebrate these unique animals and protect them, and their habitats, for generations to come.

> Original label on a largetooth sawfish saw from the Amazon River, held at the Smithsonian National Museum of Natural History.

> > Nicole Phillips and Annmarie Fearing holding a largetooth sawfish saw at the Smithsonian National Museum of Natural History.

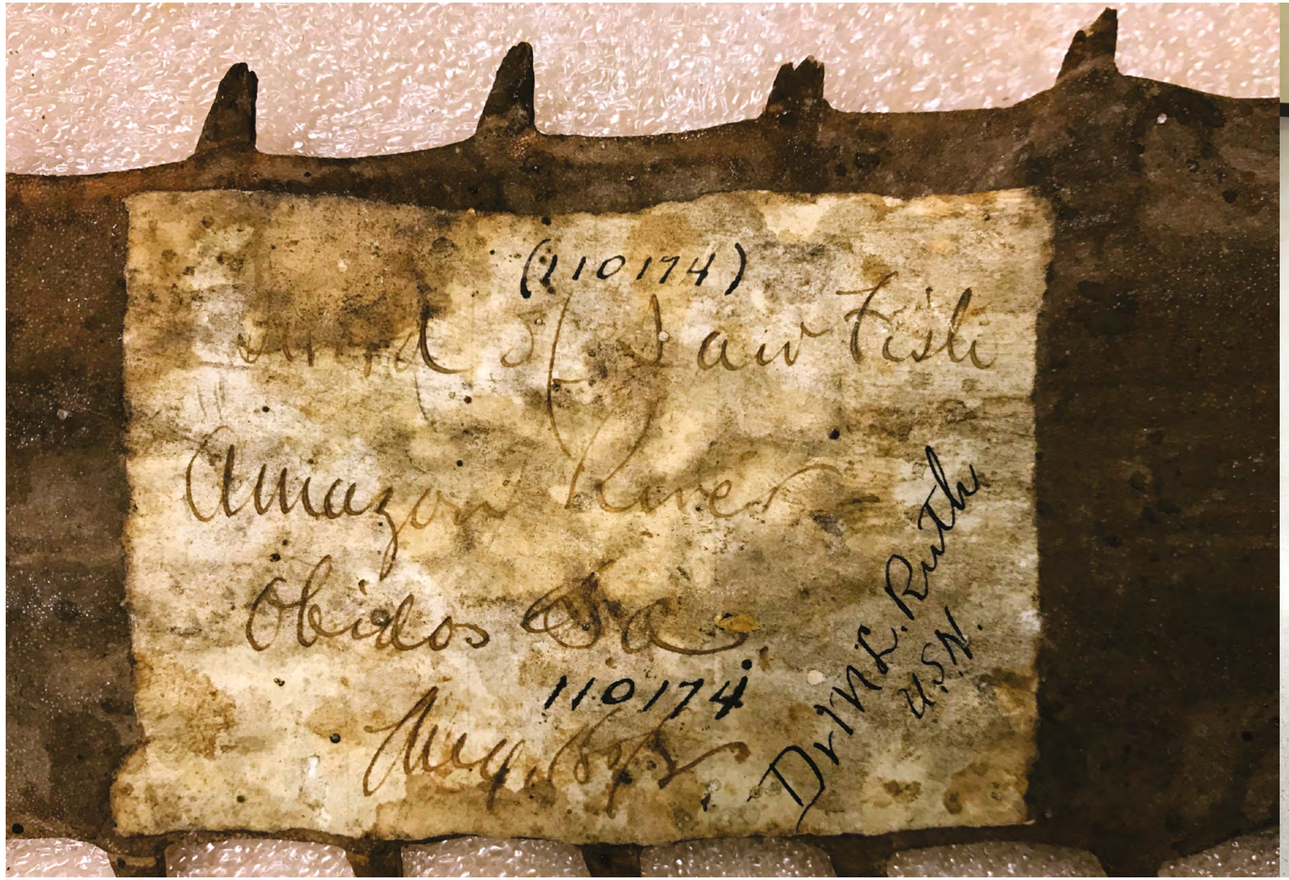


Photo by Annmarie Fearing

Photo by Kelcee Smith

Gregg Poulakis with a 1.5-metre (five-foot) total length smalltooth sawfish.

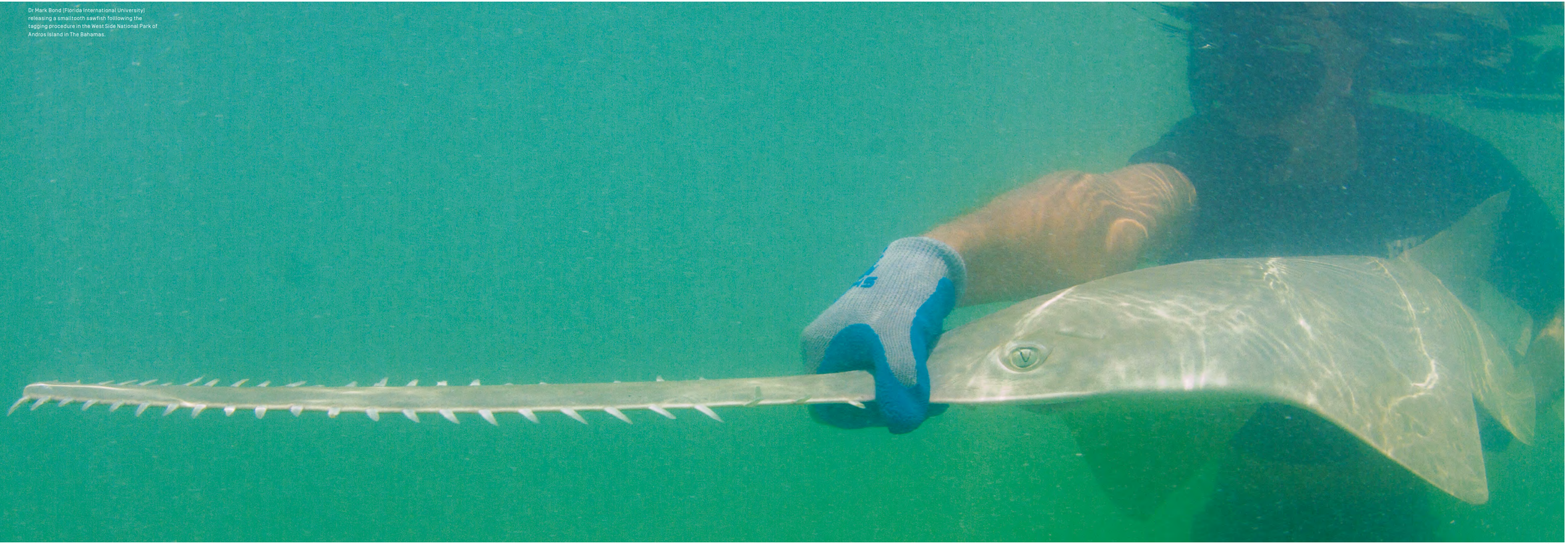
Photo by Gregg Poulakis | Florida Fish and Wildlife Conservation

The SARA team is stoked to be releasing this large juvenile freshwater sawfish *Pristis pristis* with an accelerometer tag attached to its saw.

Photo by Sarah O'Hea Miller | Sharks and Rays Australia

Dr Dean Grubbs (Florida State University | Coastal and Marine Laboratory) and Dr John Carlson (NOAA Southeast Fisheries Science Center | National Marine Fisheries Service), working on a smalltooth sawfish in the West Side National Park of Andros Island in The Bahamas.

Photo by Matthew Potenski



Dr Mark Bond (Florida International University) releasing a smalltooth sawfish following the tagging procedure in the West Side National Park of Andros Island in The Bahamas.

Photo by Matthew Potenski

INSIDE STORIES

REPORTS FROM THE SAVE OUR SEAS FOUNDATION
CENTRES AROUND THE WORLD

Photo by Jeffrey Rotman | BiosPhoto

SOSF D'ARROS RESEARCH CENTRE

RYAN DALY & CLARE KEATING DALY

Photo by Michael Scholl

INTRODUCTION

save our seas
d'arros research centre

OVERVIEW OF SOSF-DRC IN 2018

The mission of the SOSF-DRC, to be a regional centre of excellence for marine and tropical conservation, motivates the activities and research undertaken on this small island of the Amirantes Group in the Seychelles. In 2018 access to D'Arros was restricted, resulting in limited research activities. For this reason, the 2018 annual report details the remote activities, results and publications of SOSF-DRC staff and project leaders.

Through the generous support of the Founder of the Save Our Seas Foundation, the D'Arros Research Centre strives to achieve its vision and fulfil its mission and objectives. Its vision is to be a centre of excellence for marine and tropical island conservation; its mission is to preserve and showcase the ecological integrity of D'Arros Island and St Joseph Atoll through research, monitoring, restoration and education.

The research centre's objectives are to:

- Demonstrate that D'Arros Island and St Joseph Atoll harbour unique ecosystems and species assemblages and that they constitute vital components of the region's natural heritage.
- Minimise deleterious anthropogenic disturbances to the area through continued effective management and regular surveillance.
- Utilise innovative technology to monitor long-term trends in population numbers of sensitive species, important ecosystem processes and climate change.
- Identify, propose, implement and manage pertinent targeted research projects.
- Restore certain ecosystems to a more natural, biodiverse and productive state.
- Establish collaborative partnerships with universities, local NGOs, neighbouring Amirante Islands and other key role players, and share data.
- Promote conservation in the Seychelles through environmental education, collaboration, media productions and by sharing expertise.
- Produce peer-reviewed scientific publications, popular articles and useful managerial aids.

To reach its objectives and fulfil its vision, the SOSF-DRC comprises full-time staff as well as researchers, and it collaborates with universities, other external research institutes and Seychelles NGOs. In 2018, the SOSF-DRC permanent staff comprised Clare Keating Daly and Dr Ryan Daly. There were no research assistants over the course of the year. The Dalys resigned in 2019.

No researchers visited D'Arros in 2018. Researchers supported by the SOSF-DRC but not present on D'Arros were Dr Jeanne Mortimer, Evan Byrnes, Ornella Weideli and Lauren Peel.

In close collaboration with Dr James Lea of Danah Divers, the SOSF-DRC supports and maintains a network of 88 acoustic receivers (VR2W-69 kHz, VEMCO), which is significant as the only one of its kind and size in the region. Multiple research projects rely on the acoustic array for a variety of study objectives. The receivers were downloaded in November 2018.

RESEARCH ACTIVITIES

I. TURTLE MONITORING
PRINCIPAL INVESTIGATOR: DR JEANNE MORTIMER
FIELD PERSONNEL: SOSF-DRC STAFF, TURTLE TEAM WITH TEAM LEADERS MICHAEL LUC & LOUIS BONIFACE, LUKE GORDON, PRINCIPAL INVESTIGATOR
AUTHOR: DR JEANNE MORTIMER

D'Arros Island and St Joseph Atoll, considered together as a single site, host the largest nesting population of hawksbill turtles not only in the Seychelles, but in the entire Western Indian Ocean region. In addition, they have been recognised as one of the most important and unique sites for sea turtles in the Western Indian Ocean, given the relatively high numbers of hawksbill and green turtles sharing the same breeding beaches. This is important because the hawksbill turtle is listed by the IUCN as a Critically Endangered species and the Seychelles hosts one of the four largest national populations of nesting hawksbills anywhere in the world. Green turtles are listed as an Endangered species.

The D'Arros/St Joseph turtle monitoring programme, initiated in 2004, was the first such study to be implemented anywhere in the Amirantes Islands. Over the years the D'Arros programme gathered valuable data that document many aspects of the status and biology of the turtle populations.

Photo by Michael Scholl

Photo by Olivier Born

Photo by Michael Scholl

II. HABITAT AND RESOURCE PARTITIONING OF JUVENILE SHARKS

PRINCIPAL INVESTIGATOR: ORNELLA WEIDELI (CRIOBE)

Although assessments of shark nursery sites are important for shark management and conservation, in the Western Indian Ocean they are very limited. The remote and uninhabited St Joseph Atoll is, after the renowned Aldabra Atoll, the second atoll in the Seychelles where blacktip reef sharks and sicklefin lemon sharks were found to coexist. Given its remote location and pending proclamation as a marine reserve, St Joseph represents a relatively pristine ecosystem and provides a great opportunity to study these animals. The first objective of this research is to assess the shark populations of the atoll to determine their characteristics and ecology. In addition, a diverse set of methods, including active tracking, dietary investigation and stable isotope analysis, are used to better understand whether interspecific competition influences the sharks' use of habitat and resources.

Photo by Michael Scholl

PUBLICATIONS

In 2018, a manuscript detailing the findings of the population characteristics and ecology of coexisting blacktip reef and sicklefin lemon sharks at St Joseph was submitted to the *Journal of Fish Biology* and is currently under review:

Size frequency, dispersal distances and variable growth rates of young sharks in a multi-species aggregation. Weideli OC, Papastamatiou YP, Planes S.

Juvenile nursery-bound sharks are among the best-studied age group of elasmobranchs, yet the functional significance of young shark habitats remains equivocal. Recent findings provide evidence that such nearshore habitats might not provide sufficient protection and prey resources, which may considerably impact site-faithful, or philopatric species in remote or communal nurseries. During a mark-recapture survey from November 2014 until April 2017, 333 neonatal and juvenile blacktip reef sharks *Carcharhinus melanopterus* and 302 neonatal and juvenile sicklefin lemon sharks *Negaprion acutidens* were tagged and measured at the uninhabited and isolated St Joseph Atoll (Republic of Seychelles). Both species demonstrated seasonal reproductive synchronicity and relatively large sizes at birth. Despite the extended times at liberty of over 2.5 years, the majority of recaptures were found in close proximity to the initial tagging location (< 500 metres). Annual growth rates in 24 *C. melanopterus* and 62 *N. acutidens* long-term recaptures ranged from 6.6–31.7 cm year^{-1} (mean ± S.E.; 16.2 ± 1.2 cm year^{-1}) and 0.2–32.2 cm year^{-1} (11.8 ± 1 cm year^{-1}), respectively and are to date the most variable ever recorded in wild juvenile sharks. High abundances of both species coupled with long-term and repeated recaptures are indicative of a habitat where juveniles can reside for their first years of life. However, large variability in annual growth rates in both species may suggest high intra- and interspecific competition induced by a possibly resource-limited, isolated habitat.

ADDITIONAL CO-AUTHORED PAPER

Bouyoucos IA, Weideli OC, Planes S, Simpfendorfer CA, Rummer JL. 2018. Dead tired: evaluating the physiological status and survival of neonatal reef sharks under stress. *Conservation Physiology* 6. *doi: 10.1093/conphys/coy053*

CONFERENCE

Weideli OC, Papastamatiou YP, Planes S. 2018. Size frequency, dispersal distances and variable growth rates of sharks in multi-species nursery. 7eme Rencontre de l'Ichtyologie en France. Paris, France.

PRESENTATION

Weideli OC, Papastamatiou YP, Heithaus M, Planes S. 2018. Multi-dimensional niche patterns and underlying competitive interactions in sympatric juvenile predators. Oral presentation, Doctoral CRIOBE, Moorea, French Polynesia.

POPULAR ARTICLES

• Weideli OC. 2018. Haisser Job. *Coop Zeitung*, Switzerland.
• Weideli OC. 2018. Diese Tiere haben mich von der ersten Sekunde an fasziniert. *Bluewin*, Switzerland. *https://www.bluewin.ch/de/entertainment/tv/diese-tiere-haben-mich-von-der-ersten-sekunde-an-fasziniert-140455.html*

FILM

• *Seeking Sanctuary*, a short film featuring the work of the principal investigator, was produced and shot by Nick Jones, in association with the University of the West of England, and highlighted the importance of St Joseph Atoll as a critical location for young sharks. It was aired at seven film festivals in six countries and won a conservation award from the International Ocean Film Festival 2018.
• *Wasserwelten* (*Water World*) was aired in September on Swiss and German national television and featured Dr Karl Fleischmann and Terence Vel from the University of Seychelles on Mahé, as well the principal investigator. Promoted in several printed and online articles and by the principal investigator's appearance on a Swiss TV show, the documentary was one of the ways in which awareness of sharks, and of the need in general to conserve nature, was raised in 2018.

LOOKING AHEAD

Trophic and ecological niche investigations as well as competition experiences will be analysed throughout 2019. The goal for 2019 is to submit four manuscripts to peer-reviewed journals and to submit and defend the principal investigator's PhD. Meanwhile, the principal investigator continues to raise awareness through education and outreach presentations.

Photo by Michael Scholl

III. THE ASSESSMENT OF D'ARROS AND ST JOSEPH AS A REFUGE AREA FOR THE ENDANGERED HUMPHEAD WRASSE

PRINCIPAL INVESTIGATOR: DR KEVIN WENG & DR RYAN DALY

The humphead wrasse is a conservation-dependent species, but details about its spatial ecology are insufficient, partly because of its exiguous populations. Some of the highest densities of humphead wrasse known in the world occur in the Seychelles, however, and this gives us a unique opportunity to study the species.

According to preliminary data collection from tagged humphead wrasse, 344,129 detections were recorded between October 2017 and November 2018 (see figure 1).

Perhaps most surprisingly, all the detections of the 20 tagged fishes were recorded on only 25 of the 89 receivers located throughout the Amirantes Bank. This highlighted the fact that all tagged fishes (representing males and females, adults and juveniles) exhibited very restricted habitat use, favouring D'Arros Island and St Joseph Atoll. Specifically, all the tagged fishes appeared to favour the channel wall at the western edge of St Joseph Atoll, which clearly makes it a key habitat for humphead wrasse (see figure 2).

Tagged fishes also exhibited clear diel movement patterns, confirming in situ observations. Fishes were active during the day and rested at night (see figures 3A and 3B).

The results of this study confirm that the reefs surrounding D'Arros Island and St Joseph Atoll are critical habitat for the Endangered humphead wrasse. All the tagged fishes exhibited high site fidelity and restricted habitat use. Specifically, the western side of St Joseph Atoll appeared to be particularly important to tagged humphead wrasse and incorporated key refuge areas for individuals. In light of the fact that humphead wrasse populations continue to decline globally due to threats from overfishing, it is recommended that D'Arros Island and St Joseph Atoll are afforded protection in order to prevent the fishing of this vulnerable population. Additionally, evidence from this study suggests that a no-take marine protected area surrounding D'Arros and St Joseph will effectively protect the core areas of habitat use of humphead wrasse and vastly improve the conservation of the species in the Seychelles.

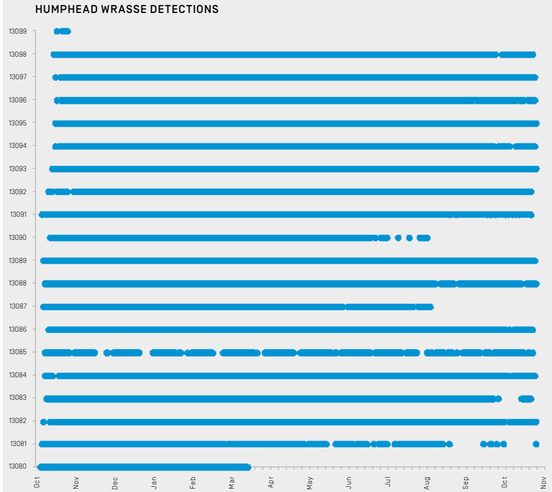
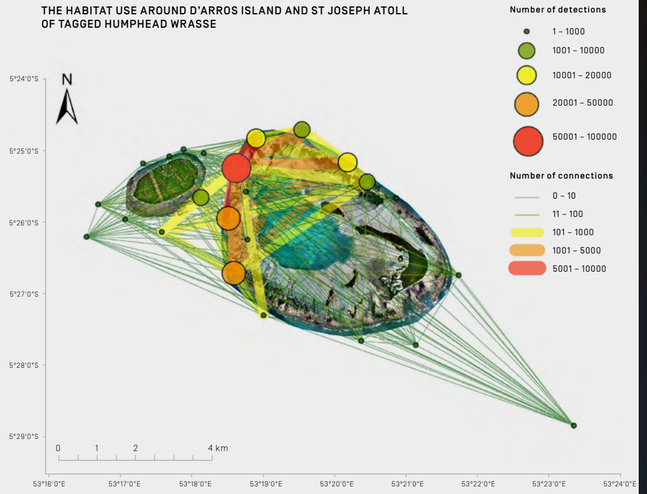


Figure 1:
The daily presence of tagged humphead wrasse at D'Arros Island and St Joseph Atoll. Tagged fishes exhibited high site fidelity throughout the monitoring period, with the exception of four individuals (ID 13080, 13087, 13090 and 13099), which were not detected after periods ranging between nine days (ID 13099) and 10 months (IDs 13087 and 13090).



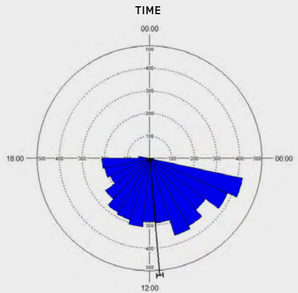


Figure 3A:
A rose diagram showing the time of detection frequency data from receiver 18, located on the west side of St Joseph Atoll. Results confirm that humphead wrasse are only active during the day between sunrise and sunset, when they are foraging.

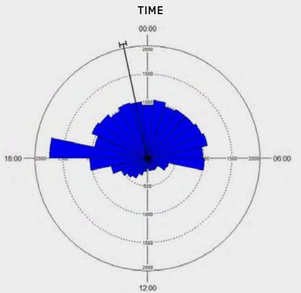


Figure 3B:
A rose diagram showing the time of detection frequency data from a receiver located at the known night-time resting location for humphead wrasse at St Joseph Atoll. These results confirm that St Joseph Atoll is a key refuge habitat for humphead wrasse.

< Figure 2:
A network plot representing the habitat use around D'Arros Island and St Joseph Atoll of tagged humphead wrasse between October 2017 and November 2018. Tagged fishes appeared to favour the channel habitat of D'Arros Island and St Joseph Atoll as well as the shallow western reef crest and slope of St Joseph Atoll. No wrasse were detected in the St Joseph lagoon.

< Andrew Grey releases a tagged humphead wrasse in October 2017. Twenty humphead wrasse were tagged during field work .

Photo by Ryan Daly

IV. MOVEMENT PATTERNS AND TROPHIC ECOLOGY OF REEF MANTAS

PRINCIPAL INVESTIGATORS: LAUREN PEEL
FIELD PERSONNEL: MANTA TRUST, UNIVERSITY OF WESTERN AUSTRALIA, AUSTRALIAN INSTITUTE OF MARINE SCIENCE

The aim of the Seychelles Manta Ray Project is to investigate the population dynamics, movement patterns, trophic ecology and genetics of the reef manta rays at D'Arros Island and St Joseph Atoll in order to further our understanding of the biology and conservation needs of this species in the Western Indian Ocean. The results of this study will be used to promote a more global view of the connectivity and conservation needs of reef manta ray populations and to highlight the importance of using scientifically informed management strategies to protect and conserve the species' populations in the Seychelles.

POPULATION DEMOGRAPHICS AND DYNAMICS OF REEF MANTA RAYS

A total of 1,562 manta ray sightings have been recorded in the Seychelles to date, with 56 new records having been added to the database in 2018. In addition, 23 incidental sightings of mobulid rays – 10 of which were made in 2018 – have been reported, including a rare sighting of spine tail devil rays *Mobula mobular* at Mahé in November 2018.

Despite limited field time in 2018, 23 new reef manta rays were identified and added to the Seychelles Manta Ray Project database, bringing the total number of identified individuals to 237. A single oceanic manta ray also sighted in 2018 was just the fifth individual *M. birostris* to be reported in the region.

Of all the confirmed reef manta ray sightings reported in the Seychelles, 1,417 (90.7%) have been made around D'Arros Island and St Joseph Atoll; of these, 19 were reported in 2018. The maximum number of sightings recorded for a single individual is 61 (SC-MA-0002; Four Stroke; sub-adult male).

The Seychelles reef manta population is currently equally represented by females (48.5%) and males (47.7%); 3.8% of identified individuals could not be sexed. Adults and sub-adults dominate the population (45.6% and 40.5%, respectively), with only a small number of juveniles (13.9%) being reported. Throughout the Seychelles as a whole, the re-sighting rate for individuals has increased since 2017 (56%) and currently sits at 63%. For individuals that were first sighted either at D'Arros Island or St Joseph Atoll, the re-sighting rate also increased in 2018 from 68% to 78%.

No additional inter-island movements of reef manta rays were recorded in 2018, keeping the current number of reported events at two.

MOVEMENT AND RESIDENCY PATTERNS OF REEF MANTA RAYS

Acoustic telemetry data collected between 2013 and 2015 and between 2016 and 2017 were merged in early 2018 and re-analysed. Collectively, the 164,336 detections emphasise the residency of reef manta rays at D'Arros Island and St Joseph Atoll and highlight the importance of this location to these charismatic animals. Statistical modelling was subsequently used to reveal the environmental drivers of the movement patterns of this species across the Amirantes receiver array. A manuscript detailing these findings is currently under review at *Marine Ecology Progress Series* (submitted 16 November 2018).

The most recent download of the Amirantes receiver array was completed in November 2018. On receipt of these new data, the full acoustic telemetry dataset will be collated and assessed to determine how many tags are still active on manta rays around D'Arros Island. If possible, acoustic detections will also be used to ground-truth the satellite track of SC-MA-0134.

Four archival satellite tags were deployed in the Seychelles for this project in 2017, three at D'Arros Island (two males, one female) and one at Alphonse Island (a male). Two of the tags deployed at D'Arros released successfully and 44% and 84% of their data were decoded. The third tag deployed at D'Arros Island also released, but appears to have suffered some sensor damage as position estimates and data records are sporadic.

Analysis of the satellite telemetry data has now commenced alongside that of the photo-ID data to quantify Seychelles-wide movement patterns in this species. Deployment of the remaining two satellite tags for the Seychelles Manta Ray Project has been delayed until 2019 due to logistical issues.

Photo by Michael Scholl

TROPHIC ROLE AND ECOLOGY OF REEF MANTA RAYS AT D'ARROS ISLAND

The processing and analysis of stable isotope samples were completed in 2018 on campus at the University of Western Australia (UWA) and the collected data were used to investigate the feeding ecology of reef manta rays at D'Arros Island and St Joseph Atoll. An experiment that examined the treatment effects of urea and extraction procedures on reef manta ray tissue was completed successfully and it is anticipated that the results will guide future trophic studies of this kind on reef manta rays.

A manuscript detailing the findings of the trophic ecology and tissue treatment studies has been prepared for submission to *Marine Biology* and is currently being examined by co-authors for comment and review.

Fatty acid analyses were scheduled to commence on campus at UWA in March 2018, but were delayed due to machine breakdowns. Procedural and optimisation trials began in July and were finalised at the end of November. It is anticipated that remaining zooplankton and manta tissue samples will be processed by the end of January 2019 at the latest. The results generated from this study will complement and expand upon those of the stable isotope analyses described above.

POPULATION GENETICS OF REEF MANTA RAYS IN THE SEYCHELLES

The processing of reef manta ray tissue samples collected for genetic analysis was completed in September 2018. DNA extracted from 68 samples was shipped to Diversity Arrays Technology (DArT) for sequencing and the resulting sequenced data will be used to assess the relatedness of reef manta rays in the Seychelles.

PUBLICATIONS

In 2018 two manuscripts were submitted to peer review publications:

Environmental drivers of the movements of reef manta rays (*Mobula alfredi*) in the Amirantes Island Group, Seychelles. Peel LR, Stevens GMW, Daly R, Daly CAK, Lea JSE, Clarke CR, Collins SP, Meekan MG.

Reef manta rays (*Mobula alfredi*) are large filter-feeding elasmobranchs that are undergoing substantial population declines on a global scale. In order to effectively conserve and manage populations, it is crucial that the environmental drivers of movement patterns are defined and that areas of critical habitat for this species are identified and protected. Here, we used passive acoustic telemetry to monitor and assess the movement ecology of *M. alfredi* in the remote Amirantes Island Group, Republic of Seychelles. Acoustic transmitters were externally deployed on *M. alfredi* at D'Arros Island (n = 46), and movement data retrieved from an array of 70 acoustic receivers located throughout the Amirantes between November 2013 and October 2017. Individuals were detected year-round, with a peak in detections occurring between November and April, coinciding with the arrival and departure of the north-west monsoon. Individuals were most likely to be detected within the array during the day and when water temperatures were approximately 28˚C. Additionally, individuals were more likely to be detected during a new moon, when the tidal range was at its highest, and on the slack of high tide. *M. alfredi* travelled widely within the Amirantes, with larger individuals travelling greater distances per day than smaller individuals and juveniles. The majority of detections (89%) were recorded within 2.5 km of the shoreline of D'Arros Island and the neighbouring St Joseph Atoll, highlighting the importance of these sites to *M. alfredi* in the Amirantes and supporting the proposed development of a marine protected area at this location.

Submitted to: *Marine Ecology Progress Series*

Phylogenomics and species delimitation of mobulid rays reveals cryptic diversity and a new species of manta ray. Hosegood J, Humble E, Ogden R, De Bruyn M, Creer S, Stevens G, Abudaya M, Bassos-Hull K, Bonfil R, Fernando D, Foote AD, Hipperson H, Jabado RW, Kaden J, Moazzam M, Peel L, Pollett S, Ponzo A, Poortvliet M, Salah J, Senn H, Stewart J, Wintner S, Carvalho G.

Practical biodiversity conservation relies on delineation of meaningful units, particularly with respect to global conventions and regulatory frameworks. Species delimitation methods have been revolutionised with the advent of next-generation sequencing approaches, allowing diversity within species radiations to be assessed with genome-wide data. Manta and devil rays (*Mobula* spp.) are threatened globally primarily from targeted and by-catch fishing pressure, resulting in recent protective measures under several global conventions and frameworks. However, a collective lack of representative global samples, ongoing taxonomic ambiguity, and ineffectual traceability measures combine to constrain the development and implementation of a coherent and enforceable conservation strategy for these species. Here we generate genome-wide Single Nucleotide Polymorphism (SNP) data from a globally and taxonomically comprehensive set of mobulid tissue samples, producing the most extensive phylogeny for the Mobulidae to date. We assess patterns of monophyly and combine this with species delimitation based on the multispecies coalescent. We find robust evidence for an undescribed species of manta ray in the Gulf of Mexico, and for the resurrection of a recently synonymised species, *Mobula eregoodootenkee*. Further resolution is achieved at the population level, where geographic population structure is identified in *Mobula* species. In addition, we estimate the optimal species tree for the group and identify substantial incomplete lineage sorting, where standing variation in extinct ancestral populations is hypothesised to drive taxonomic uncertainty. Our results provide genome-wide data to support a taxonomic review of the Mobulidae, and generate a robust taxonomic framework to support effective management, conservation and law enforcement strategies.

Submitted to: *Molecular Biology and Evolution* (full pre-print available at Biorxiv; *https://doi.org/10.1101/458141*)

ADDITIONAL CO-AUTHORED PAPER

Stewart JD, Jaine FRA, Armstrong AJ, Armstrong AO, Bennett MB, Burgess KB, Couturier LIE, Croll DA, Cronin MR, Deakos MH, Dudgeon CL, Fernando D, Froman N, Germanov ES, Hall MA, Hinojosa-Alvarez S, Hosegood JE, Kashiwagi T, Laglbauer BJL, Lezama-Ochoa N, Marshall AD, McGregor F, Notarbartolo di Sciara G, Palacios MD, Peel LR, Richardson AJ, Rubin RD, Townsend KA, Venables SK, Stevens GMW. 2018. Research Priorities to Support Effective Manta and Devil Ray Conservation. *Frontiers in Marine Science 5. doi 10.3389/fmars.2018.00314*

CONFERENCE

Peel L, Daly R, Keating Daly C, Stevens G, Collin S, Meekan M. 2018. Movement patterns and social structure of reef manta rays in the Amirantes Island Group, Seychelles. 4th Sharks International Conference. João Pessoa, Brazil, June 2018.

PRESENTATIONS

Peel L. 2018. First insights into the population size and habitat use patterns of reef manta rays at the Alphonse Island Group, Seychelles. University of Western Australia's School of Biological Sciences Postgraduate Retreat. Rottnest Island, Western Australia, 5 February 2018.

Peel L. 2018. Trophic ecology of the reef manta ray at D'Arros Island and St Joseph Atoll, Seychelles. Robson and Robertson Awards Ceremony. University of Western Australia, 10 July 2018.

Peel L. 2018. Movement patterns of reef manta rays (*Mobula alfredi*) in the Amirantes Island Group, Seychelles; implications for conservation. University of Western Australia's Oceans Institute Postgraduate Symposium. Perth, Western Australia, 2 November 2018.

LOOKING AHEAD

I continue to work towards submitting my PhD thesis at the University of Western Australia at the end of March 2019. On completion of my thesis, I plan to continue leading the Seychelles Manta Ray Project. I aim to expand our network of collaborators in the region in order to gain greater insight into the Seychelles-wide movement patterns and population dynamics of these species.

COMPONENT	DATA COLLECTION	ANALYSIS	FUTURE DATA COLLECTION
Photo ID	Complete	In progress	Yes
Acoustic telemetry	Complete	Complete	No
Satellite telemetry	Ongoing	In progress	Yes (Final dep. in 2019)
Stable isotopes	Complete	Complete	No
Fatty acids	Ongoing	Pending lab work	No
Genetics	Complete	In progress	No

Photo by Rainer von Brandis

Principal investigator and PhD student Chantel Elston prepares to release a porcupine ray in St Joseph Atoll after collecting dietary samples during field work in 2015. The paucity of information on batoids, particularly in remote places, means that the results of Chantel's work are novel. This project is significant for St Joseph Atoll and Seychelles, putting the atoll on the map as a critical nursery area, and the country for its contribution to the advance of scientific knowledge of three species of stingray.

V. ECOLOGY OF STINGRAYS AT ST JOSEPH ATOLL

PRINCIPAL INVESTIGATOR: CHANTEL ELSTON (RHODES UNIVERSITY)

This was the final year of the project funded by the Save Our Seas Foundation. All field work and lab work had been finished prior to 2018 and throughout the past year the collected data were analysed and the results written up into a PhD thesis titled 'The trophic and spatial ecology of a sympatric stingray community at a remote atoll, Seychelles'. The thesis was submitted to Rhodes University in November 2018 and the result is pending. A manuscript titled 'Movement patterns of juvenile porcupine rays *Urogymnus asperrimus* at a remote atoll: a potential nursery ground within a proposed Marine Protected Area' was submitted to a peer-reviewed journal and is currently under review.

Stingray fin clips were sent to Gavin Naylor for DNA sequencing to confirm the visual species identification. Results confirmed that two species, *Urogymnus asperrimus* and *U. granulatus*, had been correctly identified. However, the species thought to be *Pastinachus sephen* was identified through DNA analysis as *P. ater.*

PUBLICATIONS

Movement patterns of juvenile porcupine rays *Urogymnus asperrimus* at a remote atoll: a potential nursery ground within a proposed Marine Protected Area. Elston C, Cowley PD, Von Brandis RG.

Marine protected areas (MPAs) can provide distinct conservation benefits for threatened species, particularly in regions where there is a lack of population assessments. St Joseph Atoll, Seychelles, has been under consideration for MPA designation due to the presence of multiple threatened and important species. This study aimed to assess the nursery role of this isolated habitat for Vulnerable (IUCN) porcupine rays *Urogymnus asperrimus*. Twenty porcupine rays were tagged with Vemco transmitters and their movements passively monitored for a 2.5-year period using an array of 88 acoustic receivers. The majority (71%) of porcupine rays displayed medium (RI: 0.34–0.66) to high (RI: 0.67–1) levels of residency and 82% of individuals were detected in the atoll for periods close to or exceeding one year. Horizontal movements were limited as small home ranges and activity spaces were identified (mean of 0.65km^2 and 4.35km^2 respectively). General linear mixed models highlighted that larger individuals had larger home range sizes and that there was dispersal from the atoll over time. These results have implications for the proposed marine protected area at St Joseph Atoll and suggests that protecting this habitat will provide strong conservation benefits for this poorly understood species.

Submitted to: *Environmental Biology of Fishes*

CONFERENCE

Elston C, Cowley PD, Von Brandis RG, Frisk A. 2018. A multi-technique approach to reveal resource partitioning in stingrays. 4th Sharks International Conference. João Pessoa, Brazil, June 2018.

COURSE

Stable isotope analysis at Dr Elizabeth Yohannes Stable Isotope Lab, Institute of Limnology, University of Konstanz, Germany. April 2018.

LOOKING AHEAD

Three papers resulting from the PhD thesis will be prepared for submission in 2019 to appropriate journals.

The research, monitoring and conservation detailed in the preceding pages are made possible by the passion and support of the Founder of the Save Our Seas Foundation, to whom SOSF-D'Arros Research Centre staff and researchers wish to express their deepest gratitude.

All research and activities described in this chapter fall under the research permit issued to SOSF-DRC by the Seychelles Ministry of Environment and Energy (6/10/2013).

Photo by Michael Scholl

Photos by Michael Scholl

Photo by Olivier Born

Photo by Michaël Scholl

SOSF SHARK EDUCATION CENTRE

ELEANOR YELD HUTCHINGS

save our seas
shark education centre

'Between taught lessons, rock-pool explorations, board games, beach-based quizzes and races, and now a tablet-based app, there is a big variation of learning techniques employed …, which makes the whole experience extremely interactive'

2018 was a year of challenging change at the Save Our Seas Foundation's Shark Education Centre: change in staff, change in planned and budgeted activities, change in organisational structure. Looking back, though, it was definitely a year in which the centre came out stronger in the end, more vibrant and more cohesive than ever. The year was also marked by another large increase in the number of learners who came through our doors. We are exceptionally proud of this, especially in view of the reduced budget and budgeted activities for 2018. The number of groups itself did not increase substantially from 2017, but the group size did. Many more of the groups had doubled in size or brought multiple classes in one visit. With the centre's exhibits all up and running, and our Treasure Hunt app working and fully implemented into the programming, we were able to offer an exceptional interactive learning experience.

The centre also saw some changes in staff. After eight years with us, Paul Millar resigned as the education coordinator and left in June 2018 to take up a teaching position at a high school. After we had conducted a thorough recruitment process and received a record number of excellent applications, Wisaal Osman was appointed as the new education coordinator and started work in September 2018. Wisaal graduated from the University of Cape Town with a Master's degree in science, specialising in applied marine science. Her subsequent career path took her from WWF South Africa's Sustainable Seafood Programme (WWF-SASSI) to the Council for Scientific and Industrial Research (CSIR), where she was involved with strategic environmental assessments in support of national strategic integrated projects that further the country's development goals.

Wisaal is passionate about sustainability and how to live in harmony with nature and she takes a keen interest in projects that contribute to the development of communities. Since 2016 she has been teaching maths and science to high school students at an under-resourced school in Mitchell's Plain, a suburb of Cape Town. Her aim is to help students to grasp new learning concepts, as well as to contribute to their holistic development as they navigate their life path. The challenge is to make learning fun and relevant to the student, using whatever tools are available. She wasted no time in getting stuck in at the centre and immediately started redesigning and refreshing the programmes, coming up with new ideas, participating in everything and adding a new and enthusiastic presence to the team that was welcomed by one and all.

There was also a fairly significant operational change, with the formation and registration of the Save Our Seas Foundation Non-Profit Company (SOSF NPC) in South Africa, which took over all the assets and operations of the Shark Education Centre from the Save Our Seas Foundation. This involved changing to a new bank account, moving all supplier and contractor accounts and acquiring a new lease agreement for our building. It also meant that all staff of the SOSF Shark Education Centre had to be issued new contracts under the SOSF NPC and that a new payroll had to be set up; that registrations for tax and tax exemptions had to be applied for; and that new auditors for the SOSF NPC audit had to be appointed.

The Shark Education Centre hosted a number of people in the two accommodation bedrooms upstairs. Some of the guests who stayed with us during the year were Dr Ryan Daly and his wife Clare, the programme and research directors of the Save Our Seas Foundation's D'Arros Research Centre; Dr Courtney Cook, Dr Bjoern Schaffner and Dr Olena Kudlei from the Water Research Group at the Unit for Environmental Sciences and Management, North West University, who came to research South African shark parasites; Eva Meyers, the project leader for the Save Our Seas Foundation's project 'Angel of the Canary Islands'; and Dr Ruth Leeney, the project leader for the Save Our Seas Foundation's project 'Protect Africa's Sawfishes'. We love having visitors here, as it is a wonderful opportunity to collaborate and to learn more about what shark science and research is being done around the world.

2018 was a busy year for our formal education programming, with classes visiting the Shark Education Centre for a day out to explore the rock pools and learn about sharks and what we can do to help conserve our oceans and marine environment. The number of learners has increased from nearly 2,000 in 2016 to approximately 2,700 in 2017 and now to 3,600 in 2018. Because the number of groups was fairly constant from 2017 to 2018, it was clear that the groups

Photo by Michael Scholl

Photos by Francis Moult

Photos by Francis Moult

themselves increased in average size. This was noticeable to the staff, as we often had to make use of our second classroom, which enabled us to accommodate two or more classes together. Holiday Clubs remained popular and we counted 148 person days, with 20 children attending each day. As has been the case previously, they were fully booked long in advance. The youngsters took part in such activities as shark lessons, rock-pooling, science experiments, beach hunts, coastal walks, harbour tours, arts and crafts, baking and, of course, a lot of swimming!

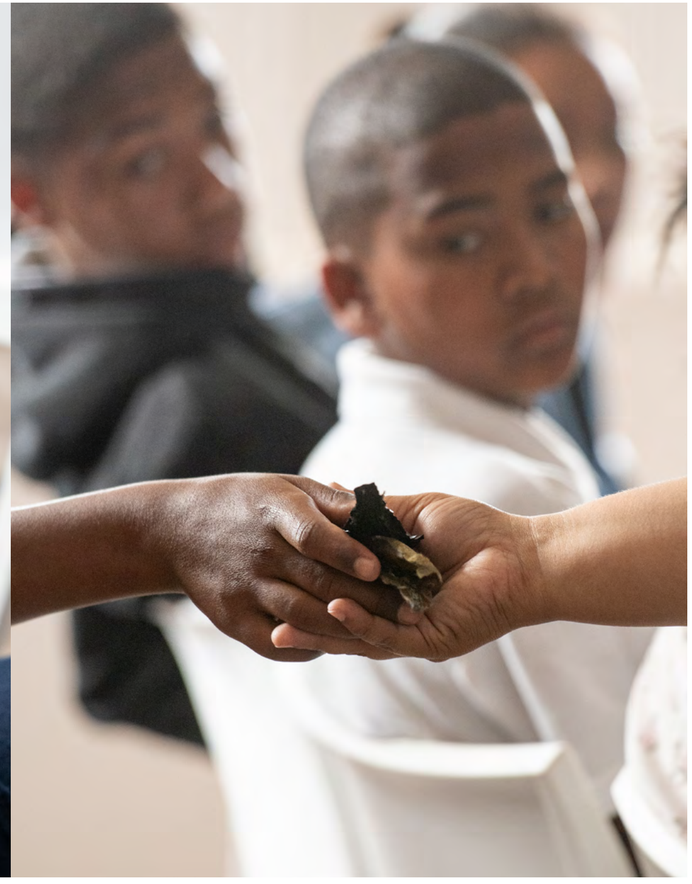
The extremely popular and successful Marine Explorers programme continued in 2018 with Capricorn Primary School and Muizenberg Junior School, both of which are located within easy reach of False Bay and Muizenberg beach. Both schools have seen real value in this programme and have reported very positive impacts on the learners who participate. We are so grateful for the wonderful collaborations with our partners in this programme: Xpression on the Beach, University of Cape Town Underwater Club and Pisces Divers, each of whom contributes significantly to the success of the programme and to the incredible experience that the participants have. This year both Wisaal Osman and Ntombizanele Mayiya were certified as PADI skin divers through the Marine Explorers Club, along with the learners.

Here are a few of the feedback comments we have received from teachers who brought their learners to the centre during 2018:

- *'I wanted to thank you for an awesome morning. We all really enjoyed it to the max! It was so interesting and I wish we could have stayed a bit longer.'*
- *'The students, and myself, walked away with more knowledge.'*
- *'I could see the passion you have for what you guys are doing there.'*
- *'Just wanted to thank you for our marvellous visit there yesterday. The educators were excellent guides, with a wonderful ability with, and energy for, young children. [There are] not many of those around! I eagerly await the children's return after the weekend to see which pictures of our seas you have engraved in their minds.'*

Photos by Francis Moult

Photos by Nicholas James Good | Fresh Air Crew



Photos by Francis Moult

- *'We really enjoyed our day with you all. All the best for your very important work.'*
- *'Thank you so much for an enjoyable morning at the Shark Centre. You are all doing such a great job. Keep it up!'*

We also helped to organise or participated in a number of events during 2018. Some of the highlights were: the LIMPET (Longterm Intertidal Monitoring citizen science initiative) workshop to train teachers how to participate in LIMPET with their learners, held at the centre in February; a beach-based holiday programme coordinated with the 9Miles Project in March; an exhibit for the Western Cape Education Department aimed at teachers at the Western Cape Marine Educators Fieldtrip Fair (advertising the programmes that we run to teachers) in August; an exhibition and interactive sessions at the Zandvlei Festival in October; and the TRAFFIC (wildlife trade monitoring experts) workshop to train its collaborators at the centre in November.

This year the South African Marine and Coastal Educators Network (MCEN) held its annual January conference in the Northern Cape. The week began in the Augrabies Falls National Park, moved to Port Nolloth, a diamond mining and fishing town on the coast, and then returned inland to Upington. The Northern Cape in mid-summer is a challenging environment, with midday temperatures rising to 47 °C (116 °F) at midday. This week is always such an inspirational time for us, as we network with other coastal and environmental educators, learn some new ideas and activities, share our own experiences and get ready for the year ahead. This year I shared two activities: Shark Bingo, which is a version of the popular game Bingo using different shark species (allowing you to share shark information and fun facts while the children are playing an entertaining game); and 'Oceanopoly', a game modelled on Monopoly that I created for younger learners. This game encourages numeracy, literacy, monetary literacy, knowledge of False Bay marine creatures – and it's a lot of fun too. Highlights of the week included visiting the Augrabies Falls, a waterfall system on the Orange River, exploring the diamond mining museum at Port Nolloth and a

visit to three Northern Cape schools where the MCEN group presented various curriculum-aligned activities. Another highlight was the sunset cruise on the Orange River, which is a spectacular contrast of water and greenery set against the arid desert of the Northern Cape!

As I am the Western Cape representative on the MCEN's National Steering Committee, it is my responsibility to organise the annual regional meeting. The 2018 Western Cape Regional MCEN conference was held at the SOSF Shark Education Centre in October, which is National Marine Month. It was a great success, with keynote addresses from the likes of Emeritus Professor George Branch and some wonderful in-field sessions run by the crew from the LIMPET citizen science programme.

One of the real challenges for NGOs and education centres is how exactly we assess the impact that we are having with our programmes. This goes beyond just keeping a detailed list of schools, numbers of educators and kids, visitor numbers and the like; it needs to be an ongoing process of monitoring, evaluating and learning. In order to do this, we have been working with a specialist company to develop an evaluation system to assess the impact of the SOSF Shark Education Centre. This very important process needs to be targeted specifically to our audience and facilities and can take a lot of time and effort to set up properly. The first step was to conduct a rapid evaluation and then develop the centre's 'theory of change'. This theory is used as a framework on which to construct exactly what we need to measure and how we go about it. We began trialling some of our data collection tools for measuring our impact during 2018. It adds a fair bit of time and effort in the preparation of our programmes, but it should be worth it! The first data collection tool consists of a 'pre and post' question session, where the learners are asked a set of eight questions at the beginning of their day with us (basic questions to which they answer 'yes', 'no' or 'don't know') and are asked the same set of questions at the end of the day. The answers are anonymous and the learners can't see what their classmates answer. The two sets of answers are then scored and compared, so that we can assess whether we are teaching them any of the knowledge associated with our identified key messages.

Photos by Francis Moult

Photos by Francis Moult

'With the centre's exhibits all up and running, and our Treasure Hunt app working and fully implemented into the programming, we were able to offer an exceptional interactive learning experience'

We have also been implementing the 'Ocean Pledge', where at the end of the day we ask each learner to write his or her own ocean pledge. This is a personal promise on their part either to do something or to stop doing something in order to help save our seas. This is aimed more at assessing whether we are effecting any attitude changes, or are giving them the tools they feel they need to take action. Once the learners have written their pledges, we take a photo of the whole class's pledges. They take their pledge home with them as a reminder. We will follow up with their teachers later in the year so that they can ask who has been keeping their promises. This serves as an active reminder to the learners that they themselves have the power to take environmentally responsible actions that have positive consequences. In addition, we are working with a researcher doing her M.Phil. on 'Conservation benefits of interpretation at a wildlife tourism site: Using sharks as ambassador animals to encourage pro-conservation behaviour'. In conjunction with her, we are doing teacher surveys with all teachers who bring their groups to the Shark Education Centre. This research will aim to measure the impact that interpretation (educational signage, exhibits, interactive experiences and presentations) in a free-choice learning centre has on the visiting public. It will thus be a valuable resource for us to use as well.

The Treasure Hunt app, developed specifically for the SOSF Shark Education Centre by RetroEpic, is designed to lead players around the centre with mandatory explorations of every exhibit – from the signage to the detailed information within the exhibit itself – in order to earn a 'reward'. After being trialled in 2017, the app was incorporated fully into our outward-facing programmes in 2018. We have purchased 10 Apple iPad Air tablets for the centre, pre-loaded with the app, and have put them into extremely robust protective cases. This means that the app can be used for groups of 30 to 40 learners, as it really only works with a maximum of three or four young children sharing an iPad. Teachers have been really enthusiastic about this new addition, as it adds a different element of learning. Between taught lessons, rock-pool explorations, board games, beach-based quizzes and races, and now a tablet-based app, there

Photos by Nicholas James Good | Fresh Air Crew

Photos by Nicholas James Good | Fresh Air Crew

'We are here to help kids discover the magic of the sea and we do it through the imagining of the scientific information to make learning fun'

is a big variation of learning techniques employed for groups visiting the centre, which makes the whole experience extremely interactive.

The drought that South Africa's Western Cape endured due to very low rainfall during our 2015, 2016 and 2017 winter seasons was alleviated to some extent by reasonable rainfall in winter 2018. However, it has not broken entirely and the City of Cape Town has maintained water restrictions for municipal water use. We have cut our water use substantially at the centre by collecting all grey water, reducing toilet flushing (and using rain or grey water to do this), reducing dish washing, asking visitors to take extremely short showers and to collect their shower water for toilet flushing, and catching as much rain water as possible by diverting downpipes into barrels, buckets and outside sinks. Four large rainwater tanks, with a total capacity of 5,100 litres (1,347 US gallons), were also installed at the centre. Collected water really helped us during the drought to wash wetsuits, flush toilets and clean the centre. Staff, visiting guests and school groups all helped to keep our water usage to a minimum. The garden managed to survive well with very little watering, thanks to having been replanted with water-wise, indigenous plants during the previous year.

Looking back at 2018, I asked the rest of the Shark Education Centre's team for the most important lesson that they took away from the year.

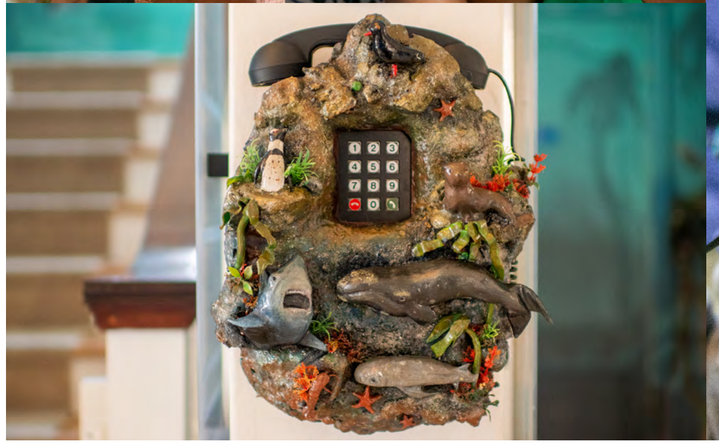
Wisaal Osman (education coordinator): 'We are here to help kids discover the magic of the sea and we do it through the imagining of the scientific information to make learning fun. I am always evaluating myself and my teaching style: the content is similar but how can I get kids excited about the world of sharks and the marine ecosystem? Is there a new, creative or innovative method I could use?'

Ntombizanele Mayiya (assistant educator): 'Once you get a job work very hard and make sure that you give your employer more than he or she ever expected.'

Claire-Frances Metcalf (facilities administrator): 'The wheel turns slowly when it comes to certain processes, but it does turn. Keep at it and be patient and persistent until you get it right.'

Nosakhele Lillian Ngotshane (housekeeper): 'One thing that I noticed this year is that we were very busy, but it brought out the best in everyone because we had to really work as a team to make everything happen.'

For me, the lesson was definitely not to underestimate the power of teamwork and determination. With a number of real challenges facing us this year, we pulled together and, by dint of everyone having a 'can do' attitude and displaying grit, passion and enthusiasm, we have really gone from strength to strength. And with Wisaal as our new education coordinator, the future looks bright for the SOSF Shark Education Centre and its incredibly important work. As the renowned anthropologist Margaret Mead said, 'Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it is the only thing that ever has.'



Photos by Francis Mouli

Photo by Francis Mouit

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SOSF SHARK RESEARCH CENTER

MAHMOOD SHIVJI

save our seas
shark research center

'In 2018 we completed the analyses of the vast amounts of DNA sequence data we had collected by comparing our white shark genome sequences to genome sequences of the only two other chondricthyan genomes available'

The Save Our Seas Shark Research Center (SOSSRC) is located at Nova Southeastern University, Florida, and housed in the modern research facilities of the Guy Harvey Oceanographic Center. In addition to being one of three global centres of the Save Our Seas Foundation, the SOSSRC is an academic unit of Nova Southeastern University, with a dual mission of conducting advanced marine science research and providing student education at university level.

The SOSSRC focuses on using a multi-disciplinary approach to research by developing and employing methods from genetics, genomics and field ecology. This approach to research is based on our philosophy that a reliable, holistic understanding of animals is best obtained by using a diverse set of tools from different disciplines and in a carefully considered, integrative manner. Understanding animal biology and behaviour from a holistic perspective provides the best scientific information for developing conservation plans for imperilled wildlife.

Given the interdisciplinary breadth of SOSSRC research, many of our projects are accomplished by combining resources and expertise from multiple sources. We work in close partnership with the Guy Harvey Research Institute on a wide variety of shark and ray research projects. We collaborate not only with this key programmatic partner, but also with scientists from across the world to achieve the best possible scientific outcomes.

In 2018, the SOSSRC continued its global research on sharks and rays to understand the population dynamics of these animals. A major emphasis was on using genetics and, increasingly, genomics tools to identify genetically distinct populations within widespread species of sharks, to determine the level of genetic diversity in these species and to decipher trends in their population sizes. A key issue in the world of managing and conserving globally distributed shark species captured in fisheries is answering the basic question: how many genetically different populations of the species are there? This typically means identifying how many genetic stocks exist, where they occur and how different they are (genetically) from one other.

Why is this information important? Because a fundamental requirement for properly managing exploited marine species is to conserve their genetic diversity. This diversity is critical for providing species with the ability to adapt to ongoing changes in the environment – and thus a buffer against extinction. In other words, genetic diversity allows some individuals in a species to adapt to changes in their environment that might otherwise wipe out other individuals. And the individuals that can adapt because of their specific genetic make-up will survive, find mates and reproduce, leaving offspring with their genes – the very definition of biological fitness, or Darwinian fitness, as it is also known – and thus ensuring survival of the species.

In 2018, another major effort by the SOSSRC team and its collaborators was our continued research on decoding entire genome sequences of sharks to obtain a highly detailed view of the genetic basis underlying the biological and ecological functioning of these extraordinary animals.

'We found striking occurrences of specific DNA sequence changes indicating molecular adaptation (also known as positive selection) in numerous white shark genes that have important roles in maintaining genome stability'

I. DECODING SHARK GENOMES

The SOSSRC continued its research collaboration with colleagues at Cornell University (USA), Saint Petersburg State University (Russia) and the Monterey Bay Aquarium, California (USA), and extended this international collaboration to involve scientists from the University of Porto (Portugal) and the California State University, Monterey Bay, and Clemson University (USA). The overall goal of this massive project is to understand how sharks function at their most fundamental level – their entire genomes and expressed genes – and use that knowledge to increase awareness of the biology and ecological importance of sharks.

This international collaboration brought together financial resources and highly specialised expertise in genomic technologies to achieve our ambitious project goals. We are pleased to report that a major scientific paper on decoding the entire genome of the great white shark was accepted for publication in a prominent journal, the *Proceedings of the National Academy of Sciences, USA*.

Our goal was to obtain a high-quality DNA sequence characterisation of the whole genome (genetic blueprint) of one of the world's most charismatic animals, the white shark, a species that is probably one of the most publically recognised animals in the world. In 2018 we completed the analyses of the vast amounts of DNA sequence data we had collected by comparing our white shark genome sequences to genome sequences of the only two other chondricthyan genomes available (that of the whale shark and the chimaera, elephant shark), and also to biomedical model vertebrate genomes more broadly, including humans. The intensive computational analysis required a whole team of experts in various bio-informatics specialities (hence the international team of collaborators). This major effort proved to be extremely worthwhile, as we made some unexpected, but very exciting discoveries.

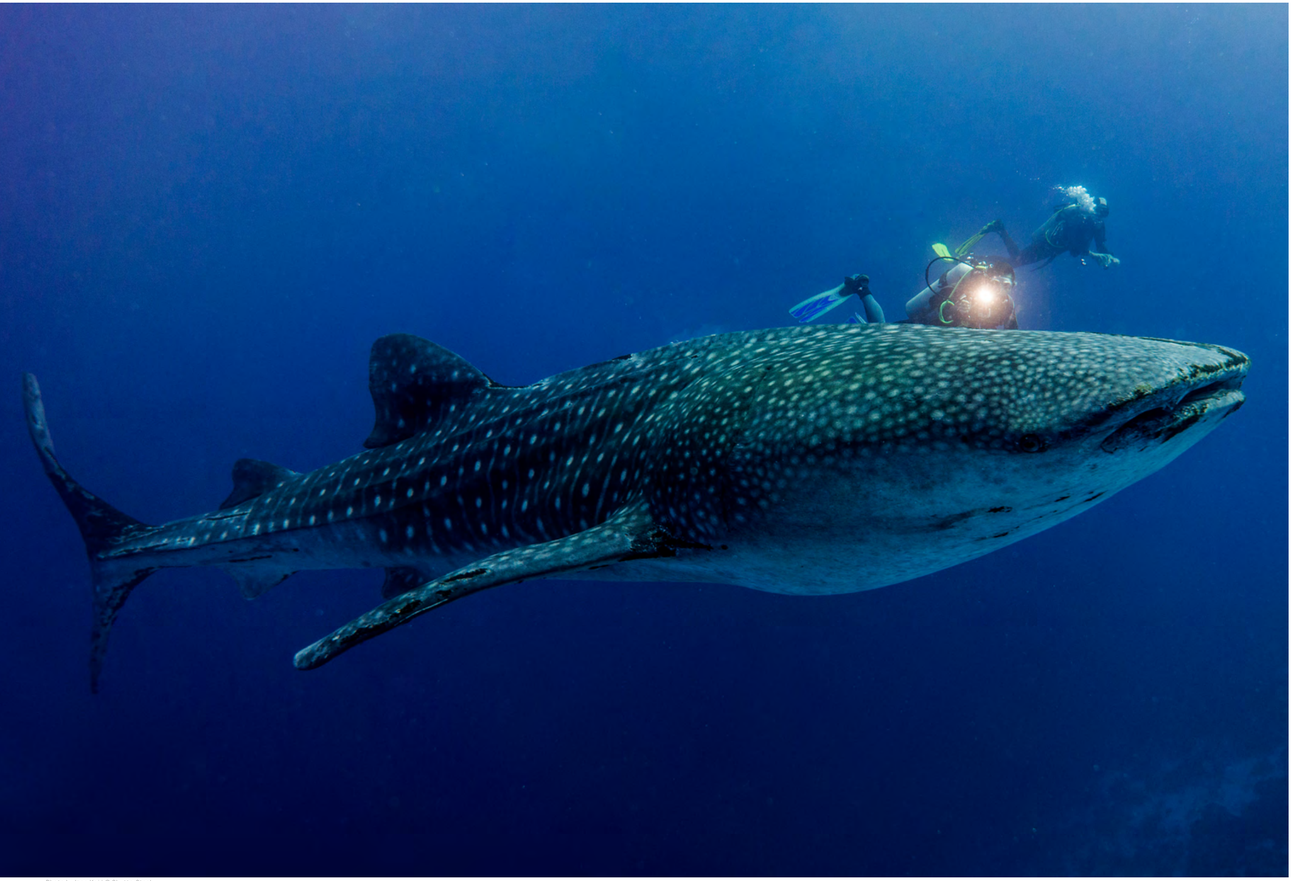
The white shark genome represents the largest vertebrate genome yet sequenced, which made the assembly and bio-informatics analyses challenging. After substantial bio-informatics analyses with cutting-edge computational approaches, we obtained a high-quality genome assembly. The final gene analysis resulted in the discovery of about 25,000 predicted genes in the white shark, a number surprisingly in line with the total number of genes found in biomedical model vertebrate species (mouse, human, chicken, zebrafish) with much smaller genomes. The question then became what explained the huge size of the white shark genome? It turns out that the explanation is in the amount of repeat DNA in the white shark genome, which makes up nearly 60% of the total DNA. This amount is very large relative to other species.

Decoding the white shark's genome revealed not only its huge size – 1.5 times the size of the human genome – but also a plethora of genetic changes that could be behind the evolutionary success of large-bodied and long-lived species such as the white and whale sharks.

We found striking occurrences of specific DNA sequence changes indicating molecular adaptation (also known as positive selection) in numerous white shark genes that have important roles in maintaining genome stability. The descriptor 'genome stability' refers to the genetic defence mechanisms that counteract the accumulation of damage to a species' DNA. The reason that such defence mechanisms are critical for survival is that the DNA in all species is continuously being damaged by mutations. If not repaired properly, such damage leads to all kinds of diseases. In fact, because the opposite phenomenon, 'genome instability', predisposes humans to numerous cancers and age-related diseases, the study of mechanisms that influence genome stability in humans has become a major area of medical research. Little is known about genome stability in non-human vertebrates. Such information is critical for understanding the evolution of genome stability mechanisms in general and has the potential to assist in improving human medicine.

Of particular note, we found that the adaptive DNA sequence changes that had occurred in the white shark genome were in genes that are intimately tied to the major genome stability mechanisms of DNA repair, DNA damage response and DNA damage tolerance, among other genes. Not only was there a surprisingly high number of genome stability genes that contained these adaptations, but there was also an enrichment of several of these genes, highlighting the importance of this genome fine-tuning in the white shark.

Photo by Saulty72's | © ShutterStock



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'We also compared the whole white shark genome sequence to that of the whale shark, another large-bodied and long-lived shark species. Much to our surprise, we found that the whale shark also had these same key genome stability adaptations'

Another notable discovery was that the white shark genome contained a very high number of 'jumping genes', or transposons, and in this case a specific type, known as LINEs. In fact we found that the white shark has one of the highest proportions of LINEs (nearly 30%) discovered in vertebrates so far! These LINEs are well known to cause genome instability by creating double-stranded breaks in DNA when they jump around the genome. We believe that this proliferation of LINEs in the white shark genome could represent a strong selective agent for the evolution of efficient DNA repair mechanisms, which is reflected in the positive selection and enrichment of so many genome stability genes we found in this shark.

As part of our study, we also compared the whole white shark genome sequence to that of the whale shark, another large-bodied and long-lived shark species. Much to our surprise, we found that the whale shark also had these same key genome stability adaptations! This result is significant because, in theory, the risk of developing cancer should increase with both the number of cells (large bodies) and an organism's lifespan. In fact, there is statistical support for a positive relationship of body size and cancer risk within a species. Interestingly, this does not tend to hold up across species. Contrary to expectations, very large-bodied animals do not get cancer more often than humans, suggesting they have evolved superior cancer-protective abilities. The genetic innovations discovered in genome stability genes in both the white and the whale shark could be adaptations leading to their large bodies and long lifespans.

But the innovations we found in the shark genomes did not end with genome stability genes. In fact, the shark genomes revealed other intriguing evolutionary adaptations in genes linked to wound-healing pathways. Sharks are known for their impressively rapid wound healing, but the mechanisms underlying this characteristic are unknown and of great interest for potential applications to human medicine. We found positive selection and gene content enrichments in both white and whale sharks involving several genes tied to some of the most fundamental pathways in wound healing. One standout gene that had undergone DNA adaptations was FGG (full name: fibrinogen gamma chain), which produces a protein known as fibrinogen, a key ingredient in the formation of blood clots. These adaptations involving wound-healing genes may underlie the vaunted ability of sharks to heal efficiently from even large wounds.

We have explored only the tip of the iceberg with respect to the white shark genome. Genome instability is a very important issue in many serious human diseases; now we find that nature has developed clever strategies to maintain the stability of genomes in these large-bodied, long-lived sharks. There's still a great deal to be learned from these evolutionary marvels, including information that will potentially be useful to fight cancer and age-related diseases, and improve wound-healing treatments in humans, as we uncover how these animals do it.

Decoding the white shark genome has other benefits too. In addition to making a major scientific contribution to understanding sharks at their most fundamental genetic level and the potential for human medicine benefits down the road, this genome information will assist in the conservation of white sharks and their relatives. The genome data will be a great asset for understanding white shark population dynamics to better conserve this amazing species that has captured the imagination of so many. From a big-picture perspective, decoding the white shark genome is providing science with a new set of keys to unlock lingering mysteries about these feared and misunderstood predators – and why sharks have thrived for some 500 million years, longer than almost any vertebrate on earth.

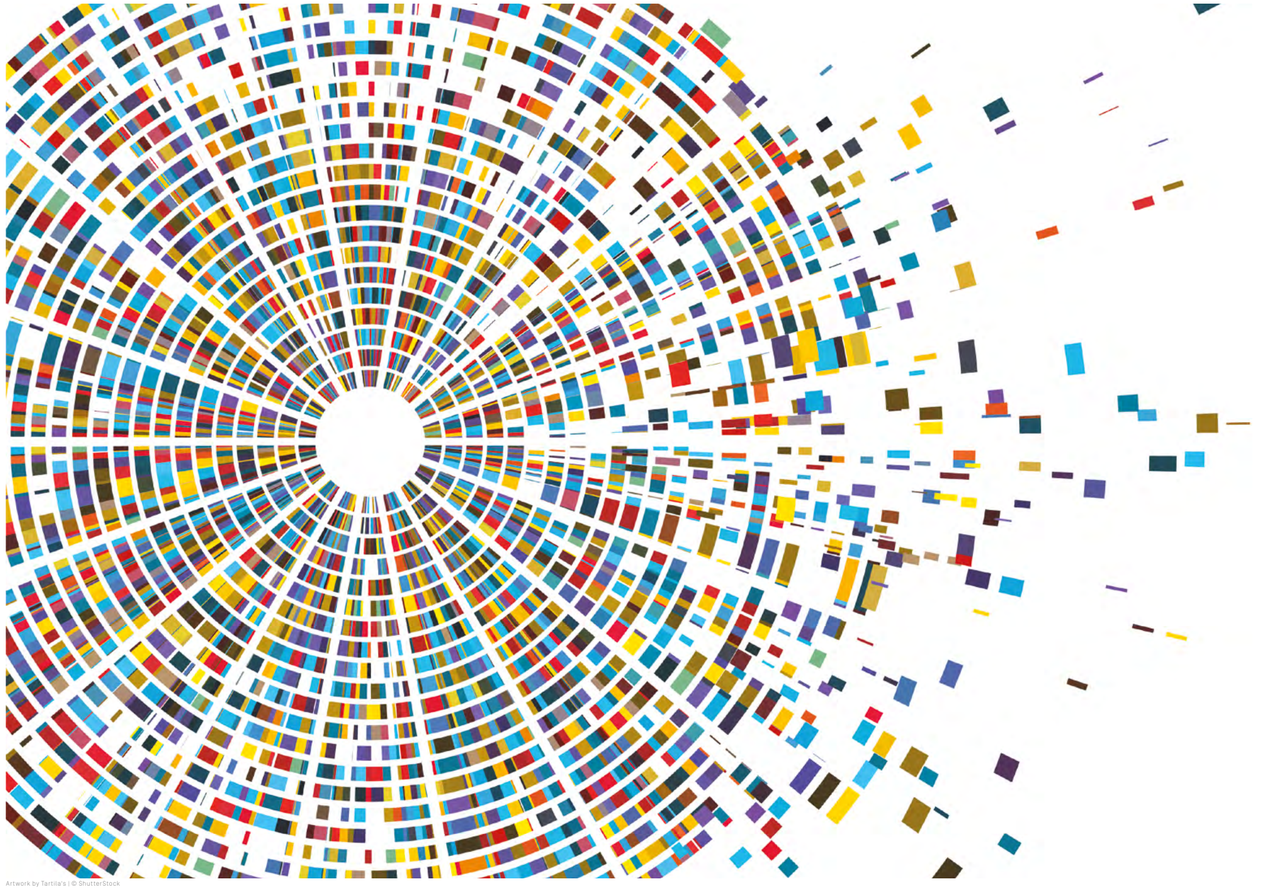
II. USING GENOMIC TECHNOLOGY TO REVEAL THE POPULATION DYNAMICS OF WHITE SHARKS

Key information needed for improving the management and conservation of sharks is the identification of genetically distinct populations within a species. It is particularly crucial for shark species that have widespread distributions, because individual populations living in different geographic regions can become genetically adapted to their specific environments. As mentioned earlier, these genetic changes (manifested in genetic diversity) are critical for providing species with the ability to adapt to ongoing changes in the environment (nowadays, think climate change), thus providing an

evolutionary buffer against extinction. Furthermore, if individuals from geographically widespread populations do not interbreed over long periods of time, then their gene pools can diverge to the point that these populations evolve into different species altogether.

A major quest in the world of investigating differences among populations is developing and using DNA markers that provide the highest resolution to identify such genetic variations. With the advent of faster DNA sequencing machines and methods (known as Next Generation Sequencing; NGS), the ability to obtain huge amounts of sequence data at the genomic-scale is now feasible. The SOSSRC has embraced these sophisticated new technologies and is applying them to investigate the detailed population dynamics of sharks and rays at the highest resolution possible.

The white shark is a globally distributed species in temperate to tropical oceans. Given the low frequency of encounters with this species outside limited aggregation areas, it is believed that white sharks have small population sizes, and the species is listed as Vulnerable to extinction on the IUCN Red List. To gain a more detailed view of white shark population dynamics, including the extent of genetic differences, the SOSSRC collaborated with colleagues from Cornell University and Clemson University to obtain a huge amount of NGS-generated data (transcriptomes) from a white shark. The study, led by Dr Andrea Bernard of the SOSSRC, then conducted a series of bio-informatics and laboratory analyses to discover and test a large number of genetic markers (known as microsatellites) that can be used to conduct high-resolution population analyses. Using this genome-scale approach, we were able to quadruple the available marker set from an existing 10 to 40 microsatellites! This powerful set of microsatellites was then used to investigate the genetics of white sharks sampled across the Pacific. Our results revealed that despite the demonstrated ability of white sharks to swim vast distances across ocean basins, the populations of this species from the western and eastern Pacific are not interbreeding and are genetically distinct, and therefore deserving of population-specific management.



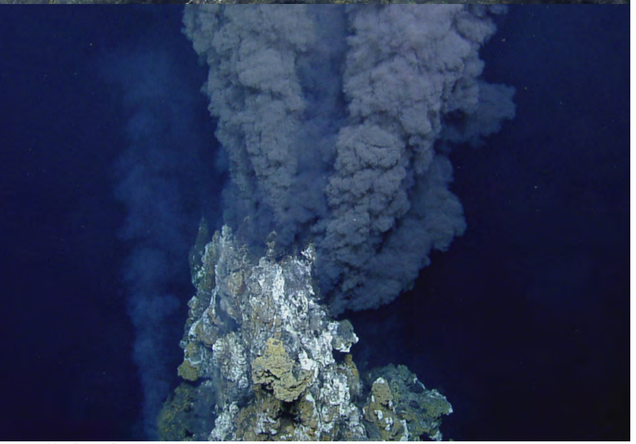
In addition to allowing us to examine population differences in white sharks across the Pacific Ocean in high resolution, our study has other applications. We have made available a powerful set of genetic markers that can be utilised by researchers to study the population dynamics and mating behaviour of white sharks anywhere in the world.

Our study was published in the American Society journal, *Journal of Heredity* (see the publication list of the SOSSRC below).

III. DETERMINING THE POPULATION DYNAMICS OF THE NIGHT SHARK

The night shark *Carcharhinus signatus* is found in the North and South Atlantic and is listed as Vulnerable to extinction by the IUCN Red List because of concerns about decreasing population sizes from overexploitation in South Atlantic fisheries. There was no information about how many populations exist throughout the species' broad Atlantic distribution nor about its genetic diversity, both key information needs for guiding fisheries management. The SOSSRC hosted and collaborated with PhD student Rodrigo Domingues from the Universidade Estadual Paulista in Brazil to conduct the first detailed investigation of this little-understood species. Rodrigo (now Dr Domingues!) used multiple genetic markers developed from both the mitochondrial and nuclear genomes of night sharks to investigate whether these sharks in the western North Atlantic, where they are protected from landings, were of the same population as night sharks in the western South Atlantic, where they are fished heavily. Our study results found that not only were the North and South Atlantic populations of night sharks genetically different, but that the South Atlantic population showed much less genetic variation (diversity) – a worrying discovery. These findings provide fisheries managers with the scientific rationale for implementing management and conservation policies that will help the South Atlantic population of night sharks recover from this loss of genetic diversity.

The results of this study and its applications for the conservation of night sharks were published in the journal *Aquatic Conservation: Marine and Freshwater Ecosystems*.



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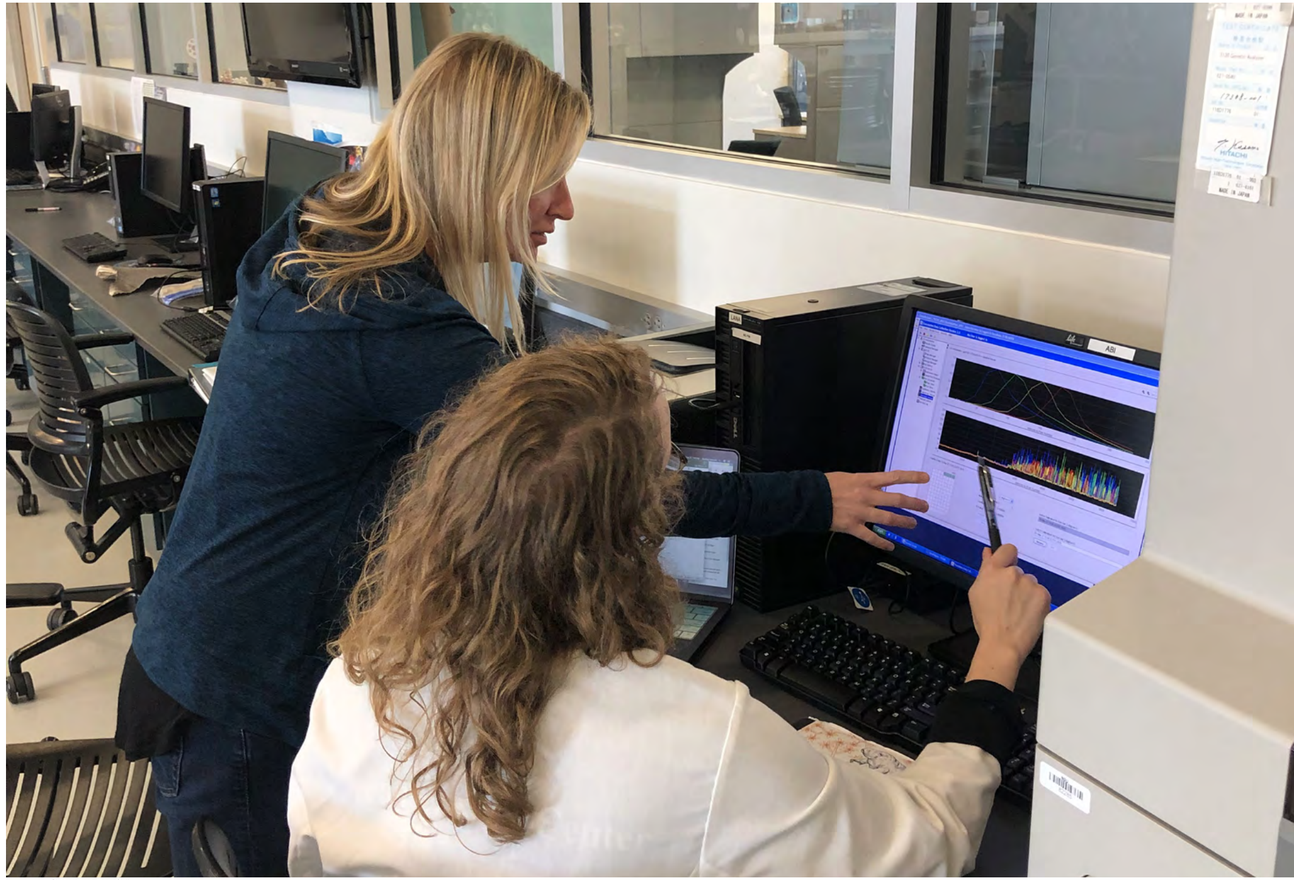
IV. DISCOVERING SKATE EGGS INCUBATING AT HOT DEEP-SEA VENTS IN THE GALÁPAGOS

The SOSSRC embarked on a unique collaborative study with Dr Pelayo Salinas-de-León of the Charles Darwin Foundation to identify what looked like egg cases that belong to a skate. The issue was, what species of skate laid eggs right next to active hydrothermal vents spouting hot water – and why? By developing methods to extract DNA from these 'leathery' egg cases, using DNA sequencing, and conducting some forensic sleuthing, SOSSRC PhD student Cassandra Ruck was able to establish that the eggs originated from a skate species that occurs at deep ocean depths. It had, however, never been known to lay eggs next to hydrothermal vents, known as 'black smokers'. We surmise that the skate may be laying eggs in this very unusual habitat because the hot water from the vents increases the temperature of the normally very cold ambient water (less than 2°C; 35°F) found at depths of more than 1,600 metres (5,250 feet). The increased water temperature would provide a more hospitable temperature for incubating the skate's eggs. This study was the first to document such novel reproductive behaviour in any marine species and gained a tremendous amount of media coverage.

The results of this study were published in the journal *Scientific Reports*.



Photos by Mahmood Sivji

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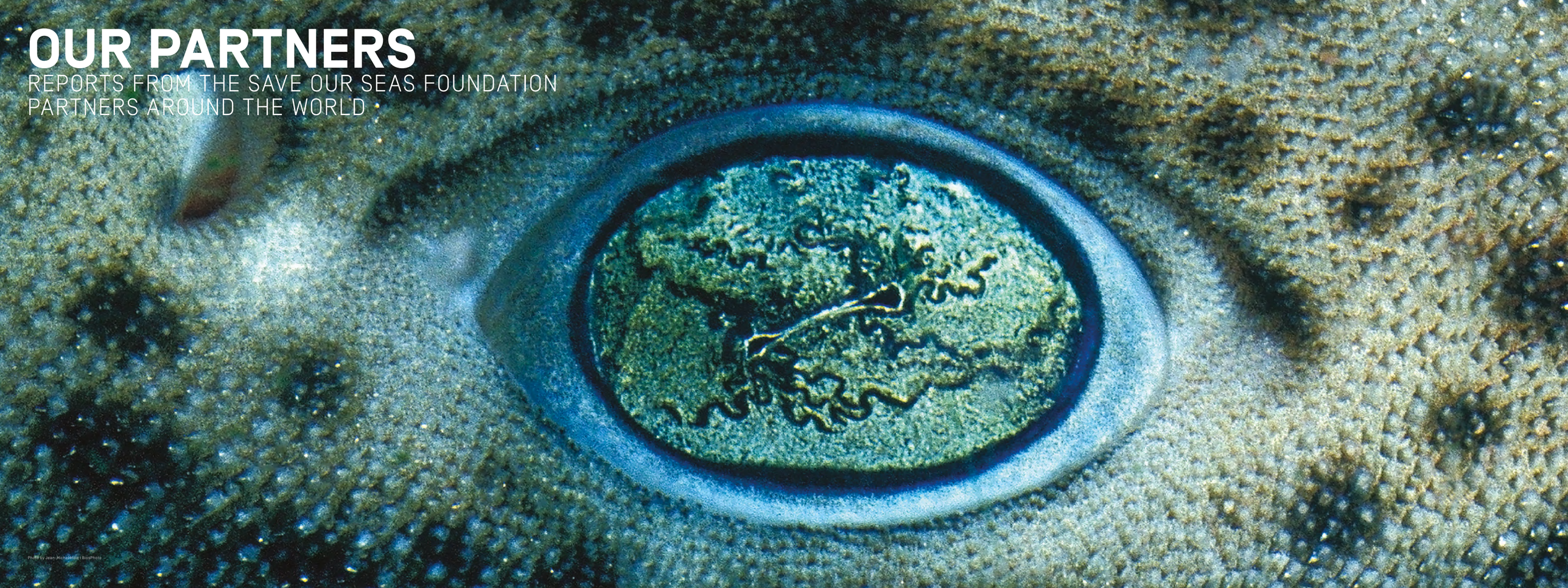


Photo by Jean-Michel Milet | BiosPhoto

BIMINI BIOLOGICAL FIELD STATION FOUNDATION

MATTHEW J. SMUKALL & SAMUEL H. GRUBER

Photo by Sophie Hart

Samuel H. Gruber

Matthew J. Smukall

Kristene Parsons

Established in 1990, the Bimini Biological Field Station Foundation (BBFSF) functions as a year-round facility dedicated to researching shark ecology, biology and behaviour. Since its inception it has been guided by three overarching missions: to improve our understanding of the elasmobranch community; to disseminate research findings to the general public; and to foster the next generation of marine scientists. Research at the BBFSF has contributed significantly to the conservation and management of sharks and marine habitats. We have provided new information to improve the management and protection of shark stocks in The Bahamas and the USA, including the establishment of The Bahamas Shark Sanctuary and the continued push for officially implementing the North Bimini Marine Reserve. The scope of the BBFSF's work is highlighted by a wide range of peer-reviewed publications, our outreach to the local community and the training of large numbers of national and international interns at both undergraduate and graduate level.

The BBFSF field station itself is a rustic research facility located on the small island of South Bimini in The Bahamas, 85 kilometres (53 miles) east of Miami, Florida. Local environs range from fringing mangroves, sand and sea-grass flats and shallow-water lagoons to coral reefs and a shelf sloping into the deeper waters of the Gulf Stream. These habitats provide access to a diversity of marine species, including abundant elasmobranch fauna. Given the diversity of marine life near Bimini, the BBFSF is dedicated not only to researching elasmobranchs, but also to taking part in collaborative projects that focus on a diversity of taxa, including reptiles, birds and invertebrates. The BBFSF is uniquely positioned to develop and carry out innovative projects that will continue to contribute to the basic understanding of the behaviour and ecology of a variety of elasmobranch species, while also using new techniques and analysis to help advance marine research. Our research aims to use the local ecosystem and focal species as models that can be shared globally. Through our educational outreach, we aim to improve marine science education as well as the public's perception and understanding of sharks and rays.

Our 28th year of operation was a period of great transition. After three years of field work, Félicie Dhellemmes, Maurits van Zinnicq Bergmann and Matthew Smukall moved on from Bimini to focus on data analysis and dissertation writing. The BBFSF welcomed Clemency White and Vital Heim as the new PhD students and principal investigators. Dr Samuel Gruber, the founder and president of the BBFSF, retired in late 2018 but he will never be far from our thoughts as we strive to move the station forward with his vision in mind. This past year, our activities ranged from studying the reproductive cycle of stingrays to satellite tagging pregnant tiger sharks. In this report we describe milestones in conservation and research, discuss our outreach and media activities and provide a short summary of our objectives for 2019.

Photo by Michael Scholl

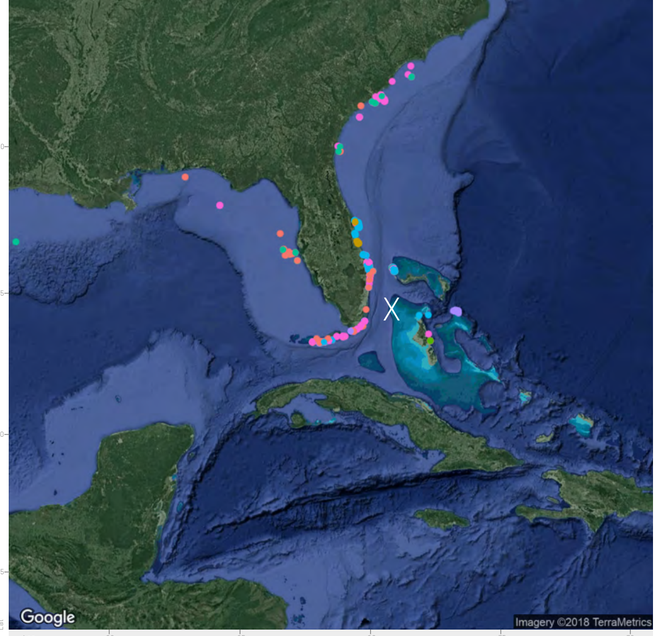
SCIENTIFIC RESEARCH
LONG-TERM PROJECTS

LEMON SHARK UPDATE

A total of 302 lemon sharks were caught and sampled in 2018 by all capture methods, although primarily by gill-netting and long-lining. Of these, 163 were first-time captures, which spanned a size range of 50.6 to 260 centimetres (20 to 102 inches) in total length. While all life stages occurred, only four adult lemon sharks were recorded during the year. Males accounted for 55% of the sharks; 45% were female. The majority of fishing effort and captures occurred during our annual PIT project, which ran from 21 May until 18 June. During this project, 192 individual sharks were caught: 103 in the Sharkland nursery and 89 in the North Sound nursery. This is a slight reduction from 2017, when 115 and 80 lemon sharks were caught in Sharkland and North Sound respectively. At the conclusion of 2018, our database has 3,884 individual lemon sharks. This was the 24th year of PIT, one of the longest-running continuous projects that focuses on large marine predators. Given that lemon sharks mature at 12–14 years of age, the BBFSF research is potentially beginning to study its third generation of lemon sharks in Bimini. It has provided tremendous insight into the reproduction, life history and behaviour of these sharks. This study will continue and future research will assess to what extent key characteristics can be inherited.

REGIONAL MOVEMENTS AND TEMPORAL RESIDENCY OF MARINE MEGAFAUNA

In 2014, the BBFSF established an acoustic receiver (VR2-W, Vemco) array in the water around Bimini, which has since expanded (n=66) through a collaboration with the Ocean Tracking Network (OTN) and continued support from the Save Our Seas Foundation (SOSF). This expansion enables us to monitor movements not only in Bimini, but also along the Gulf Stream drop-off toward Great Isaacs and Cat Cay (see figure 1). Receivers are positioned in a variety of habitats, including shallow sand flats with interspersed macro-vegetation; mangrove-bordered sea-grass beds; and shallow- and deep-water rocky and coral reefs. As a whole, these locations are used to answer research questions regarding habitat connectivity and ecosystem dynamics.



< Figure 1:
Vemco acoustic receiver array surrounding Bimini, The Bahamas

^ Figure 2:
Regional movements and migrations of seven shark species tagged with 10-year ultrasonic devices at Bimini. Detections were primarily acquired by the FACT and ACT arrays. The white X represents the location where the sharks were tagged.

SPECIES

- *Carcharhinus leucas*
- *Carcharhinus limbatus*
- *Carcharhinus perezi*
- *Galeocerdo cuvier*
- *Ginglymostoma cirratum*
- *Negaprion brevirostris*
- *Sphyrna mokarran*

'Given that lemon sharks mature at 12–14 years of age, the BBFSF research is potentially beginning to study its third generation of lemon sharks in Bimini. It has provided tremendous insight into the reproduction, life history and behaviour of these sharks'

The BBFSF has been monitoring 236 individual elasmobranchs representing eight species: 45 lemon *Negaprion brevirostris*, 20 bull *Carcharhinus leucas*, 18 blacktip *C. limbatus*, 18 Caribbean reef *C. perezi*, 20 nurse *Ginglymostoma cirratum*, 35 great hammerhead *Sphyrna mokarran* and 60 tiger sharks *Galeocerdo cuvier*, as well as 20 southern stingrays *Hypanus americanus*. In addition, our collaborations yielded an additional 55 green sea turtles *Chelonia mydas* (Florida State University) and 10 juvenile lemon sharks (Flinders University).

Acoustic monitoring over a period of more than four years has accumulated more than 2.6 million detections from sites around Bimini, throughout The Bahamas and in the north-western Atlantic Ocean. We detected individuals daily over extended periods (lemon shark 629 days; nurse shark 913 days; reef shark 1,165 days). Residency indexes (RI=the number of days detected in the array divided by the number of possible days detected in the array) provide an indication of time spent within the BBFSF array. Tagged individuals display a range of RI values from 0.00 to 0.98 (0=never present, 1=always present). For example, one great hammerhead showed an RI of 0.51 (287 of 564 days), a lemon shark had an RI score of 0.95 (280 of 296 days) and a reef shark registered an RI of 0.98 (1,165 of 1,185 days). Interestingly, RI scores vary widely within and between species, showing that some individuals are resident, whereas other conspecifics are more transient. Data collected from tiger sharks suggest that individuals are primarily transient in Bimini (RI average is 0.03, n=18), yet some individuals show a degree of philopatry and return to Bimini after prolonged absences. One mature female tiger shark has faithfully returned to Bimini for three winters and remained resident at the island for several months at a time.

Furthermore, we found that many individuals moved far away from the Bimini array and were detected on cooperative telemetry arrays throughout the north-western Atlantic Ocean (see figure 2). For example, a blacktip shark tagged off Bimini was detected at Grand Bahama Island 127 kilometres (79 miles) to the north, while another was detected near Melbourne, Florida, 389 kilometres (242 miles) to the west. Ten adult bull sharks travelled some 156 kilometres (97 miles), crossing the Gulf Stream, to mainland Florida; five of them returned to Bimini. An adult lemon shark crossed the Gulf Stream and was detected in the Florida Keys, 78 kilometres (48 miles) south-west of Bimini; another two adult lemon sharks were detected at Grand Bahama Island and Cape Eleuthera respectively. Seven adult nurse sharks tagged by the BBFSF were detected on other receiver arrays in The Bahamas and Florida, with five returning to Bimini. Six tiger sharks were detected in distant arrays, with one female travelling more than 1,560 kilometres (970 miles) to the coast of Texas. Finally, three great hammerhead sharks were detected far from Bimini, two having travelled approximately 1,000 kilometres (620 miles) in a north-westerly direction to South Carolina. The third hammerhead made its way along the Georgia coastline, a distance of about 880 kilometres (545 miles).

ASSESSING THE MECHANISMS OF COEXISTENCE WITHIN A GUILD OF LARGE MARINE PREDATORS

Understanding how ecologically similar and co-occurring species distribute themselves is imperative for predicting the consequences of accelerating environmental change and human activities on populations and communities. Distribution patterns are often shaped by a complex network of relationships between animal movement and the biological and physical environment, mediated by geographic scale. Substantial research focus has been aimed at better understanding how such relationships allow large-bodied predators, especially large terrestrial carnivores, to coexist in view of their profound large-scale effects on ecological communities and ecosystems.

The long-term research goals of our team (from the BBFSF and Florida International University) are firstly to facilitate the improved design of marine protected areas for southern stingray and bull, tiger, great hammerhead, lemon, nurse, blacktip and Caribbean reef sharks in Bimini; and secondly to assess which (group of) mechanisms facilitate their coexistence by:

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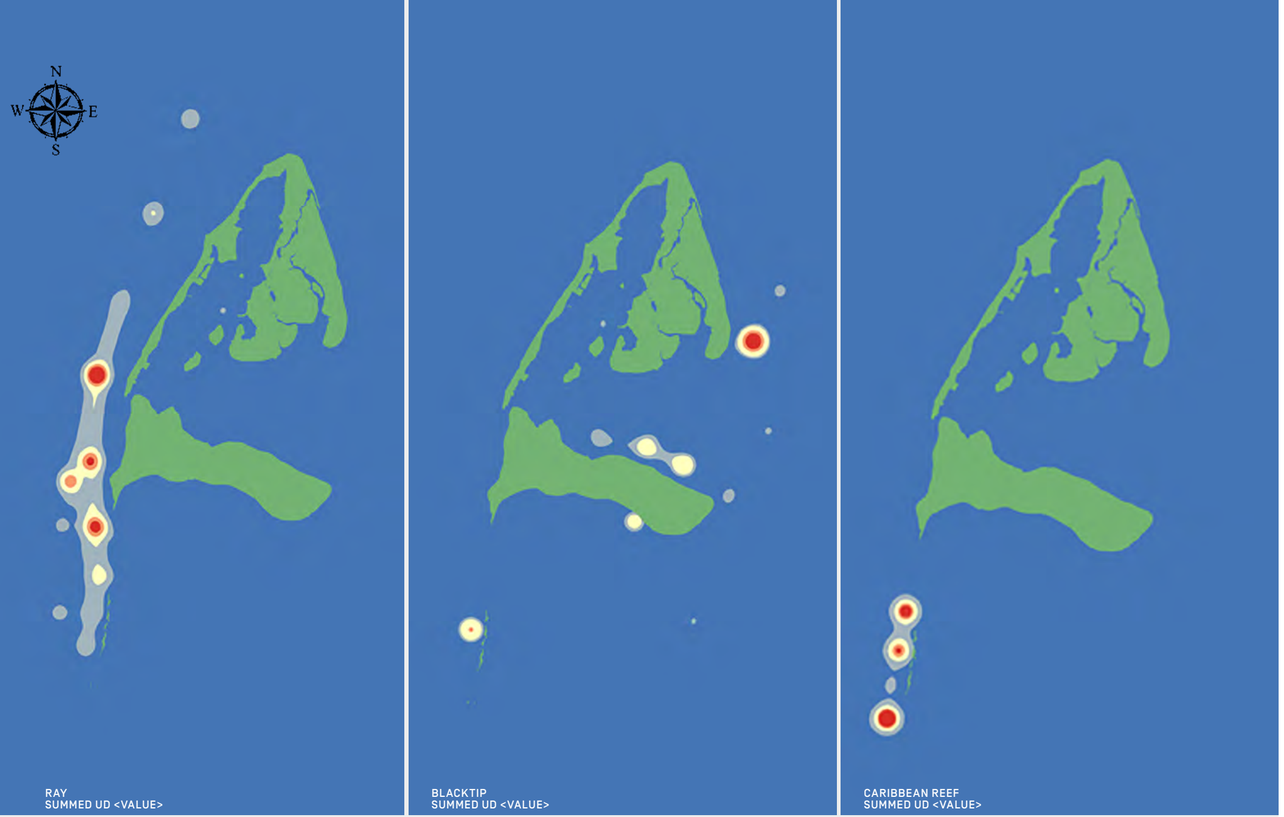

Figure 3:
Average probability estimates of utilisation density (UD) calculated using dynamic Brownian bridge movement analysis for the bull shark at Bimini, 2016–2018.

Figure 4:
Average probability estimates of utilisation density (UD) calculated using dynamic Brownian bridge movement analysis for the blacktip shark at Bimini, 2016–2018.

Figure 5:
Average probability estimates of utilisation density (UD) calculated using dynamic Brownian bridge movement analysis for the Caribbean reef shark at Bimini, 2016–2018.

1. using a conservation planning approach to identify essential marine habitat for protection;
2. applying stable isotope analysis to examine variations in foraging habitats and dietary interactions;
3. using agent-based models to build a theoretical framework that can predict habitat selection and distribution;
4. identifying important physical and biological drivers of movement to attempt a mechanistic understanding of joint habitat selection and distribution patterns.

Preliminary spatial analysis results from acoustic telemetry and dynamic Brownian bridge movement models were used to quantify patterns of space use. These results show size-dependent patterns of space use throughout North and South Bimini, indicating diverse habitat use. Some of the larger shark species such as bull (see figure 3) and great hammerhead sharks concentrate their space use off south-western Bimini, but space use patterns along the entire west side of Bimini suggest that these areas are also important movement corridors. In contrast, smaller species such as blacktip shark (see figure 4) and southern stingray concentrate their activity to the south and east of Bimini, as well as the central lagoon. Lemon sharks use most of Bimini's habitats, whereas the activity space of Caribbean reef sharks was highly constrained to the rocky, reef habitat (see figure 5).

EFFECTS OF SHARK PROVISIONING

Food attraction and provisioning are becoming increasingly popular methods to enhance ecotourism experiences with wild animals, especially those that are otherwise rarely encountered. However, such activities remain controversial owing to the limited understanding of their long-term implications on the behaviour and ecology of the target species. Consequently, there is little consensus on how to appropriately manage ecotourism. We examined how daily provisioning activities influenced the behaviour,

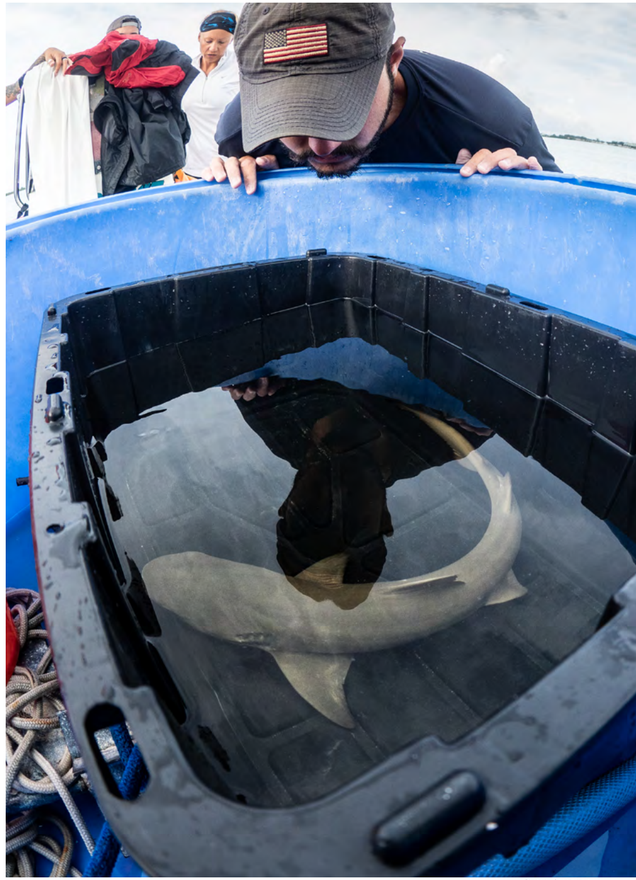

Photo by Sophie Hart

movements and space use of great hammerhead sharks in Bimini. Between January and May 2017, researchers attended 104 shark dives to quantify differences in the daily food uptake of individual sharks. Observation data were then compared to dynamic Brownian bridge movement models created from acoustic monitoring data to examine space use pattern differences between provisioned and non-provisioned sharks. The great hammerhead is known to be predominantly a seasonal winter resident of Bimini, but the impacts of provisioning on local movements are unknown. Thirty individuals were identified during the study, of which 28 attended provisioning events regularly. By quantifying individual differences in feeding and space use patterns, we provide first insights into ecotourism impacts on great hammerhead sharks. These results will be published in 2019.

SHARK PERSONALITIES

Since 2012 juvenile lemon sharks have been used as a focal species to investigate the role of personalities in sharks. Juveniles (n=812) were captured using gill nets in North Sound and Sharkland. Each June, capture sessions took place for six days in each nursery. In 2012 and 2013, additional three-day capture sessions were conducted in November and March. In the course of this study, a total of 368 sharks were tested repeatedly in the sociability and novel open-field apparatus. For each test, we calculated repeatability of the behaviour using the scores obtained by each shark in its first two test-days. Using only the first two test-days ensures that the effect of habituation to the tests was limited (Finger et al. 2016). In addition, to avoid any seasonal bias, if the second test took place more than 60 days after the first, it was removed from the dataset (n=54 observations). This information is currently being analysed and the results are expected in early 2019. It is anticipated that these results will provide insight into the role personality and behaviour play in the daily lives of wild sharks, predation risk and survival.

The second objective of this research is to determine how personality measured in a captive setting translates to wild behaviour. This was accomplished

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by incorporating passive and acoustic telemetry to track the wild movement of individuals that had previously been observed in captive behavioural trials. In 2015 and 2016, 29 tagged sharks were monitored in the North Sound nursery, while in 2017 and 2018, 33 sharks were observed in the Sharkland nursery. Passive tracking was achieved through an array of up to 18 acoustic receiver stations deployed in the Bimini lagoon. Active tracking from research skiffs was used to increase telemetry coverage and follow individual sharks. Distance from shore and water depth were assessed to determine the propensity of sharks to venture into areas that may be deemed more dangerous. Telemetry information from the ongoing BBFSF study for larger sharks will be used as a proxy for predation risks across habitats. Results of this study will be finalised in 2019.

TIGER SHARK ECOLOGY

Tiger sharks are frequently referred to as apex predators in tropical and temperate marine ecosystems worldwide and are therefore assumed to play a key role in food webs. At maturity, they can reach lengths of more than five metres (16.4 feet) and are undoubtedly capable of consuming large prey items, potentially exerting top-down control over lower trophic level consumers. However, this predatory control is likely to depend on size and to vary across ontogeny and habitats. Bimini offers a unique system in which to determine how diet, habitat use and movements change across ontogeny. Preliminary stable isotope analysis (carbon and nitrogen) indicate that trophic position and foraging habitat use increase with size. Juveniles consume prey low on the food chain, with a diet derived predominantly from sea-grass habitats. Mature individuals have a broad diet and forage in various sea-grass, near-shore and pelagic habitats. Complete analysis will be conducted in 2019, including fatty acid profiles to determine more specific prey assemblages.

Given the high mobility of tiger sharks, collaborative acoustic telemetry arrays throughout the region have been incredibly important for understanding their movements. Individuals tagged near Bimini have been detected in The Bahamas and south-eastern USA, including Florida, Georgia, South Carolina

Photo by Sophie Hart

and Texas (see figure 6). However, there are large spatial and temporal data gaps from the acoustic detections. It is hypothesised that Bimini is an important habitat for tiger sharks and increased resolution of movements and residency is needed. Therefore, fin-mounted satellite tags are being used to provided more complete movement data of sharks.

Each winter and spring, large and presumably gravid tiger sharks enter the shallow water sea-grass flats surrounding Bimini. Ultrasonography has been implemented to determine the reproductive status of these sharks and to estimate an expected pupping season. Satellite tags are fixed to the first dorsal fin to track the shark's movements and determine its habitat use during the upcoming pupping period. In total, six females have been fitted with satellite tags. Two sharks caught in May and June were determined to be recently post-partum, indicated by distension in the uterine lining. One of these sharks was caught at a depth of 400 metres (1,312 feet) on the west side of Bimini and had been previously caught in the same location nearly seven years before. Both post-partum sharks have shown relatively confined movements, remaining predominantly within Bahamian waters. Three tagged sharks were determined to not be pregnant and currently maturing. These individuals were shown to be much more transient and rapidly leave Bahamian waters. Gravid individuals will be targeted in early 2019 for the deployment of additional satellite tags in order to complete this study. This information will be important for determining pupping location, with implications for management and conservation.

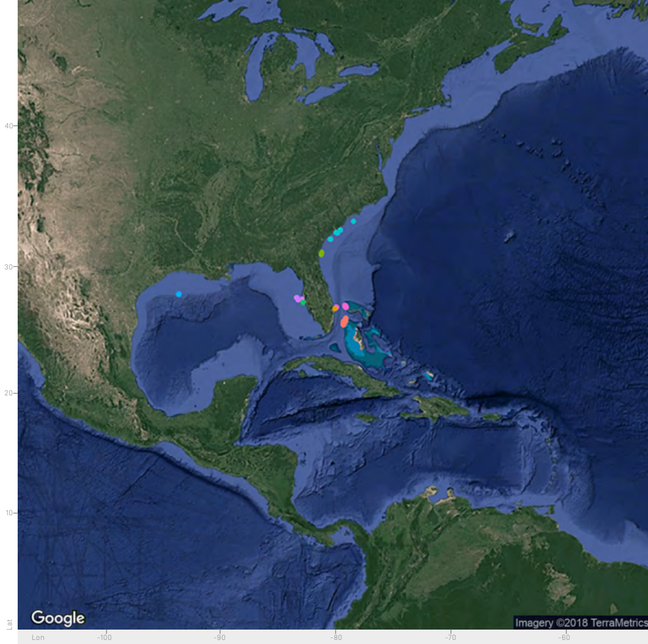

Figure 6: Acoustic detections in the NW Atlantic and Gulf of Mexico for tiger sharks originally tagged in Bimini, The Bahamas.

SCIENTIFIC RESEARCH NEW PROJECTS

'The BBFSF is uniquely positioned to develop and carry out innovative projects that will continue to contribute to the basic understanding of the behaviour and ecology of a variety of elasmobranch species, while also using new techniques and analysis to help advance marine research'

INFERRING ONTOGENETIC SHIFTS IN LEMON SHARKS

Tracking technology serves as a tool for revealing animal movement and behaviour when visual observation is limited, which is particularly useful for marine species (Hussey et al. 2015, Sundström et al. 2001). It can be implemented to produce detailed baselines of space use in order to identify ontogenetic shifts and inform conservation management (Roberts 2000). Passive and active tracking data of lemon sharks obtained at the BBFSF between 1992 and 2018 were used to provide information on space use across a broad timescale and age classes. Data, some previously unpublished, were compiled from previous research efforts conducted by past and present BBFSF scientists. A total of 143 sharks were included in the study, with an average tracking period of 16 months per shark. Dynamic Brownian bridge movement models (developed by Kranstauber et al. 2012) were completed for each individual and population level models were run for each group, including sexes, life stages (neonate/juvenile/adult) and stages of industrial development (before/during/after). The models produced utilisation distributions and a spatial reference for activity space used. With this information it was possible to determine the strength of utilisation distribution across defined spatial scales, representing core areas of use and potential 'corridors' connecting them.

Over the past 26 years, home ranges have expanded with progressive life stages. This is particularly pronounced in neonates, which utilise small activity spaces very close to the island's fringing mangroves for protection from predators. We did not identify any differences between male and female space use. The successive increase in activity space also suggests that for protection to be effective for lemon sharks, and other similar species capable of long-range migration, robust temporal and spatial protection regulations are required. We also identified significant differences in space use before and after industrial development. Dredging and the extensive removal of mangroves began in the North Sound in 1997 and continued until 2008, with the most damaging development occurring between 2002 and 2008. The reduction in activity space following the development and removal of habitat suggests that anthropogenic impacts are changing the sharks' natural activity patterns. This has important implications with regard to the further development in the North Sound that has been proposed and may include the destruction of more mangroves.

Our results are significant in the context of previous research about the life history of lemon sharks and the need for better marine protection in Bimini. Specifically, this study highlights the importance of the mangrove ecosystem as a nursery for this species and Bimini's lagoon as a habitat that supports its life history to some degree. As the lemon shark is considered Near Threatened by the IUCN, it is important to identify and protect areas that support its key life stages. In 2008, the North Bimini Marine Protected Area, encompassing a large proportion of the mangrove nurseries, was designated. It was, however, never officially established, despite the importance of this habitat for sharks and the commercially valuable queen conch *Strombus gigas* and spiny lobster *Panulirus argus*. Considering that The Bahamas committed to protecting '20% of the marine environment by 2020', we suggest that fully enforcing the North Bimini Marine Protected Area should be made a priority, especially in light of our results. This study also sets a firm baseline for how lemon shark populations use habitat and specifically how they use Bimini across all life stages, providing us with information to better protect them.

SENSORY AND SPATIAL CAPABILITIES OF THE LEMON SHARK

In late 2018 Clemency White returned to the BBFSF to begin developing plans and protocols for her PhD field work, which will begin in early February 2019 and run for three years. Building upon the established research of how lemon sharks use space across their life history, the project aims to distinguish the behavioural, spatial and physiological relevance of hearing and vision in navigation. In appropriate cases it will outline how these are influenced by anthropogenic disturbance. This will primarily be achieved via sensory preference trials and conditioning experiments in semi-captive pens, as well as by using telemetry and active tracking across a known light- and soundscape. Combining this information with known characteristics of space use, we can infer the impact of light and sound on natural movement patterns. These findings will subsequently

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be used to discuss the effectiveness of current protection efforts and how the local ecosystem should be managed in the best interests of lemon sharks.

GREAT HAMMERHEAD FISHERY INTERACTION AND PREDATION

In 2018 we began a new collaborative project assessing fishery interactions and horizontal movement patterns of great and scalloped hammerhead sharks in the US Atlantic to discuss the efficiency of potential time-area closures as a conservation management tool. Great and scalloped hammerhead sharks will be fitted with Smart Position and Temperature (SPOT) tags in Bimini and along the US Atlantic coast. Acoustic telemetry and visual identification techniques have been used to assess the return and continued long-term seasonal residency of great hammerhead sharks in Bimini. The BBFSF currently has an ID-database of 33 identified great hammerhead individuals. Of these 33 individuals, 12 have been identified and re-sighted this season and another 11 have been identified for the first time during this year.

Furthermore, the project looks at the ecological roles of transient great hammerhead sharks and the potential effects on a meso-consumer population in Bimini. Great hammerhead sharks and southern stingrays will be tagged with 10-year internal acoustic transmitters (Vemco). Accelerometer-enabled storage tags, stable isotope signatures and body condition analysis will be used to investigate potential ecological and physiological consequences for stingrays in the presence or absence of a top-level predator.

From July to December 2018, a total of 68 southern stingrays were captured along the mangroves of South Bimini. Those 68 captures accounted for 53 different individuals, 25 of which were new to the BBFSF database. Three of the individuals caught were male and the rest were female. The rays ranged in size from 52 to 104.9 centimetres (20.5 to 41 inches) disc width. Fin clips and white muscle tissue for stable isotope analysis were collected from 60 and 58 individuals respectively. Blood was sampled from 45 individuals to assess short-term changes in stable isotope signatures, reproductive state and body condition. Ultrasounds were conducted on 59 stingrays and at least 21 were confirmed pregnant (see figure 7).

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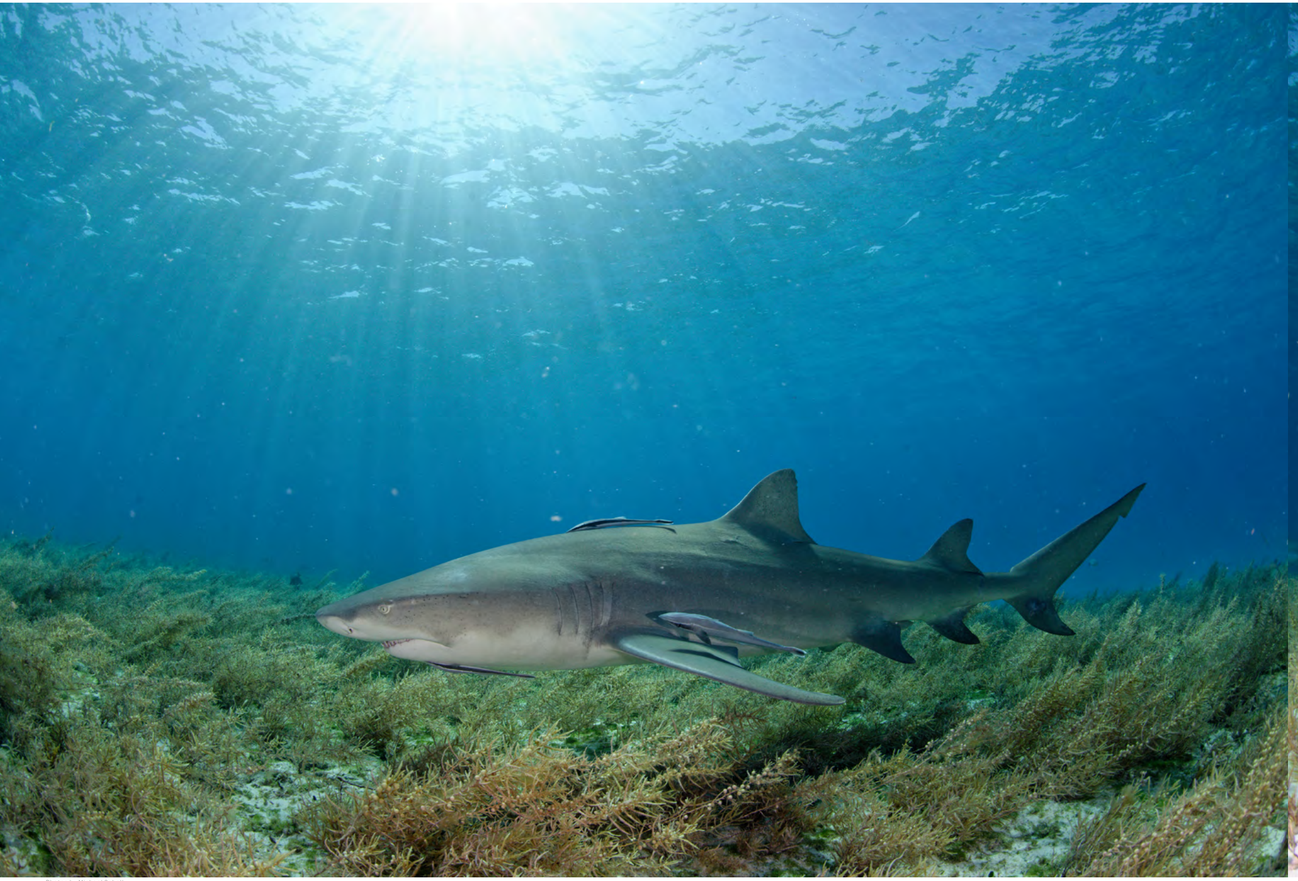

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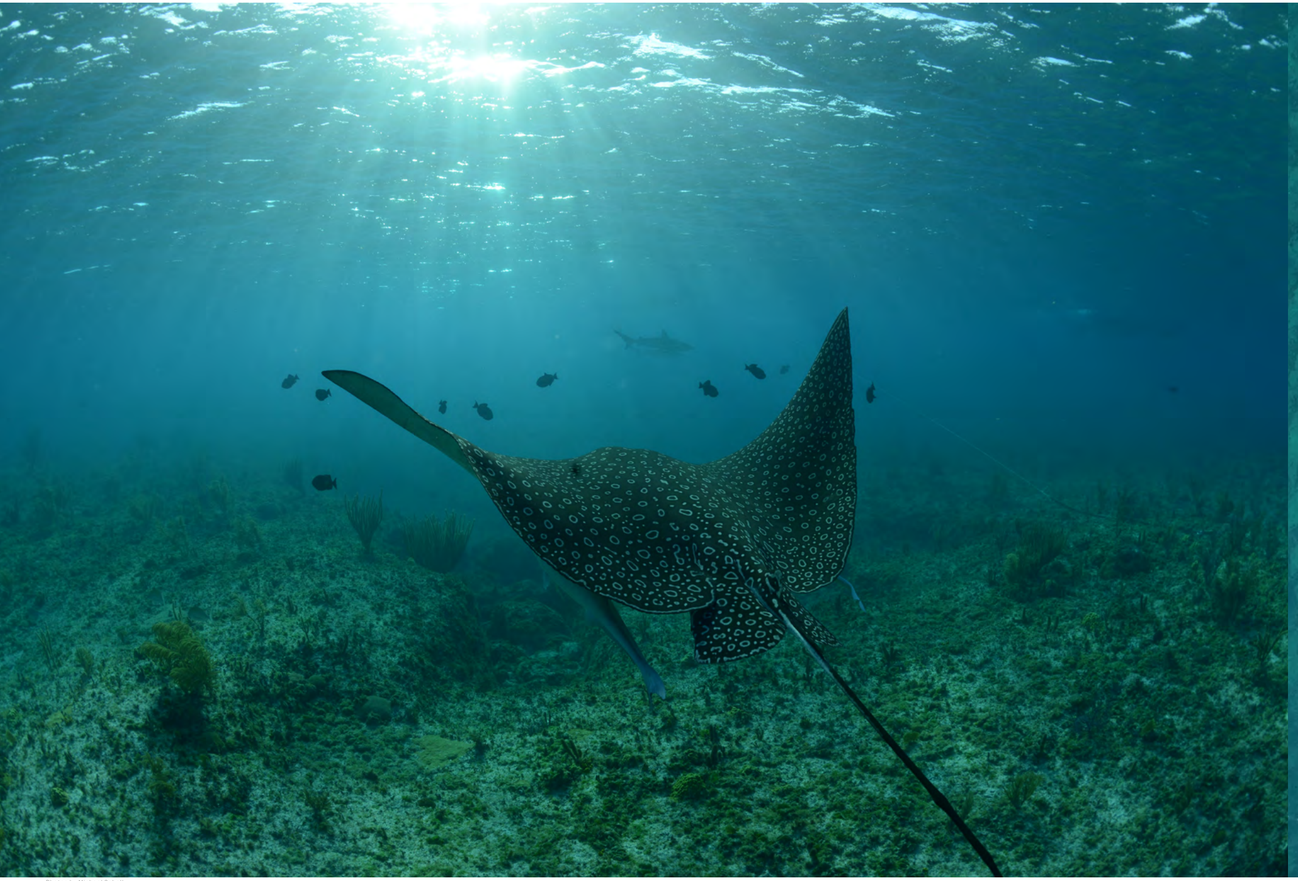

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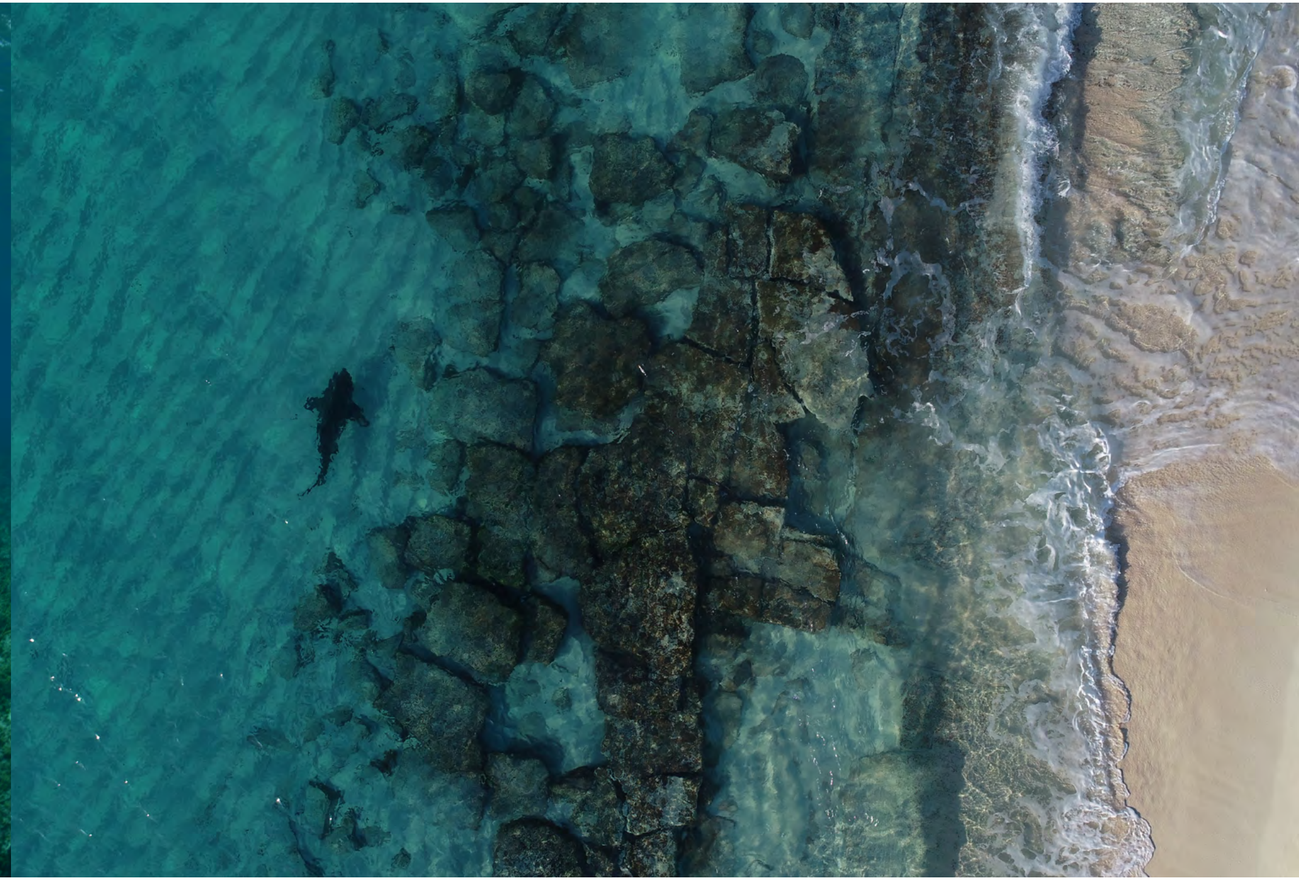

Figure 7: Ultrasound image of a pregnant southern stingray.

RISK EFFECT AND PREDATOR–PREY INTERACTIONS

Baited remote underwater videos (BRUVs) were deployed in an effort to understand the role of predator–prey interactions and risk effect in the marine environment. A total of 100 BRUVs were positioned on the north (n=50) and south (n=50) sides of South Bimini. The northern side of the island is located within the Bimini lagoon and is predicted to serve as a protected setting, while the southern side of the island is more open and the risk of predation by larger elasmobranchs is likely to be higher. This study resulted in 7,206 observations of marine species, including 54 of elasmobranchs.

COLLABORATIONS AND VISITING SCIENTISTS

The BBFSF is dedicated to understanding marine ecosystems as a whole and therefore tries to form strong relationships with collaborating scientists. In 2018 we continued our partnership with Dr Natalie Mylniczenko from Walt Disney World Orlando, who is investigating the body condition and reproduction of southern stingrays. Dr Mylniczenko is also advising on several additional studies involving reproduction, body condition and stress physiology. We continued our collaboration with Dr Mariana Fuentes from Florida State University, which focuses on the population of green turtles in Bimini. This research includes identifying the presence of fibropapilloma across habitats with varying degrees of anthropogenic disturbance, the assessment of foraging quality within habitats, and interactions between turtles and large predatory sharks. Also in 2018 we began new collaborations with Megan Mickle from the University of Windsor and Sarah Driscoll from the New England Aquarium. Megan is researching the behavioural responses of southern stingrays to noise and their acclimatisation to anthropogenic disturbances. Sarah focuses on using BRUVs to assess fish assemblages in sea-grass habitats and how they vary in relation to distance from mangroves.

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SCIENTIFIC OUTPUT
PRESENTATIONS

In June 2018 Dr Samuel Gruber, Dr Kristene Parsons, Vital Heim and Matthew Smukall attended Sharks International in João Pessoa, Brazil. Vital Heim presented data from his MSc research under the title 'Effects of provisioning on the behavior and space use of great hammerhead sharks, *Sphyrna mokarran*.' Matthew Smukall presented a recent publication from the BBFSF, 'Non-lethal recovery of internal acoustic transmitter from a large-bodied carcharhinid shark, *Negaprion brevirostris*, after 13 years at liberty.'

At the European Elasmobranch Association meeting in Peniche, Portugal, Clemency White presented data from her MSc research under the title 'Twenty-five years of tracking: using long-term datasets to infer ontogenetic shifts in the lemon shark, *Negaprion brevirostris*, and conservation implications.'

Photo by Sophie Hart

PUBLICATIONS

includes corresponding abstracts from journals

MACHINE LEARNING FOR ACCELEROMETER DATA

Brewster LR, Dale JJ, Guttridge TL, Gruber SH, Hansell AC, Elliot M, Cowx IG, Whitney NM, Gleiss AC. 2018. Development and application of a machine learning algorithm for classification of elasmobranch behavior from accelerometry data. *Marine Biology. https://doi.org/10.1007/s00227-018-3318-y*

Discerning the behaviour of free-ranging animals allows us to quantify their activity budget and provides important insight into their ecology. Over recent years, accelerometers have been used to unveil the cryptic lives of animals. The increased ability of accelerometers to store large amounts of high-resolution data has prompted a need for automated behavioural classification. We assessed the performance of several machine learning (ML) classifiers to discern five behaviours performed by accelerometer-equipped juvenile lemon sharks *Negaprion brevirostris* at Bimini, The Bahamas (25°44'N, 79°16'W). The sharks were observed to exhibit chafing, burst swimming, headshaking, resting and swimming in a semi-captive environment and these observations were used to ground-truth data for ML training and testing. ML methods included logistic regression, an artificial neural network, two random forest models, a gradient-boosting model and a voting ensemble (VE) model, which combined the predictions of all other (base) models to improve classifier performance. The macro averaged F-measure, an indicator of classifier performance, showed that the VE model improved overall classification (F-measure 0.88) above the strongest base learner model, gradient boosting (0.86). To test whether the VE model provided biologically meaningful results when applied to accelerometer data obtained from wild sharks, we investigated headshaking behaviour, as a proxy for prey capture, in relation to the following variables: time of day, tidal phase and season. All variables were significant in predicting prey capture, with predations most likely to occur during early evening and less frequently during the dry season and high tides. These findings support previous hypotheses from sporadic visual observations.

TELEMETRY FOR MANAGEMENT AND CONSERVATION

Brooks JL, Chapman JM, Barkley A, Kessel ST, Hussey NE, Hinch SG, Patterson DA, Hedges KJ, Cooke S, Fisk A, Gruber SH, Nguyen VM. 2018.

Biotelemetry informing management: case studies exploring successful integration of biotelemetry data into fisheries and habitat management. *Canadian Journal of Fisheries and Aquatic Sciences. DOI:10.1139/cjfas-2017-0530*

Biotelemetry data have been successfully incorporated into aspects of fishery and fish habitat management. However, the processes of knowledge mobilisation are rarely published in peer-reviewed literature, although they are valuable and of interest to conservation scientists. Here we explore case examples from the Ocean Tracking Network (OTN), including Pacific salmon *Oncorhynchus* spp. in British Columbia, Canada, Greenland halibut *Reinhardtius hippoglossoides* in Cumberland Sound, Canada, and lemon sharks *Negaprion brevirostris* in Florida, USA, to document key processes for science integration. Typical recommendations documented in the literature (such as co-production of knowledge, transdisciplinary methodologies and applied research questions) were recorded to have had successful fisheries management integration, although we documented some exceptions. In each case, it was early, active and ongoing communication outside traditional science communication and the visual evidence of fish movement that were critical to engaging all parties with a vested interest. Networks offer forums for knowledge sharing on lessons learnt and the development of skills to engage in active communication. Greater investment and attention to developing these skills are needed to foster positive and active relationships that can impart real change in management and conservation.

SOCIAL BEHAVIOUR IN SHARKS

Finger JS, Guttridge TL, Wilson ADM, Gruber SH, Krause J. 2018. Are some sharks more social than others? Short- and long-term consistencies in the social behavior of juvenile lemon sharks. *Behavioral Ecology and Sociobiology. https://doi.org/10.1007/s00265-017-2431-0*

Despite substantial research interest in understanding individual-level consistency in behavioural attributes, significant knowledge gaps remain across traits and taxa. For example, relatively few studies have looked at social personality in large marine species such as elasmobranchs and whether or not individual differences in behaviour are maintained in unstable social groups (fission-fusion dynamics). However, it is important to investigate this topic in model species other than the usually small species with short generation times typically investigated in these areas of behavioural ecology. Indeed, studies on ecologically diverse taxa could provide mechanistic insights into the emergence and maintenance of animal personality and dynamics of social groups in animals. In addition, understanding social behaviour at group and individual levels could improve conservation management of these large animals with long generation times (such as the removal of particular behavioural types by fisheries practices). Here we investigated consistent individual differences in sociability in wild juvenile lemon sharks *Negaprion brevirostris* over both short-term (four- to 18-day) and long-term (four-month) sampling periods. Individual sharks were observed in social groups and scored according to the number of social interactions performed during observations. Despite varying individual group compositions in repeated trials, sharks showed consistent individual differences in their social behaviour over both time scales. These results suggest reduced plasticity and highlight individuality as an important explanatory variable for the social dynamics of juvenile lemon sharks. In addition, long-term stability observed in this wild population demonstrates the importance of personality in the daily behavioural repertoire of juvenile lemon sharks. Our results are discussed in the context of other shark studies and taxonomic groups, and potential avenues for future research are proposed.

DETERMINING MPA HOTSPOTS FOR GREEN TURTLES IN BIMINI

Fuentes MMPB, Gillis AJ, Ceriani SA, Guttridge TL, Bergman MvZ, Smukall MJ, Gruber SH, Wilderman N. 2018. Informing marine protected areas in Bimini, Bahamas by considering hotspots for green turtles (*Chelonia mydas*). *Biodiversity and Conservation. https://doi.org/10.1007/s10531-018-1647-2*

Knowledge about the spatial distribution, habitat use and processes of site selection by marine turtles is fundamental to identifying key habitats, critical resources and discrete foraging aggregations for protection. This is particularly

Photo by Sophie Hart

EDUCATION & OUTREACH

important for regions of known importance for marine turtles and where widespread habitat degradation is taking place. The waters surrounding Bimini, The Bahamas, provide important foraging areas for threatened juvenile green turtles *Chelonia mydas*, but these habitats are being severely degraded by coastal development. To inform managers about the design of planned future no-take marine protected areas (MPAs) in Bimini, we used a spatial planning approach and incorporated diverse methodologies (such as visual surveys, capture events, passive acoustic telemetry) to identify areas of high use by juvenile green turtles. We also assessed forage items to understand habitat use by these turtles. This information was compared with how various stakeholders use the local waters in order to identify priority areas for protection within Bimini that would maximise the conservation of green turtles while minimising the impact to society, and to meet the conservation target previously stipulated by government officials. Two regions within Bimini (South Flats in South Bimini and Bonefish Hole in North Bimini) were identified as important areas for protection and suggestions are made for their consideration as marine protected areas.

LONG-TERM RETENTION OF ACOUSTIC TRANSMITTER

Smukall MJ, Kessel ST, Franks BR, Feldheim KA, Guttridge TL, Gruber SH. 2018. No apparent negative tagging effects after 13 years at liberty for lemon shark, *Negaprion brevirostris*, implanted with acoustic transmitter. *Journal of Fish Biology. http://doi.org/10.1111/jfb.13856*

An intact and uncompromised internal acoustic transmitter was non-lethally recovered from a lemon shark *Negaprion brevirostris* after 13 years at liberty. The shark, first tagged at an estimated age of two years near South Bimini, The Bahamas, in 2004, was recaptured in 2017 with a total length of 264 centimetres (104 inches). The tagged shark displayed the typical growth rate, pregnancy, natal homing and pupping behaviour of other individuals in this population. This observation provides important evidence regarding the effects of the long-term retention of implanted acoustic transmitters in a carcharhinid shark.

DOCTORAL RESEARCH

In 2018 BBFSF scholarships supported three outgoing doctoral candidates: Félicie Dhellemmes of Humboldt University, Germany; Matthew Smukall from the University of Alaska, USA; and Maurits Van Zinnicq Bergmann of Florida International University, USA. Félicie, Matthew and Maurits are currently completing their analysis and dissertation writing. Two incoming doctoral students, Clemency White from the University of Exeter and Vital Heim from the University of Basel, will be supported by the BBFSF with room and board, research supplies, personnel and scientific guidance over the next three years.

MASTER'S RESEARCH

Vital Heim successfully defended his research on the impacts of provisioning on the movement ecology of the great hammerhead shark *Sphyrna mokarran* in Bimini, The Bahamas. Clemency White, defended her thesis 'Long-term study of ontogenetic shift and habitat use by *Negaprion brevirostris* in Bimini, Bahamas'. Master's student Kendall Brancart of Nova Southeastern University completed all the field work for her thesis 'Risk effect predator-prey interactions of communities in Bimini, Bahamas'.

VOLUNTEERS

In 2018 the BBFSF hosted 40 volunteers from around the globe, representing North America, Europe and Asia. These students resided at the BBFSF for between two and six months and assisted with all research activities and daily operations of the station. Two Bahamian students attended the BBFSF as part of the Alf Thompson Memorial Scholarship programme and in partnership with the Bahamas Marine EcoCentre.

COURSES IN SHARKS AND RAYS

Three university, one high school and one naturalist course were hosted at the BBFSF in 2018. This provided an opportunity for 70 students to spend one week learning about the local marine environments, with a main focus on sharks and rays. These courses included:

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- Eckerd College (Florida, USA): two undergraduate courses in shark biology and conservation;
- Coastal Carolina University (South Carolina, USA): undergraduate course in shark biology and conservation;
- Institut Le Rosey (Switzerland): high school course in shark conservation;
- Naturalist course: open to the public with students from around the globe, a course in shark biology, research and conservation.

PUBLIC TOURS

More than 900 members of the public, mostly tourists, visited the BBFSF research facility in 2018. These tours are an important opportunity for staff and volunteers to disseminate information about past and current BBFSF research, the biology of sharks and pressing conservation concerns.

RESEARCH EXPERIENCES

Forty members of the public visited the BBFSF to participate in five-day educational research experiences. These opportunities enable these visitors to immerse themselves in research methods, to assist in data acquisition and to learn about ongoing conservation efforts.

BIMINI SCHOOL OPEN DAYS

The BBFSF hosted two open days for local schoolchildren, with 40 students visiting the research station. In collaboration with Sharks 4 Kids, BBFSF staff spoke to approximately 200 students on North Bimini. This presentation informed students about the important role of sharks in the local ecosystem, the need for conservation, and the research conducted at the BBFSF.

GOOGLE HANGOUTS

Sharks 4 Kids hosted three Google Hangout sessions at the BBFSF, reaching approximately 230 students per session. These sessions provide an opportunity to communicate with students around the world about ongoing

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Photo by Eugene Kitslos

MEDIA

shark research, conservation efforts and the importance of healthy shark populations.

MAKE-A-WISH FOUNDATION

The BBFSF hosted a special research experience for the Make-A-Wish Foundation in November 2018. The 16-year-old recipient's wish was to spend a week with the BBFSF in order to participate in shark field research and learn more about conservation. He and his family spent the trip with BBFSF staff and volunteers, participating in shark handling, shark workups and snorkelling trips.

TORTUGA MUSIC FESTIVAL

The BBFSF hosted a booth at the Tortuga Music Festival in Ft. Lauderdale, Florida, which partners with the Rock The Ocean Foundation. This increases public awareness about issues impacting the world's oceans and supports scientific research, education and ocean conservation initiatives. Our booth provided different activities to engage visitors in our research through interactive games, media (video clips of field research) and engaging conversation with volunteers, staff and principal investigators.

TRASH CLEAN-UPS

The BBFSF helped to organise seven trash clean-ups of local roads, reefs and beaches.

VETERINARY CLINICS

Nassau Palmdale Veterinary Clinic was hosted at the BBFSF on four occasions. These clinics provide an opportunity for local dogs and cats to receive medical attention as well encourage spaying and neutering in an effort to help curb the local feral populations.

FILM TEAMS

The BBFSF hosted three film teams from the USA and Germany in 2018. The films produced included two one-hour features as part of Discovery Channel's 'Shark Week': *Bear vs Shark* and *Sharkcam Stakeout*. These media appearances provide important public exposure to the research conducted at the BBFSF and serve as a means to disseminate conservation messages to audiences that may not be reached by other media.

SOCIAL MEDIA

We use social media platforms to engage with the general public, including daily updates of research activities, research findings and conservation messages. The BBFSF currently has 16,000 followers on Facebook, 60,800 followers on Instagram and 9,700 followers on Twitter.

Photo by Michael Scholl

THE MANTA TRUST

ISABEL ENDER & GUY STEVENS

Photo by Guy Stevens

Guy Stevens

The practice of decluttering and organising to bring more clarity into one's life seems to be a hot topic of conversation at present, which makes me smile as in 2018 we intuitively did just that. The Manta Trust charity reached a major milestone when, through an incredible collaborative effort, we finally achieved international protection for all species of mobulid rays under the Convention on International Trade in Endangered Species (CITES) and the Convention on Conservation of Migratory Species (CMS). Following these successes, our work has focused on implementing these measures effectively, which came with a whole new range of challenges. Increasingly we heard comments like 'you are done now' and that we should 'focus on other species', yet we knew we were nowhere near our goal of conserving these species and their habitat.

Mobulid populations around the world are still threatened by a myriad of factors, such as unregulated tourism and being taken as by-catch, and there is still so much we do not know about these species. Over this past year, therefore, we decided to 'organise' our thoughts and produced two really important pieces of work: A Global Conservation Strategy & Action Plan for mobulid rays and a scientific publication *Research Priorities to Support Effective Manta and Devil Ray Conservation*. These pieces provide a comprehensive overview of the current status of mobulid rays and give clear directions on what needs to happen to safeguard the future of these species.

Over a year in the making and funded by the Shark Conservation Fund and the Save Our Seas Foundation, the Manta Trust's Global Strategy & Action Plan outlines what actions need to be taken to ensure the long-term survival of mobulid rays. We started out by defining our overall vision: to see all manta ray species and their relatives protected or effectively managed for sustainable or non-consumptive use by the people closest to them and in a way that promotes wider ocean conservation. By asking ourselves what is preventing this from happening right now, we identified the key threats that still exist: targeted fishery, by-catch, unregulated tourism and the indirect threat from environmental degradation, which includes climate change and pollution. Through a theory of change approach, we defined the individual factors that influence the threats and what actions need to occur to eliminate or reduce each one. We then defined the priority, cost, scale and time it would take to tackle individual actions and the party that should be responsible (NGOs, governments, industry) and developed graphic illustrations of our thinking.

Although global in scope, the strategy highlights how the Manta Trust fits into it all and the areas where we believe we can be most effective as part of the wider conservation effort. We were thrilled to officially present and launch our strategy at the 3rd CMS Sharks MoS meeting in December, held at the breathtaking Oceanographic Museum in Monaco. The strategy is now freely and publicly available to download from our website.

Mobulid rays were relatively understudied for most of the 20th century, but in recent years public awareness of these species and scientific research into them has increased dramatically. Yet although progress in mobulid research has been made, major knowledge gaps still exist that hinder the development of effective management and conservation strategies. For *Research Priorities to Support Effective Manta and Devil Ray Conservation*, we assembled 30 leaders and emerging experts in the fields of mobulid biology, ecology and conservation. The aim of this publication was to identify pressing knowledge gaps that must be filled to facilitate improved science-based management of these vulnerable species. We highlighted focal research topics in the subject areas of taxonomy and diversity, life history, reproduction and nursery areas, population trends, by-catch and fisheries, spatial dynamics and movements, foraging and diving, pollution and contaminants, and sub-lethal impacts. Mobulid rays remain a poorly studied group so the list of important knowledge gaps is extensive, yet we hope that by identifying these gaps we will stimulate and focus future research.

An exciting new project for the Manta Trust in 2018 was the launch of The Cyclone, a membership and fundraising platform that enables supporters to contribute directly to the conservation of the oceans, manta rays, their relatives and their habitats. By joining The Cyclone, anyone can get a front-row seat to our global conservation efforts. We created an exclusive area on our website available only to The Cyclone members, where we introduce our manta family, show the

Photos by Guy Stevens

Photo by Jobo Rodrigues | Chimera Visuals

'A highlight of 2018, after many years in the making, was the publication and launch of Guide to the Manta and Devil Rays of the World *by Stevens, Fernando, Dando and Notarbartolo di Sciara'*

research we are doing and explain why it is so important. We share our successes and discoveries as they happen, as well as the challenges we face along the way, giving The Cyclone supporters a unique view 'behind the scenes' through videos, stories and regular updates from the field. Members donate whatever they can each month, united by a desire to create a lasting future for these animals and the oceans they call home. We love to share what we do and are excited to see The Cyclone community grow every month. Check it out via *https://www.mantatrust.org/the-cyclone*.

This year marked another great milestone for our policy achievements. In September, Thailand officially declared measures to protect 12 marine species by adding them to its national protected list – including all six species of manta and devil rays seen in Thai waters. This means it is now illegal to kill, trade or possess any of these species. This legislation was made possible thanks to the efforts of our Thailand Manta Project and its collaborators. Their combined data, presented to decision-makers, coupled with years of discussions with the Thai government, helped to achieve this goal. The underwater beauty of Thailand is famous in the world's diving community, making the country one of the top dive destinations in South-East Asia. Between November and April divers visit the Andaman Sea in the hope of seeing the oceanic mantas that frequent its reefs at this time of year. In terms of oceanic manta tourism, Thailand is the second most popular place in Asia to dive with these gentle giants, and manta tourism pours millions of dollars into the nation's coffers each year. What great news to know that these manta rays, and the tourism industry they support, will receive better protection.

Over in the Pacific Ocean, our New Caledonia Project Manta Initiative received a special visit from Shawn Heinrichs, associate director of the Manta Trust. Shawn produced the short movie *New Caledonia, Mother of the Coral Sea*, which was funded by Conservation International, our local partner. The film describes the incredible biodiversity of the Coral Sea in New Caledonia and how it provides for the people of the archipelago, where nature and people are inextricably linked. Narrated in French with English subtitles, it features Conservation International's Marine Program coordinator Mael Imirizaldu

and the Manta Initiative researcher Hugo Lassauce, and is available at *www.conservation.org/coralsea*. We see the different aspects of New Caledonia – from Noumea, the capital, to the magnificent Ouvea, referred to as 'the closest island to Paradise' – as well as the bountiful life that flourishes in these waters: turtles, sharks, manta rays and large schools of fish, many of which are respected as culturally significant totems. Local community members take us through their world and their way of life, sharing their bond with nature and their aspirations to preserve this bond for generations to come. Conservation International and the Manta Initiative are working with partners to conserve the Coral Sea and its incredible diversity.

This year was very productive in terms of scientific publications by Manta Trust members and affiliates. Our genetics project leader, Jane Hosegood, submitted the results of many years of PhD research in her manuscript 'Phylogenomics and species delimitation of mobulid rays reveals cryptic diversity and a new species of manta ray'. Practical biodiversity conservation relies on the delineation of meaningful units, particularly with respect to global conventions and regulatory frameworks. This paper shows robust evidence for an undescribed species of manta ray in the Gulf of Mexico and for the resurrection of a recently synonymised species, *M. eregoodootenkee*. Jane's results provide genome-wide data to support a taxonomic review of the Mobulidae and generate a taxonomic framework to support effective management, conservation and law enforcement strategies.

Our chief executive, Guy Stevens, also published his PhD findings this year, in his paper 'Courtship and mating behaviour of manta rays *M. alfredi* and *M. birostris* in the Maldives'. The aim of Guy's 14-year study was to shed light on the entire courtship and mating behaviour of manta rays using observations of their behaviour and video and photographic records. He categorised courtship activity into seven distinct stages and described them in detail: initiation, endurance, evasion, pre-copulatory positioning, copulation, post-copulatory holding and separation. Photographs provide the first scientific record of manta ray courtship and mating in their entirety, and we now know that oceanic and reef manta rays engage in the same elaborate courtship rituals.

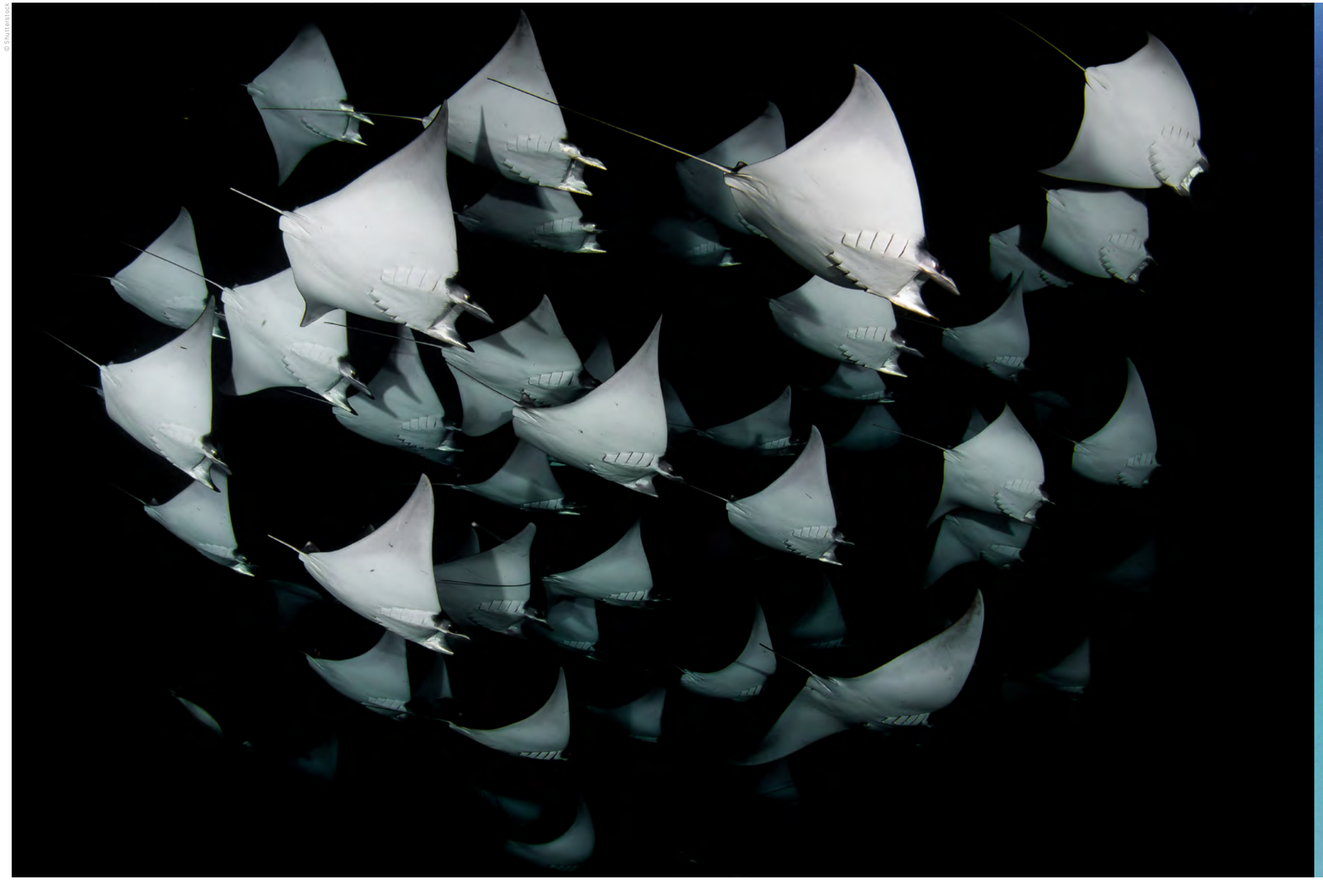
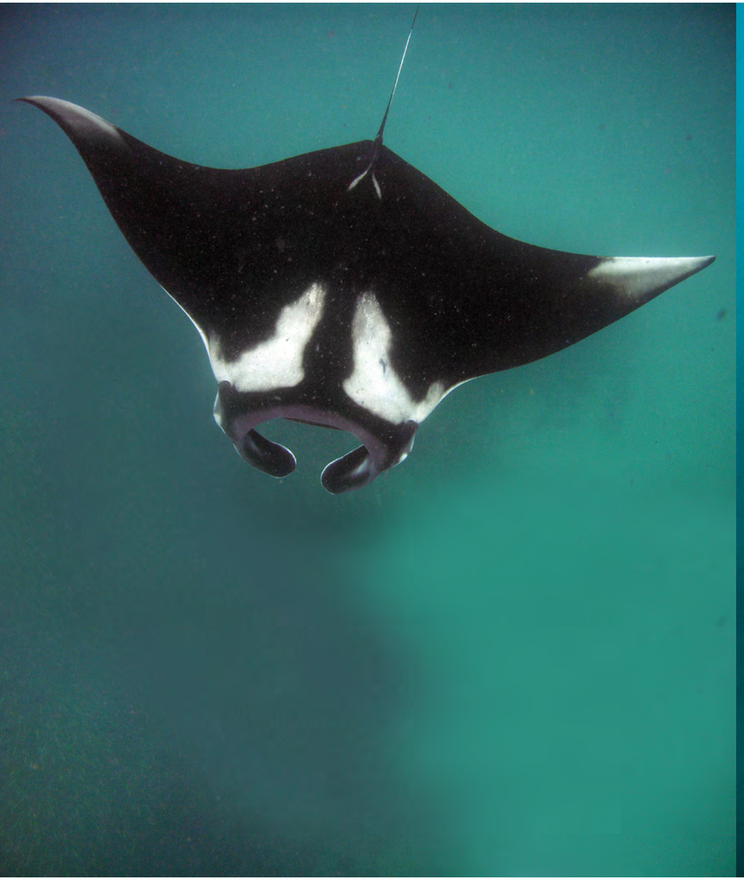
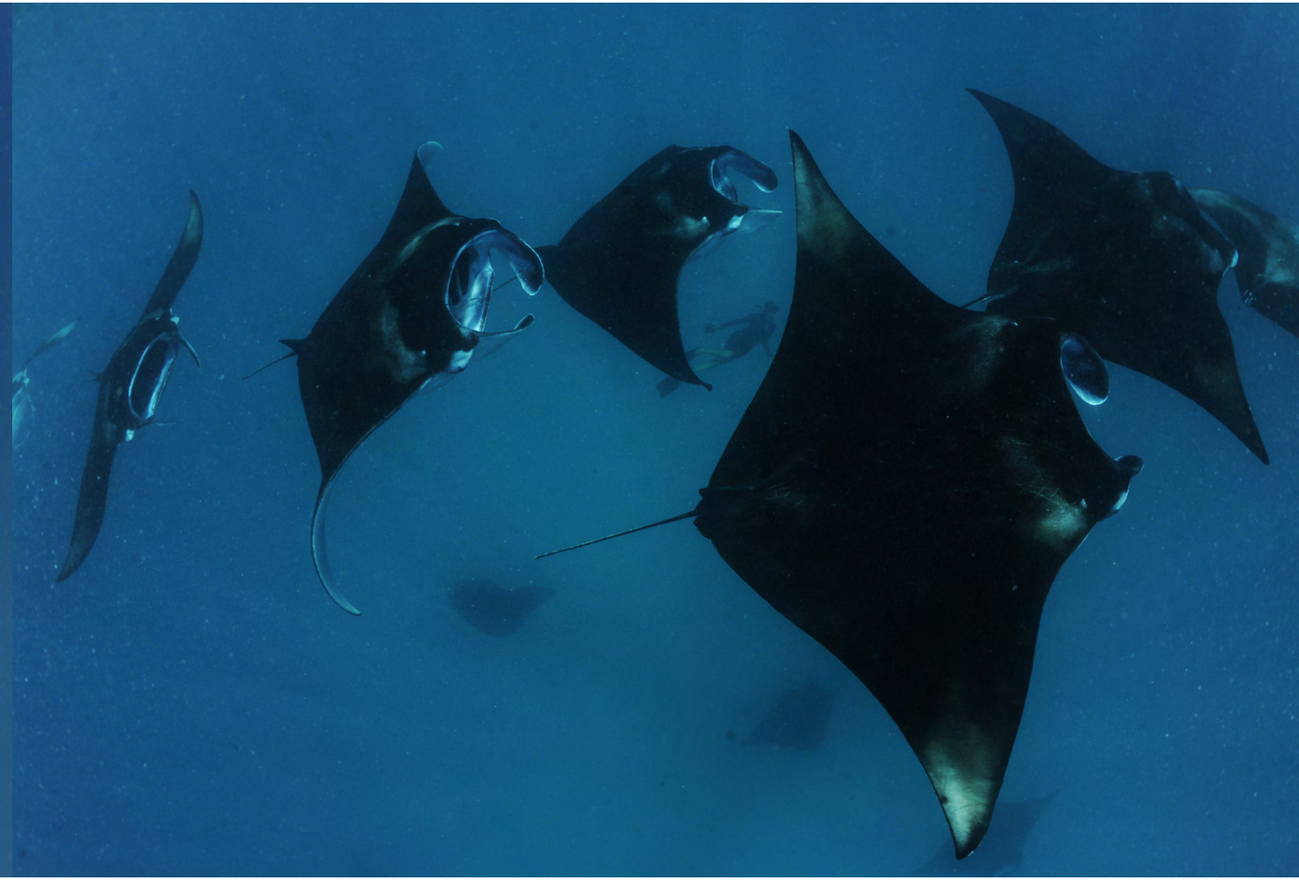


Photo by Guy Stevens



Photos by Guy Stevens



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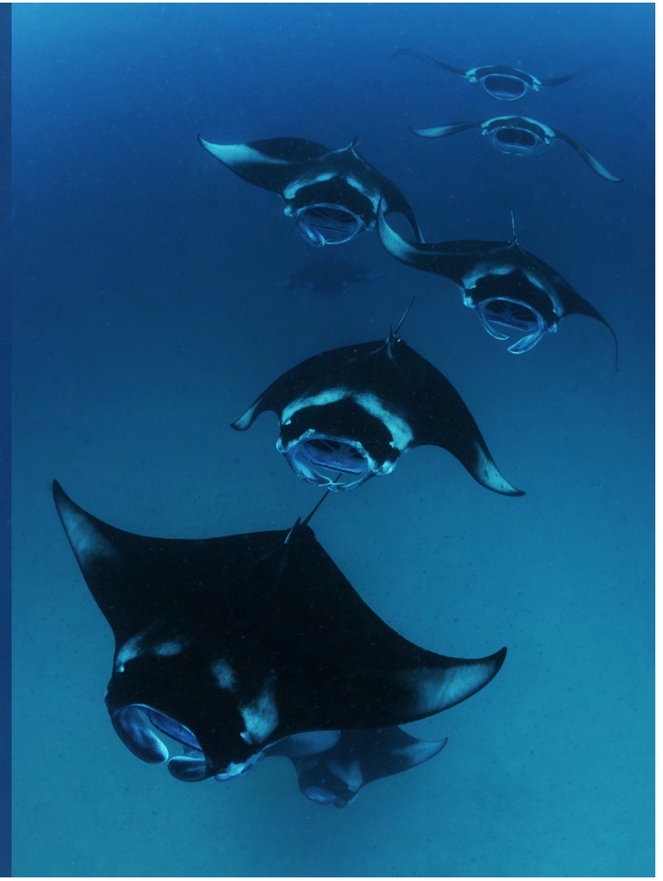

Photos by Guy Stevens

'The aim [of the educational project] would be to develop a Manta Trust curriculum that can be used by schools and projects all over the world'

Other publications included the work by Murray et al. 'Protecting the million-dollar mantas; creating an evidence-based code of conduct for manta ray tourism interactions'; the paper 'Environmental drivers of reef manta ray movements in the Amirantes, Seychelles' by Peel et al.; and the manuscript 'First insights into the population characteristics and distribution of manta rays in French Polynesia' by Carpentier et al.

A highlight of 2018, after many years in the making, was the publication and launch of *Guide to the Manta and Devil Rays of the World* by Stevens, Fernando, Dando and Notarbartolo di Sciara. Manta and devil rays are among the most charismatic creatures in the ocean, and yet there has never been a guide to these fascinating animals – until now. This comprehensive, 144-page field guide provides detailed information about the identification, characteristics, threats and distribution of each of the species and is illustrated by more than 200 beautiful colour photos, drawings and plates. An expansive introduction is packed full of useful information about the general taxonomy, biology and behaviour of these iconic animals. Light to carry and easy to use, the guide is an invaluable field companion for any scientist, diver or marine enthusiast who has an interest in rays. It is also an essential resource for fisheries management and international trade enforcement, and for anyone wanting to become involved in the ongoing efforts to research and conserve this threatened family.

As part of our Global Mobulid Conservation Programme (GMCP), we continued our fisheries monitoring in Sri Lanka and documented over 10,000 elasmobranch specimens (all sharks and rays) over more than 500 survey days across eight main survey sites. We also completed a year of detailed data collection that sheds light on the shark and ray fishery in a fishing hotspot in Java, Indonesia. This provides the most comprehensive dataset on the shark and ray fishery in this location, supported by socio-economic information that we gathered through fisher interviews. Indonesia is currently the leading elasmobranch fishing nation globally, and sharks and rays are important for the nation's food security and provide a major source of income for fishing communities. However, elasmobranch management in Indonesia is challenging because of the paucity of

Photo by Buddhi Maheshika

'A primary objective of the Global Mobulid Conservation Programme is to work directly with governments, researchers, NGOs and communities in key mobulid fishing countries to improve the knowledge and management of these species and the policy measures for them'

data on fisheries, especially at species level. Through an ongoing collaboration with James Cook University in Australia, the data we collected were analysed and a manuscript, 'Elasmobranch fisheries of the Bali Strait: species, size and sex composition', was completed. The findings emphasise the need for improved management of sharks and rays in Indonesia. We were particularly proud to hear that one of the two Indonesian interns we employed and trained for monitoring the elasmobranch fishery, and who is a co-author of the manuscript, has received a job offer as fisheries researcher from the Indonesian government. This is the true aim of building capacity: to provide the tools and expertise for local talents to continue this important work even when our projects and their funding come to an end. We hope to see many more similar examples of capacity building in the future.

A primary objective of the GMCP, which was established in 2014, is to work directly with governments, researchers, NGOs and communities in key mobulid fishing countries to improve the knowledge and management of these species and the policy measures for them. Policy change is critical to mobulid conservation, as it is the basis upon which enforcement of fisheries and trade regulation can be undertaken. To ensure that relevant and comprehensive policies that are informed by scientific knowledge are in place, there needs to be robust and comprehensive data on mobulid rays, shown through an increase in publications about mobulid fishery, biology and ecology.

Secondly, the governments of target countries need to be supported in developing protective policy. This past year we organised an interdisciplinary National Elasmobranch Working Group (NEWG) meeting in Sri Lanka and Indonesia, two key mobulid fishing countries. In Sri Lanka, this was the first meeting that brought together scientists, governments and NGOs to review national management and regulations on mobulid rays, learn about research being conducted and discuss steps forward. At this meeting, we presented the fisheries data collected across Sri Lanka to government representatives. Leading national and international marine scientists, including Dr David Ebert (Lost Sharks/Pacific Shark Research Center), Debra Abercrombie (Abercrombie & Fish), Sarah Fowler

Photo by João Rodrigues | Chimera Visuals

Photo by Isabel Ender

Photo by Isabel Ender

Photo by Buddhi Maheshika | blueresources.org

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Photos by Isabel Ender

(Save Our Seas Foundation), and Moazzam Khan (WWF Pakistan) shared their knowledge with regard to shark and ray management and conservation with Sri Lanka's Department of Fisheries and Aquatic Resources, National Aquatic Resources Research Development Agency and the Department of Wildlife Conservation. These initial conversations will pave the way for future actions and national policy developments for mobulids in Sri Lanka.

In Indonesia, a NEWG meeting was organised in conjunction with the National Shark and Ray Symposium. We presented on global mobulid policy developments and shared with government representatives from Indonesia and Malaysia, scientists and NGOs the findings from elasmobranch fisheries monitoring in Java. Through an interactive workshop led by the Manta Trust, we identified strategic priorities for the research and management of mobulid rays in Indonesia. These were compiled in the proceedings of the workshop and circulated to all participants. A series of informal government meetings has been held to provide guidance on mobulid policy developments since the start of 2017.

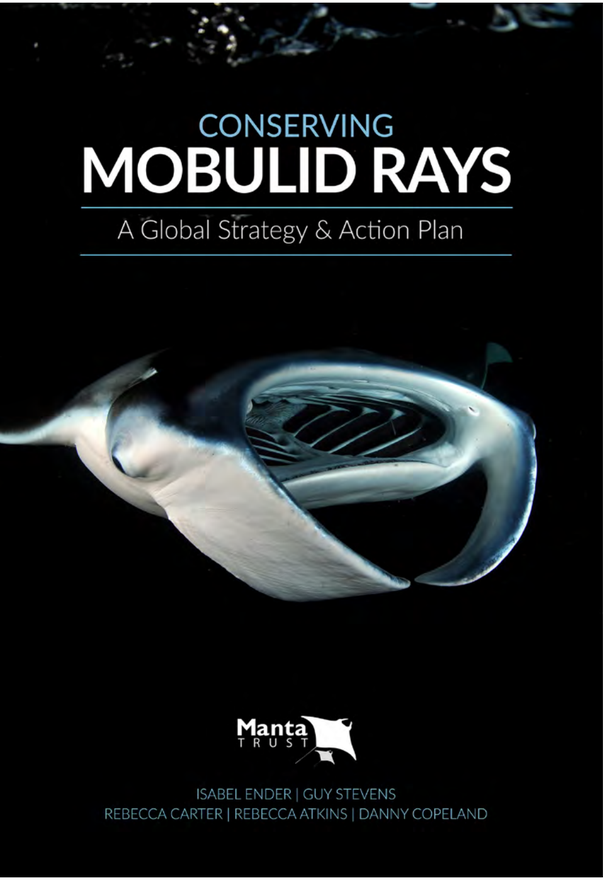
The Manta Trust delivered training at the regional CITES Implementation workshop in Sri Lanka in March 2018 to support governments in their bid to identify mobulid products in trade and to show them how to implement CITES regulations effectively. Government representatives from Bhutan, Bangladesh, Maldives, Nepal, India, Pakistan and Sri Lanka gathered to hear from leading elasmobranch researchers about the steps being taken to improve the study and management of shark and ray species, and from the CITES Secretariat about sustainable trade. We developed resource materials, including a gill plate identification poster and species guides, which were distributed to participants. We also provided mobulid trend data and participated at the IUCN Red List re-assessment for mobulid rays, in November 2018.

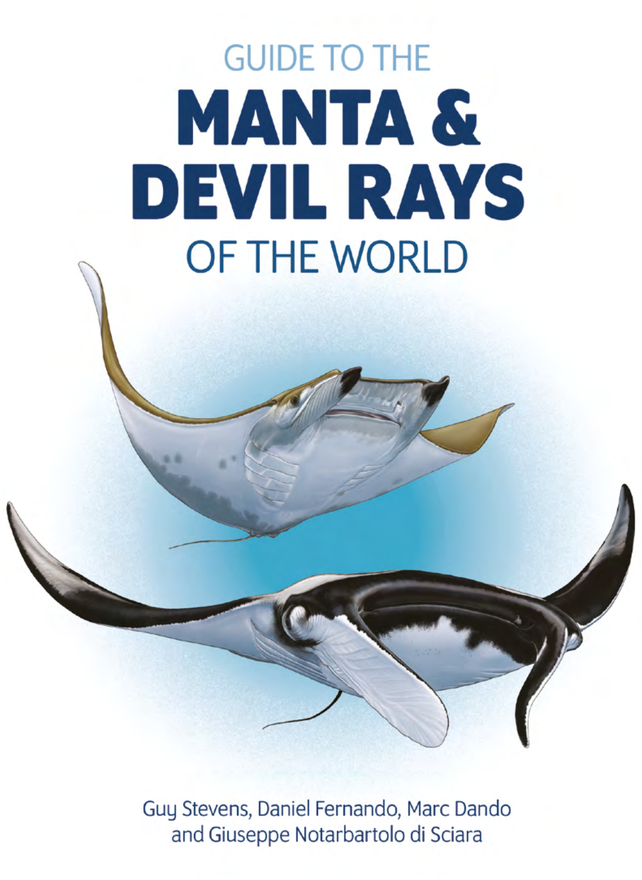
In the third target country of the GMCP, Peru, we organised two capacity-building workshops for fisheries observers on tuna fishing vessels and for the Peruvian government. At the first workshop, held in partnership with the Inter-American Tropical Tuna Commission (IATTC) and the Monterey Bay Aquarium, 28 observers were trained to identify mobulid species, deploy tags and collect data, including sampling for genetic studies. Thirty participants from the Ministry of Environment and Fisheries Department were taught skills in species identification, data collection and fisheries monitoring for field investigators in northern Peru. Data collection was practised through a hands-on session with live specimens, and participants were provided with resource materials, including resource protocols and a Manta Trust species ID guide for Peru.

Improved data collection results in the Peruvian government being able to make better-informed decisions about fisheries management. During a symposium in Lima, we used our data to update the government on the current knowledge about manta rays and the threats to them in Peru. We participated in the Department of Environment's Consultoria and provided information about mobulid rays relevant to the assessment of Peru's elasmobranch populations, thus helping the government to make decisions about mobulid policy and legislation. In conjunction with a student from Cambridge University, a socio-economic survey was undertaken to identify the 'motivations for compliance and the role of local ecological knowledge in Peruvian manta ray fisheries'. Through this socio-economic research and our educational activities, we aim to shift the attitudes and habits of communities towards conserving manta rays and their habitats, develop a new generation of ocean ambassadors, and understand how to better support community members in their transition away from mobulid fisheries.

Back in the Pacific, the Manta Trust's affiliated projects conducted drone aerial surveys around Palau's reefs to survey manta and dugong movements. Our team finished an acoustic tagging project in Pohnpei, and found new spawning aggregations that manta rays are targeting. They also obtained a NOAA MET grant for training students in the Mariana Islands and launched the FISSH (Fish Survey Species Habitat) project for training and surveys. In Fiji, our project continues to monitor the environmental conditions in the Yasawas, adding current meters to the manta channel to assess the correlation between aggregation and current strength, and meters at weather stations.

In Fiji our project worked with the WWF to draft a cabinet paper for sustainable tourism and mobulid interaction guidelines, using the Manta Trust's





Photos by Olivier Born

'The Manta Trust charity reached a major milestone when we finally achieved international protection for all species of mobulid rays under CITES and CMS'

Code of Conduct as a resource, and carried out educational workshops with local communities. The team also worked with the Fiji tourism authority to produce a short film for CoP23 in Bonn, Germany, that raises awareness of Fiji's dedication and leadership role in mobula protection and sustainable tourism as a whole. Finally, an on-site field laboratory and education centre was established in Fiji, including a life-size manta exhibit for the Centre for Marine Science and Education, which will be used by various community, stakeholder and international university workshops.

The Mexico Caribbean Manta Ray Project continues to thrive and this past year it launched a plastic pollution study in partnership with the Mexican government. We collaborated with the 'Eye on the Reef programme for marine debris in the Mexican Caribbean, which is an initiative of the Australian government, and delivered recommendations and a 'Guide for Good Practices with Mobulid Interaction' to the Mexican Caribbean Biosphere Reserve, the Whale Shark Biosphere Reserve and the National Park of Contoy. Finally, this project became a collaborator in and the organiser of the Latin American Congress of Sharks, Rays and Chimaeras in Caribbean Mexico, scheduled for March 2019.

Throughout 2018 we continued our successful conservation programme in the Maldives through the Maldivian Manta Ray Project (MMRP), the founding project of the Manta Trust. Our programme of research, education and outreach was delivered by nine full-time members of staff, in partnership with Four Seasons Landaa Giraavaru in Baa Atoll, Six Senses in Laamu Atoll, Prodivers at Hurawalhi Resort & Spa in Lhaviyani Atoll, and Euro-Divers in Ari Atoll and North Malé Atoll. During the year the MMRP hosted six volunteers as part of the research internship programme at Four Seasons, now in its 10th year, as well as an MSc student from the University of York who is studying the impacts of tourism on manta rays. In July 2018, the MMRP team attended the Second Maldives Marine Science Symposium in Malé, giving a presentation on our research on manta tourism in the Maldives and recommendations for our Code of Conduct (*www.swimwithmantas.org*), as well as poster presentations on 'A summary of current knowledge on Oceanic Manta Ray (*Mobula birostris*) demographics in the Maldives' and 'The Effectiveness of a Marine Environmental Education Program in the Maldives'.

The MMRP launched a successful crowd-funding campaign, 'Eyes on the Reef', in June 2018 to uncover the hidden habits of reef mantas using remote underwater camera rigs installed on cleaning stations. In September, in collaboration with Manta Expeditions, the Manta Trust conducted its first Citizen Science Expedition in the Maldives with employees of Salesforce. The MMRP took part in numerous educational festivals in the Maldives throughout 2018, and also organised the first Manta Festival, held at the local Island of Dharavandhoo in Baa Atoll. We have also continued our Marine Education Programme in the Maldives, working with more schools and local communities in Baa Atoll, Laamu Atoll and Lhaviyani Atoll.

Finally, our core team in the UK has been busy developing the Manta Trust's fundraising, communications and media campaigns. We secured funding from Paul M. Angell, developed a new website, participated at various dive shows and festivals, and recruited a team of supporters for the British 10k sponsored event. We developed and launched a new digital manta adoption pack, and spoke about mantas and the Manta Trust at the Natural History Museum in London in November 2018, during a launch event for the book *Call of the Blue*.

It has been such an honour to see the Manta Trust charity grow and develop and to be part of driving its achievements near and far. We are the largest and possibly most diverse global network of mobulid ray experts, and I cannot wait to see what else lies ahead. Thank you to all our projects, collaborators, funders and friends for sharing this journey so far. Here's to a fantastic 2019!

Photo by Simon Hilbourne

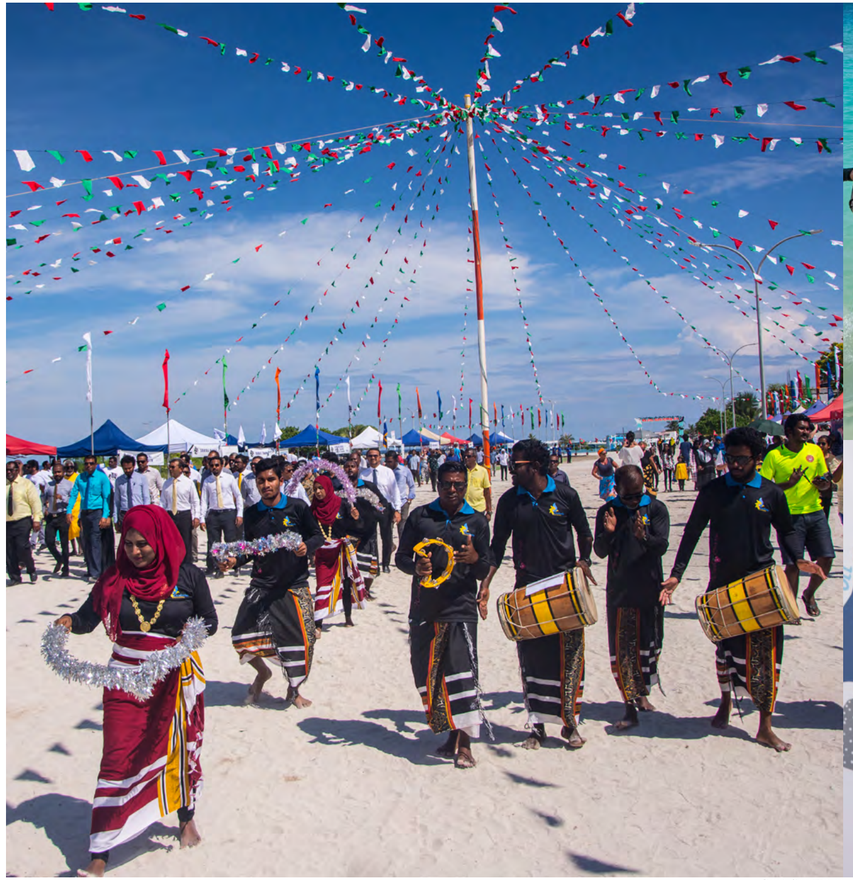


Photo by Simon Hilbourne

Photo by Martin Bairaud

Photos by Simon Hilbourne

SHARK SPOTTERS

SARAH WARIES & TAMLYN ENGELBRECHT

Photos by Sarah Waries

SHARK SPOTTERS
SAFETY CONSERVATION EDUCATION RESEARCH

Sarah Waries

Sikweyiya Monwabisi

SAFETY

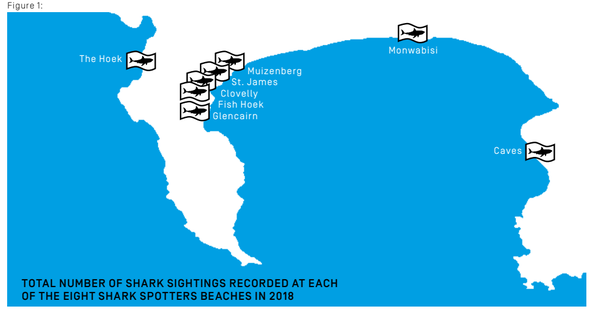
Shark Spotters continues to maintain the balance between the safety of beach-goers and the conservation of the large coastal shark species that inhabit the waters around Cape Town. This is achieved through proactively mitigating the spatial overlap between water-users and sharks at eight of the most popular beaches around False Bay and the Cape Peninsula. Shark Spotters acts as an early warning system, alerting water-users to the presence of potentially dangerous sharks in close proximity to people in the inshore zone. In addition to this, the programme continues to implement novel and innovative strategies to further reduce the risk of human–shark conflict, including the deployment of a unique, non-lethal shark exclusion barrier at Fish Hoek Beach.

In 2018 we recorded 75 shark sightings, which brings the total number of sightings to 2,218 since the Shark Spotters programme began in 2004. Of these, 52% resulted in a temporary beach closure, immediately reducing the risk of a shark encounter without impacting the natural behaviour of sharks in the inshore zone (see figure 1).

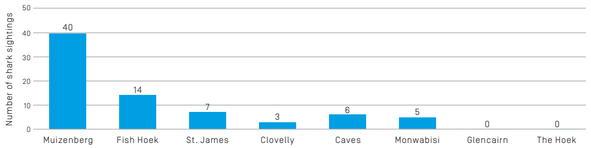
In addition to this, our award-winning exclusion net was deployed 112 times in 2018, providing a safe enclosure for bathers during the spring and summer seasons. Once again the exclusion net has proven to be a reliable, cost-effective and environmentally friendly approach to further reduce the risk of a negative shark encounter for water-users over the busiest time of the year at Fish Hoek beach. The net is deployed each morning and retrieved in the evening to reduce any potential environmental impact and prevent damage to the net when sea conditions are unfavourable.

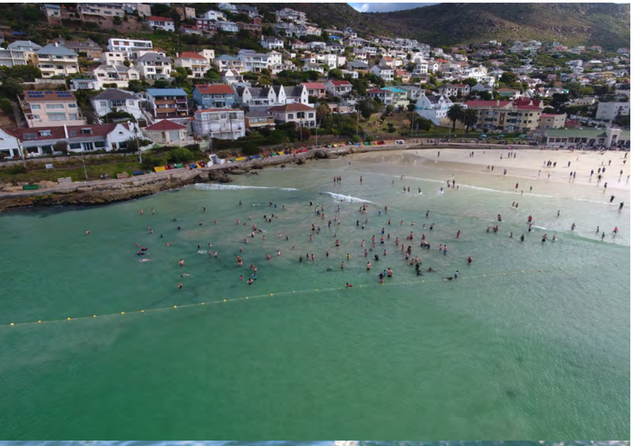
We have continued the use of drones at our two most popular beaches, Muizenberg and Fish Hoek, and they have been invaluable in assisting with species identification during a shark sighting. This is important as many of the sightings recorded in 2018 were of the bronze whaler shark *Carcharhinus brachyurus*, which is less of a potential threat to water-users than the white shark *Carcharodon carcharias*. This information is also significant from an ecological perspective, as it helps us understand the occurrence and behaviour of different shark species in the inshore zone across different seasons and years. In addition to supplying information with regard to shark safety, the drones have become an invaluable education tool, enabling us to share a new perspective of False Bay with the public and with fellow scientists studying charismatic marine megafauna in our area. From showing surfers that the fin they have seen is a sunfish, not a shark, to recording bottlenose and humpback dolphins in areas where they have previously not been seen before, the drones have become an integral part of our operations.

Figure 1:



TOTAL NUMBER OF SHARK SIGHTINGS RECORDED AT EACH OF THE EIGHT SHARK SPOTTERS BEACHES IN 2018



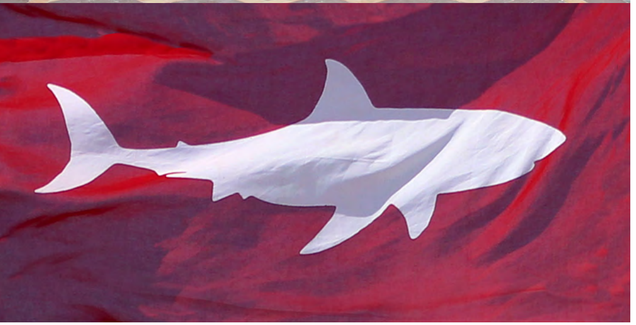


Shark Spotters continues to share expertise and lead by example on sustainable shark safety strategies. In 2018 we were approached by the NSRI at Jeffery's Bay, a world-renowned surfing spot in the Eastern Cape of South Africa, for guidance and support with regard to Shark Spotters protocols and standard operating procedures with a view to potentially implementing a similar system in that area. We also continue to liaise and cooperate with local authorities and NGOs in areas of high shark risk around the world, including Réunion, Australia and the USA, to share information and ensure best practice in sustainable shark bite mitigation strategies.

EDUCATION

Since the appointment of our dedicated education coordinator, Nicole Lockett, in 2016, our education programme has gone from strength to strength. In 2018 more than 3,000 learners and students from pre-primary to tertiary level were reached through the programme, learning shark safety tips, shark diversity, the role of these predators in the ecosystem and the importance of conservation and reducing our impact on the environment. Many activities have taken place in partnership with the Save Our Seas Foundation Shark Education Centre in Kalk Bay.

In September and October we partnered with the NSRI in a campaign to teach general beach safety at underprivileged schools in local communities in order to reduce drowning and other beach-related accidents. The programme reached more than 800 Grade 7 learners, providing essential information on responsible beach use, ocean hazards such as rip tides, safe swimming areas, shark safety tips and CPR techniques in the event of an emergency. Thousands more people across a broad range of ages were given the opportunity to learn more about shark safety and conservation by attending our education and awareness events, including public presentations and interactive activity programmes, and visiting our information centre on Muizenberg beach.
In addition to being a point of call for information on shark safety and conservation, the information centre has become a central hub on the beach,



providing services such as first aid, lost property and tourism information, as well as being a focal point for lost children and injured or stranded marine animals, such as seabirds and seals.

In 2018 Shark Spotters partnered with the Two Oceans Aquarium to become the False Bay Turtle Rescue Network Point. We received training from the aquarium's turtle rescue team on how to stabilise turtles found washed up on our coastline and gave a presentation on the first stop of its Turtle Road Trip, a journey along the Western Cape coast to raise awareness of turtle strandings and turtle conservation.

RESEARCH

PhD candidate Tamlyn Engelbrecht was appointed the new research manager in March 2018. We have continued to expand the scope of our research programme, which embraces ongoing ecological and behavioural studies on large shark species in False Bay, research into human behaviour and the challenges of sustainably mitigating shark risk for water-users, and testing and developing new technology to supplement and improve shark spotting. In 2018 we published four scientific papers in high-end peer-reviewed journals, presented at three different research and education symposiums and gave four popular science talks.

We continue to maintain an extensive array of acoustic receivers in False Bay and along the Atlantic coast in Cape Town and collect data from 24 receivers in these areas. Eighteen of these receivers are privately owned by Shark Spotters and six are maintained in collaboration with the Acoustic Tracking Array Platform (ATAP). Collaboration is imperative if we are to achieve the conservation of wide-ranging apex predators and the ecosystems they frequent along our coast. Therefore Shark Spotters actively collaborates with other organisations such as the ATAP, the National Shark Advisory Group and the White Shark Research Group of South Africa. In June 2018 we participated in a stakeholder workshop hosted by the Department of Environmental Affairs to discuss the National Biodiversity Management Plan for Sharks in order to assess progress, identify challenges and setbacks and create a roadmap for the way forward.

Photo by Michael Scholl

'We recorded 75 shark sightings, which brings the total number of sightings to 2,218 since the Shark Spotters programme began in 2004. Of these, 52% resulted in a temporary beach closure, immediately reducing the risk of a shark encounter without impacting the natural behaviour of sharks'

Although shark activity has been very low, we have continued our efforts to monitor the presence of white sharks in the inshore zone and at Seal Island, and have been tagging both broadnose sevengill *Notorynchus cepedianus* and white sharks. We conducted 10 research trips to Seal Island in 2018, during which we collected dorsal IDs to continue the monitoring of the white shark population in False Bay. The exceptionally low activity of white sharks meant that none were tagged in 2018, although 15 broadnose sevengill sharks were tagged, 10 at Robben Island and five at Seal Island.

In 2018 we also began field tests with a view to implementing an automated camera system that would help spotters to detect sharks in the inshore zone. This project is funded by the Department of Science and Technology through the Eurostars programme and is being run in collaboration with the PatternLab SL, an R&D company specialising in computer vision in Switzerland. If successful, this system could overcome many of the limitations of shark spotting and allow the automated detection of sharks in new areas that are currently unsuitable for Shark Spotters because there is no natural elevation close to beaches.

SKILLS DEVELOPMENT AND EMPLOYMENT OPPORTUNITIES

An important part of our mandate at Shark Spotters is to provide opportunities and facilitate capacity building for members of local communities. Shark Spotters currently employs 30 spotters and 10 exclusion-net crew members from disadvantaged communities in Cape Town. All employees are given the opportunity to further their skills and professional development, and in 2018 they all were trained in first aid and advanced trauma management. Various staff members also completed confident communication courses, became proficient in swimming and gained drone pilot's licences or skipper qualifications.

AWARENESS AND OUTPUTS

Being key to a successful shark safety and conservation strategy, awareness is a strong focus of the Shark Spotters programme. A hugely successful addition to spreading awareness and informing the public of shark risk was the development of our mobile Shark Spotters app in 2016. Over the past 12 months the app has been downloaded more than 5,500 times, bringing the total number of downloads to 14,000 to date. This app provides the public with detailed information from each of our eight beaches, ranging from surf and weather conditions at each beach to continuously updated information on spotting conditions, shark sightings and current flag status.

We continue to have a strong media presence both locally and internationally, which provides a great platform to share rational, objective information about shark risk and shark conservation challenges. We also take every opportunity to present our work to the public, from schoolchildren to professionals. This enables us to engage directly with water-users and people living along the coast and inform them of steps they can take every day to minimise risk in the ocean environment and become responsible ocean guardians. We also maintain an active presence on social media, informing the public about important safety information, research findings and other noteworthy news via our website (*www.sharkspotters.org.za*) as well as Facebook, Twitter and Instagram.

Highlights for 2018:

- 53 news features (online and print media)
- 16 TV and radio interviews
- 52 presentations to an audience of >3,000 people
- Social media
  - Twitter >24,000 followers
  - Facebook >16,000 likes
  - Instagram > 2,000 followers
- Shark Spotters app >14,000 downloads
- 3 conference presentations

• Master's theses:

Kristina Loosen. MSc thesis (iCWild & UCT): Predictors of white shark *Carcharodon carcharias* presence at two recreational beaches in a major metropole (2017).

David van Beuningen. MSc thesis (iCWild & UCT): Environmental predictors of *Carcharodon carcharias* presence at two popular beaches in False Bay, South Africa using telemetry.

• Scientific publications:

Bird CS, Veríssimo A, Magozzi S, Abrantes KG, Aguilar A, Al-Reasi H, Barnett A, Bethea DM, Biais G, Borrell A, Bouchoucha M. 2018. A global perspective on the trophic geography of sharks. *Nature Ecology & Evolution*. 2(2): 299. *https://www.nature.com/articles/s41559-017-0432-z*

Hewitt AM, Kock AA, Booth AJ, Griffiths CL. 2018. Trends in sightings and population structure of white sharks, *Carcharodon carcharias*, at Seal Island, False Bay, South Africa, and the emigration of subadult female sharks approaching maturity. *Environmental Biology of Fishes*. 1–16. *https://doi.org/10.1007/s10641-017-0679-x*

Johnston EM, Halsey LG, Payne NL, Kock AA, Iosilevskii G, Whelan B, Houghton JDR. 2018. Latent power of basking sharks revealed by exceptional breaching events. *Biology Letters*. *https://doi.org/10.1098/rsbl.2018.0537*

Kock AA, Photopoulou T, Durbach I, Mauff K, Meÿer M, Kotze D, Griffiths CL, O'Riain MJ. 2018. Summer at the beach: spatio-temporal patterns of white shark occurrence along the inshore areas of False Bay, South Africa. *Movement Ecology*. 6(1): 7. *https://doi.org/10.1186/s40462-018-0125-5*

FUTURE WORK

In 2019 we will continue our core operations of providing a sustainable and responsible safety service to the public through our spotting and exclusion barrier programmes.

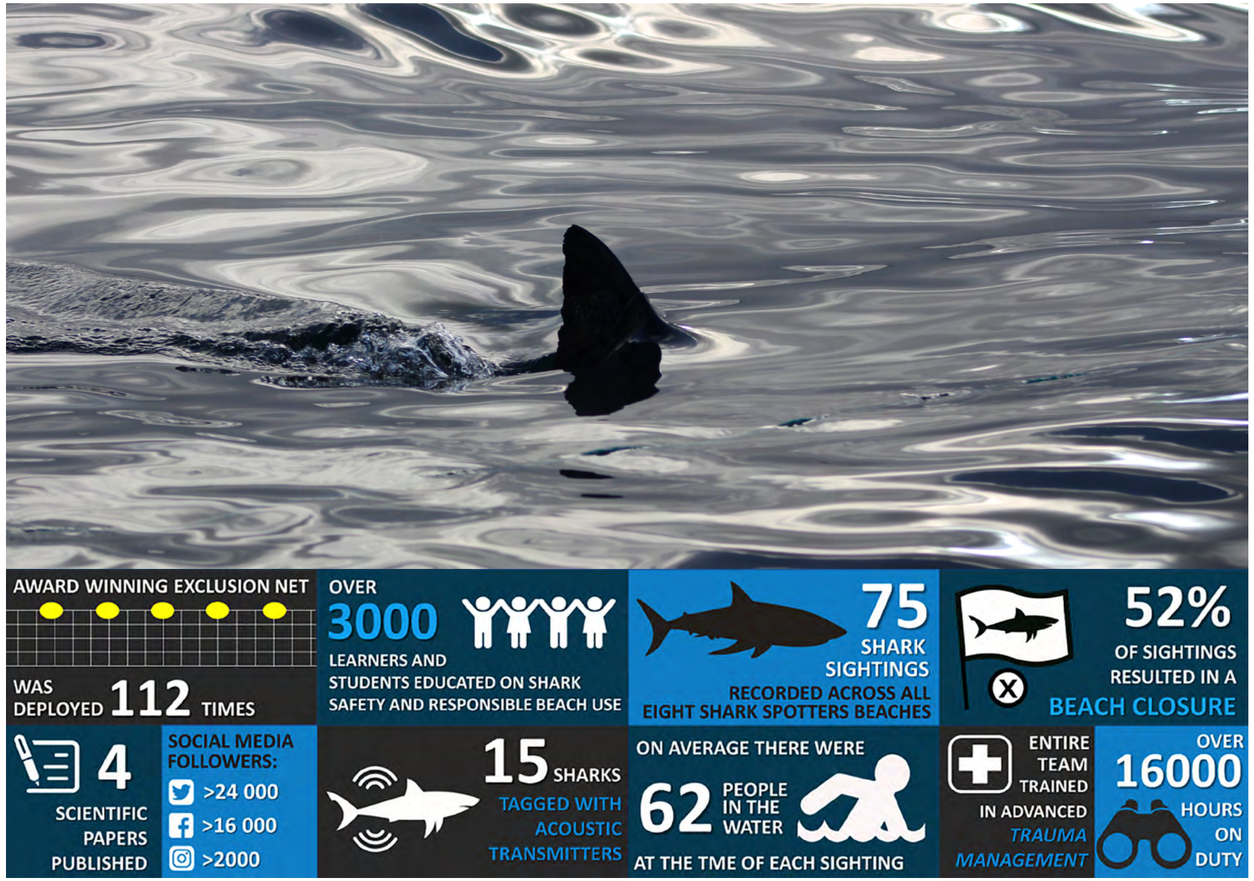
Our automated shark-spotting research project will continue to collect data in order to teach the computer algorithm how to identify shark species. It is anticipated that by the end of 2019 we will have a working prototype of the camera system that will operate in real time to identify sharks as they approach the beach, and will enhance our current spotting system.

We aim to expand the reach of our education programme even further in 2019 and have submitted an application for funding from the National Lottery of South Africa for a large-scale Ocean Safety and Conservation Education Programme (OSCEP). If the proposal is successful, this grant will fund education activities and equipment costs for 20,000 learners over the next two years. The programme will target underprivileged schools in local communities and will provide invaluable education about shark safety, responsible beach use, drowning

'We continue to liaise and cooperate with local authorities and NGOs in areas of high shark risk around the world to share information and ensure best practice in sustainable shark bite mitigation strategies'

prevention and marine conservation via interactive learning, educational activities and field trips. Children will be given stationery packs and activity books to supplement the educational programme.

Our research programme will continue to study the behavioural ecology of white and broadnose sevengill sharks in False Bay and will expand to include the bronze whaler shark, thanks to a grant we acquired from the National Research Foundation as part of its Marine and Coastal Funding Instrument. This project will investigate the diet and movement ecology of bronze whalers in False Bay using stable isotope analysis and acoustic telemetry and will recruit a PhD student through the Institute for Communities and Wildlife in Africa at the University of Cape Town.



THE NORTH COAST CETACEAN SOCIETY

JANIE WRAY & HERMANN MEUTER

Photo by Janie Wray

BCwhales.org

FIN ISLAND

Janie Wray

BC WHALES 2018 | JANIE WRAY

The 2018 season for the North Coast Cetacean Society (NCCS) and BC Whales was a year in which great teamwork ensured that a number of projects were successful. Between May and October we monitored humpback and fin whales and resident and transient orcas along the northern coast of British Columbia from four platforms: our hydrophone network; Fin Island Research Station and Cetacea Lab, both of which are land-based; and marine surveys.

In early May we opened the Fin Island Marine Institute and with an amazing team of helpers we installed a new hydrophone network in Squally Channel. The work was carried out in two phases, firstly setting up the land-based transmitters and then deploying the hydrophones. The transmitters, one for each of the four hydrophones, are located 13 kilometres (eight miles) apart and in line of sight from the lab. Each one is powered by batteries and solar panels and is placed high in a tree or on a platform so that it can transmit the signal from the hydrophone back to the lab.

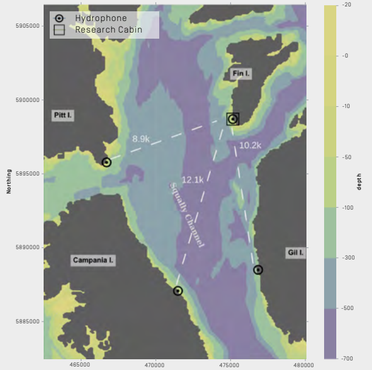
The hydrophone array covers 200 square kilometres (77 square miles) and each of the four hydrophones is located at a depth of 20 metres (66 feet). All four are time synchronised with each other and they transmit in real time to the Fin Island Research Station. They were calibrated and tested in a boat before being deployed.

It's not easy to install hydrophones, especially in such a remote area. A qualified diver is needed, and the location has to be such that the hydrophone, connected to a 36-kilogram (80-pound) cement block, can be secured 20 metres underwater. It also needs to be close enough to shore that the hydrophone can be connected to a cable that will follow the intertidal zone to shore and then link to one of the land-based transmitters. Nevertheless, we successfully set up the network and during the 2018 season recorded 3,600 hours, or eight terabytes, of humpback, orca and fin whales' calls at the Fin Island Station.

The NCCS has developed a localisation strategy and algorithms that determine a) the time differences of arrivals (TDOA) between all four hydrophones and b) a spatial model for TDOAs based on 3D acoustic ray tracing. The model incorporates the local sound speed profile, the bathymetry of the ocean floor, and surface and bottom parameters in Squally Channel. This outcome enables us to localise the vocal signatures of whales and follow their acoustic underwater pathways. Thus, for the first time ever, we have been able to follow the tracks of whales underwater and determine both their behaviour and their habitat use – and we've achieved this by using a passive technique that has no impact on the whales. The diagrams (see figures 1 to 6) illustrate examples of localisations, which were accomplished with the hydrophones alone.

To test the accuracy of the technique we employ to localise a signal from each hydrophone station we used an amplifier and an acoustic transducer, which produces a sound known as a 'ping' from a marine vessel within range of the four hydrophones. We compared the location produced by the hydrophone data with the GPS location of our boat and the results were remarkable. With four hydrophones we can confidently pinpoint the location of a vocal whale within 41.5 metres (136 feet)! This could not have been done without the expertise of postdoctoral researcher Ben Hendricks and Tom Dakin, from Ocean Networks Canada.

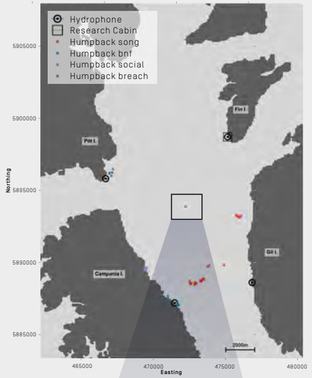
FIGURE 1: SQUALLY CHANNEL HYDROPHONES



4 Hydrophone Array:
- permanent installation
- 10km separation
- 200 sqkm coverage
- 10Hz to 32kHz bandwidth
- 20m depth
- time-synched
- real-time transmission to Fin Island Research Cabin
- data processed at Cabin

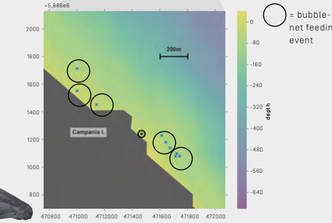
35,000 hours and 23 TB of acoustic data per year

FIGURE 2: HUMPBACK WHALE BREACHING
LOCALISATION – RESULTS

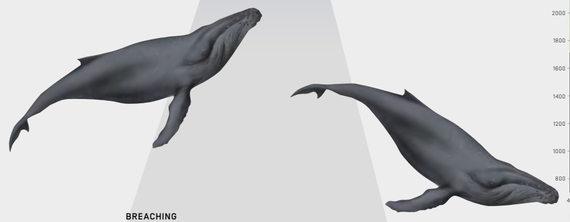


> The most common and dynamic feeding strategy observed in humpbacks is bubble-net feeding, whereby groups of up to 10 or so individuals corral shoals of fish into a trap made from underwater curtains of bubbles they have blown. The whales are vocal during the entire event and we have recorded multiple hours per day of this call type. Our ability to track and localise this feeding pattern by a method that has never before been used along the coast of British Columbia will enable us to document a habitat use that is very important to this population.

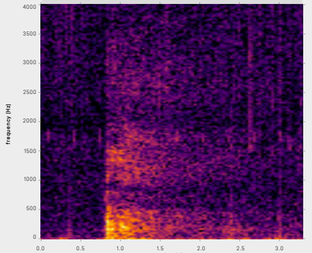
FIGURE 3: HUMPBACK WHALES BUBBLE-NET FEEDING
LOCALISATION – RESULTS | SEP 25, 2018, 08:27 – 08:45 PST



= bubble-net feeding event



BREACHING



BUBBLE-NET FEEDING

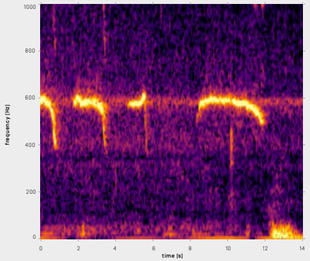
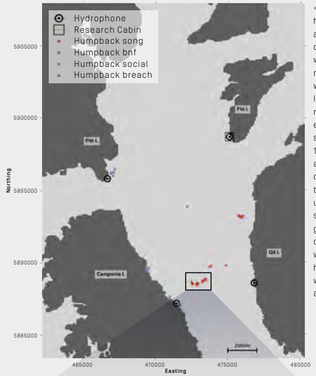
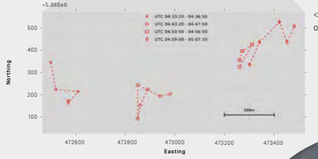


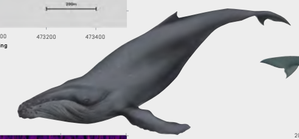
FIGURE 4: HUMPBACK WHALE SONG AFTER MIDNIGHT
LOCALISATION – RESULTS | AUG 25th, 2018, 21:33 – 22:07 PST



< Thanks to the hydrophone array, we were able to localise the calls during this humpback whale song and track the movement of the whales while they were 'singing'. It is clear that the whale moves very slowly during each sequence. The second whale joins in from 1.5 kilometres (almost a mile) away. This new development of being able to follow humpback whales underwater during their song display will help us to get a better understanding of this behaviour, which involves only male humpbacks during fall and winter, and usually only after dark.



< 4 song sequences of 3-8 min each



SONG

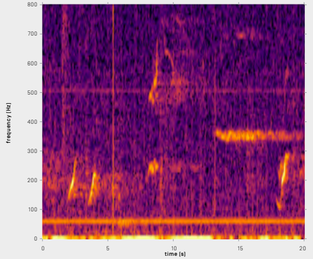
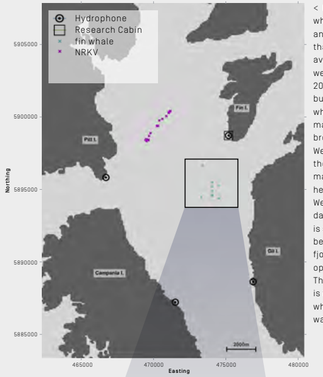


FIGURE 5: FIN WHALE CALLS
LOCALISATION – RESULTS | SEP 10, 2018, 02:30 – 02:42 PST



< Localising calls of fin whales is completely novel and the NCCS team is hopeful that more results will be available soon. Fin whale calls were detected between 15 and 20Hz. It has been speculated, but not confirmed, that the whales in question may be males vocalising during the breeding season in late fall. We also detected calls in the 40 to 50Hz range, which may be feeding calls that are heard throughout the season. We will need to collect more data to discover whether this is significant to fin whale behaviour within the narrow fjords of our research area as opposed to the open ocean. The NCCS hydrophone network is the first to localise fin whale calls within the coastal waters of British Columbia.

This diagram > clearly shows the pathway used by a family of resident orcas from the Fin Island Station towards Otter Pass – the same route proposed for tankers carrying liquefied natural gas. Our intention is to document orca travel routes to demonstrate that they have specific patterns that they follow consistently. This knowledge will be used for mitigation purposes when routes for marine traffic in the area are determined.

FIN WHALE; 20HZ PULSE

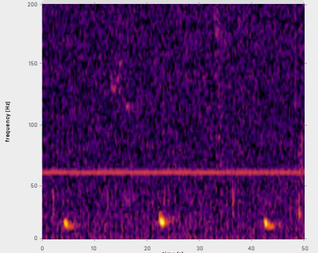
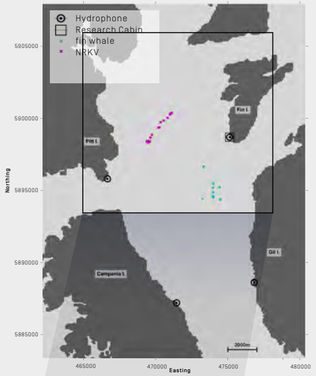


FIGURE 6: ORCAS TRAVELLING FROM FIN ISLAND TO OTTER PASS
LOCALISATION – RESULTS | SEP 25, 2018, 08:31 – 09:08 PST



ORCA CALL

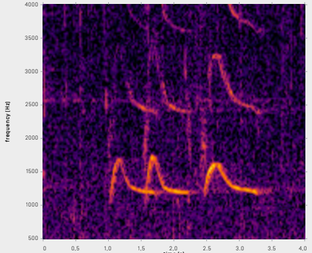


Photo by Michael Scholl

Photo by Janie Wray

Photo by Janie Wray

Photo by Florent Nicolas

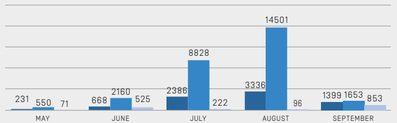
Photo by Janie Wray

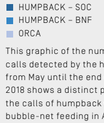
Photo by Jenn Dickie

Photos by Janie Wray

HYDROPHONE RESULTS

FIGURE 7: NUMBER OF WHALE VOCALISATIONS RECORDED 2018





This graphic of the number of whale calls detected by the hydrophones from May until the end of September 2018 shows a distinct peak in the calls of humpback whales bubble-net feeding in August. (BNF = bubble-net feeding; SOC = social calls)

FIGURE 8: TOTAL WHALE VOCALISATIONS RECORDED 2018

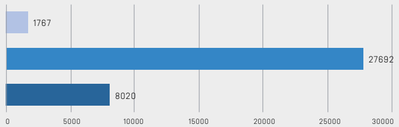
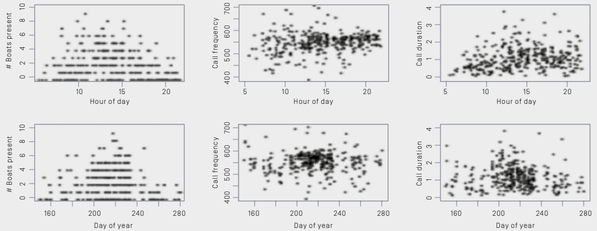


FIGURE 9: BOAT TRAFFIC



The left column shows boat traffic by time of day (above) and by day of year (below), with peaks between noon and 14h00 and in late July and early August.
The middle column shows call frequency by time of day (above) and by day of year (below). There is no strong pattern, but perhaps a peak in call frequency in July/August (like the boat data).
The right column shows call duration, with midday and mid-season peaks (like the boat data).

'For the first time ever, we have been able to follow the tracks of whales underwater and determine both their behaviour and their habitat use – and we've achieved this by using a passive technique that has no impact on the whales'

HYDROPHONE RESULTS

In 2018 we recorded 15,000 humpback bubble-net feeding calls from the Fin Island hydrophone station. From this dataset we are working on a bubble-net feeding call characterisation paper that looks at acoustic properties, time of year and time of day patterns and response to ambient noise from marine traffic. We plotted the data so that we could ask whether the number of boats in the area influenced call behaviour and discovered a weak trend that call frequency increased with the number of boats present. We did a Bayesian regression, which told us there was a 83% chance that frequency increased with boat traffic, but not by much: a mean of 1 Hz per boat. We recognised strong seasonal and daily patterns to boat presence in the area (see figures 7 to 9).

VISUAL AND ACOUSTIC SURVEYS COMBINED

One of our research goals is to assess the potential of monitoring whales and shipping along the coast of British Columbia using remote acoustics alone. Acoustic monitoring has the potential of being an extremely cost-effective means of studying whale–ship interactions in remote locations where visual surveys are not a safe or feasible option. But in order to know just how effective acoustic monitoring can be – and what exactly it is missing – we have to have examples of studies in which visual and acoustic research are carried out side by side.

To explore the potential of what our combined visual and acoustic research platform can achieve, we looked at 78 days of field effort from summer 2018. Within that time frame we completed 1,132 visual scans (384 hours of formal surveying) while the hydrophones were recording 24/7. From those recordings we extracted all humpback whale calls using our automated call detector and classifier. We could then ask whether visual or acoustic surveys were better at detecting whales engaged in certain behaviours. For example, we found that our hydrophones were much better (by 15x) at detecting bubble-net feeding groups of humpback whales, but that visual observers were better at detecting humpbacks engaged in other behaviours, particularly social behaviours when their calls are quieter and more difficult to isolate with a computer algorithm.

Most exciting, however, was the strong correlation we found between acoustic detections and visual sightings. The basic fact that we heard more whales while also seeing more whales shows great promise that visual surveys may enable us to calibrate acoustic datasets in order to monitor whale population trends using acoustics alone. This is an important and encouraging first step in the long process of refining our analyses and statistical models.

VISUAL OBSERVATIONS

The study area is surveyed from the shore-based Fin Island Research Station located at the south-western corner of Fin Island (N53° 14.214", W129° 22.325"). The station is still under construction and since we are completely off the grid, with no store within a 160-kilometre (100-mile) boat ride, whenever we were travelling by boat from one hydrophone station to another we would stop at a beach to look for driftwood that we could use to build a new viewing deck. We also hired a barge to bring in the remaining material we needed to complete the deck. During the 2018 season between one and three observers lived at the station full-time and recorded observations from sunrise to sunset.

Several methods were used for observation: scanning visually at regular intervals; following marine mammals opportunistically; tracking ships; and monitoring mammals informally using photo identification when possible. Formal visual scans were conducted hourly from 06h00 to 21h00 Pacific Standard Time (PST). Each scan was conducted for 20 minutes, during which time the position, group size and behaviour of all detected marine mammals were recorded, as well as the presence of vessels. Observers conducted scans with tripod-mounted 25x Big Eyes.

Observations were made from Fin Island between 10 May and 10 October. In this period we conducted 1,279 systematic 20-minute scans of the study area (436.1 hours), during which we logged 3,474 sightings of marine mammals and 2,089 sightings of vessel traffic. The sightings of marine mammals enabled us to map their location and characterise their group size and behaviour (see figure 10).

Photo by Jenn Dickie

Photos by Janie Wray

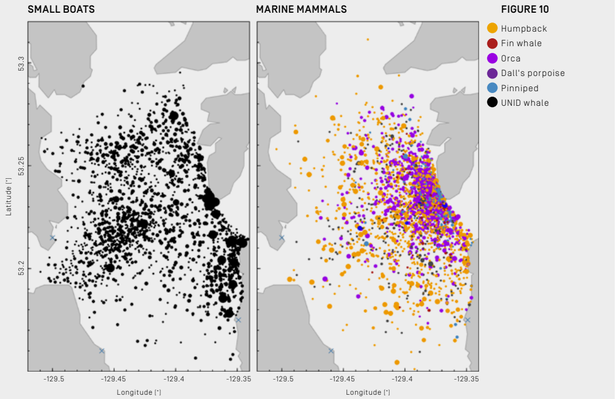


Photo by Hermann Meuter

HUMPBACK WHALE (2,574 SIGHTINGS)

Humpback whales are found in all oceans and follow the same migration pattern from cold-water summer feeding grounds to warmer waters in winter for calving. Every fall we know that, one by one, the humpback whales that have filled our days will slowly begin their annual migration south. The first humpbacks to leave are mothers with calves, then sub-adults and then adult males. The last to leave the feeding grounds are the pregnant females, who will need every ounce of nutrition to sustain them during the rigours of the long migration, giving birth and then nursing their calves. There is no food available for these mothers in the calving grounds and she will not forage again until she returns in the following season with her new calf. Some of the humpback whales travel to a group of islands east of Japan, while others make the long voyage to the Baja and Hawaii. The migration takes between four and eight weeks to complete and the estimated distance each way is 4,830 kilometres (3,000 miles) – one of the longest known migrations of any mammal. However, a change in this pattern has been observed and we now have reports of humpbacks that do not migrate at all, but remain resident in this area for the entire year.

Humpback whales demonstrate strong site fidelity to northern British Columbia and return regularly to the province's entire coast. They were hunted commercially from the late 1800s until 1965 and during that period an estimated 28,000, at least, were caught in the North Pacific. Based on the low observed density of humpback whales in British Columbia, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) proposed that the population be listed as Threatened. A recent reassessment, in view of an increase in the population, has resulted in the species being downlisted to Special Concern, a decision that is being challenged by a number of researchers.

These whales are extremely sociable and are frequently seen in the company of other humpbacks, although there are a few exceptional individuals that seem to have chosen a more solitary lifestyle. Our curiosity about these social bonds initiated a 10-year research project into the whales' diverse relationships and so far we have identified that they evolve through a series of events that lead to certain whales choosing companions based on gender, the time of year,

Photo by Jenh Dickie

Photo by Jenn Dickie

Photo by Janie Wray

'Together with the Gitga'at First Nation and the NCCS, and with funding from the Save Our Seas Foundation, Cetacea Lab conducts crucial research along one of the most remote sections of the British Columbia coast'

behaviour and location. These social connections do not necessarily relate to a family bond. In the years ahead we hope to obtain a better understanding of the complicated and intimate relationships within the North Pacific population of humpback whales.

In early fall we witnessed a change from cooperative feeding to more robust types of behaviour, such as breaching and tail or pectoral slaps. Males will form posturing groups and compete to escort a female. During these competitions males may become quite aggressive towards each other. On many occasions we have seen a group all dive at once, then moments later appear back at the surface, tonal blows echoing through the channels and fresh, bloody scratches along their bodies, the result of underwater battles. On the surface, the whales breach and slap their tails and pectoral fins very close to one other. It is during this time that we record humpback whale song.

ORCA (106 SIGHTINGS)

Resident orcas exhibit extremely strong and complex family bonds. Unique to this species is the bond between a son and his mother, a bond that is broken only by death. A daughter stays with her mother until she is ready to become the matriarch of her own family, when she begins to break away for periods of time. As a result of these connections, every family has a distinct dialect that enables us to identify it using our network of hydrophones. Observations indicate that the primary food source for resident orcas is Chinook salmon. During a feeding event, older females share a catch with calves and juveniles, whereas males were often observed feeding at a distance. They would, however, also share their catch with their mothers.

The population of northern resident orcas is divided into three clans, each with its own set of call types that differs from the set of call types belonging to other clans; in other words, their own language. Within each clan, a number of pods will share certain call types and different dialects when using these calls.

Transient orcas are often referred to as the 'wolves of the seas' as they hunt marine mammals, including other whales – behaviour that led to their

Photo by Janie Wray

Photos by Janie Wray

FIGURE 11: MARINE MAMMAL SIGHTINGS 2018

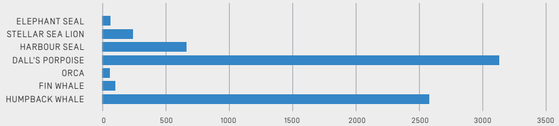
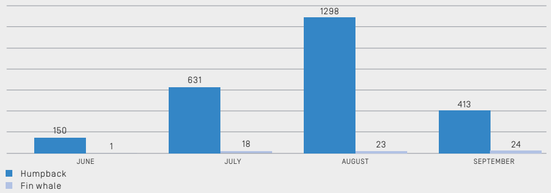


FIGURE 12: HUMPBACK AND FIN WHALE SIGHTINGS FROM FIN ISLAND



other name, killer whale. They travel mostly in silence to prevent their prey from realising they are in the area, which minimises the opportunity for a specific dialect to be passed on to family members. The family structure of transient orcas is much more fluid, with groups breaking apart and reforming into different groups for a time. The one consistent relationship is that between a mother and her oldest son – a bond that, like the residents', lasts a lifetime.

FIN WHALE (78 SIGHTINGS)

Next to the blue whale, the fin whale is the second largest mammal on the planet. It feeds on euphausiids (krill or shrimp-like crustaceans), herring, capelin and other shoaling fish, squid and copepods, which are small crustaceans. Like other baleen whales, it strains its food from the water through baleen plates.

Historically, fin whales were heavily hunted in British Columbia, with more than 7,600 taken by coastal whaling stations between 1905 and 1967 and thousands more caught by pelagic whalers up to the 1970s. Along Canada's west coast they are typically found in exposed waters off western Vancouver Island, Queen Charlotte Sound, Hecate Strait and Dixon Entrance, with sightings being documented in summer and winter and acoustic detections at least from February until August. The population currently in the north-eastern Pacific is thought to be less than 50% of its size 60 to 90 years ago and has been designated Threatened by both COSEWIC and the Species At Risk Act.

Fin whales were first documented by the NCCS in 2006 and since then sightings have been more frequent, indicating that the whales are repopulating this area since whaling stopped. Through the Pacific North Coast Integrated Management Area process, which involves interviews with experts, documented observations and historical whaling records, the coast of British Columbia has been highlighted as an important area for fin whales and it probably represents a unique near-shore habitat for them. Their return raises questions about the current and past importance of fjords such as those found along this coast to species that have historically been considered offshore. As fin whale populations continue to recover from 20th-century whaling, we will discover how and to what

FIGURE 12: HUMPBACK WHALES IDENTIFIED 2004-2018

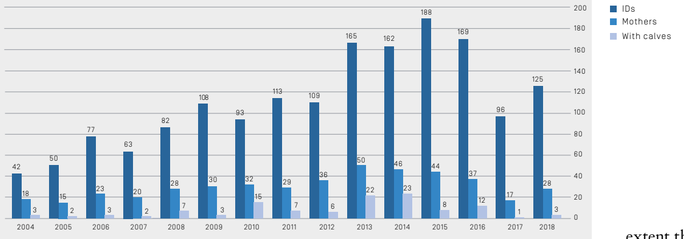


Photo by Hermann Meuter

extent they come to rely on this habitat and determine the potential importance of these whales to the ecological function of the north coast.

In 2018 our network of hydrophones detected fin whale vocalisations for the first time. The whales' pulse calls have a low frequency; at between 16 and 50 hertz they are the lowest frequency sounds made by any animal on our planet and far below the hearing ability of humans. The pulses are emitted in different combinations that can last for up to 15 minutes, each pulse lasting for one or two seconds. Thanks to the quality of the IC Listen hydrophones being used for the new Squally Channel hydrophone network, the NCCS can now detect these calls and will finally be able to document the acoustic activity and seasonal use of fin whale vocalisations within our research area. To date it has been recognised that most call displays by fin whales are seasonal and they may be directly related to mating. We are keen to investigate this theory for ourselves. If this is the case, the increase in ambient noise in our oceans may impact the ability of males and females to communicate over long distances. The call of a fin whale can travel hundreds of miles across the ocean. (See figures 11 and 12.)

In the average day of field work, there were 16 sightings of small vessels (maximum 68) and 58 detections of marine mammal individuals (max. 272), of which 21.4 were sightings of humpbacks (max. 96), 0.6 were sightings of fin whales (max. 10), 0.1 were sightings of killer whales (max. 5), and 26 were sightings of Dall's porpoises (max. 160).

A cursory comparison to 2017 data indicates that detection rates in 2018 were much lower for humpback and fin whales, but much higher for Dall's porpoises (see table below).

DETECTIONS PER HOUR OF SCANNING

SPECIES	2017	2018
HUMPBACK	9.00	5.90
FIN	1.24	0.18
DALL'S PORNOISE	1.21	7.16

Photo by Janie Wray

In view of the decline in the number of humpback whales sighted during the 2018 season, the NCCS has been in conversation with local colleagues within British Columbia and in Alaska and Hawaii. Colleagues in Alaska reported a serious decline in humpback whale sightings, whereas colleagues in southern British Columbia experienced an increase. These results have inspired us to workshop these changes in habitat use, starting in spring 2019.

We have particularly noted a decline in the number of humpback mothers with calves since 2015. During the 2017 season we saw only 17 females, and only one mother with a calf. In 2018 we identified 28 females, of which only three were seen with a calf. This alarming occurrence has also been documented in Alaska and Maui. This decline is the motivation for the NCCS drone study scheduled for 2019 (see figure 13).

MARINE SURVEYS

On 3 July we accomplished our first coastal British Columbia whale survey from Hartley Bay to Alert Bay near Vancouver, travelling 600 kilometres (372 miles) by boat over a period of three days to document the coastal habitat use of orcas and humpback and fin whales. Along the way we spoke to First Nation communities and local mariners about their own whale sightings and always received the same answer: there was a definite lack of humpback whales compared to other years. Our own results were alarming. During the July survey we sighted a total of 18 humpback whales and seven northern resident orcas.

A month later, on 5 August, we repeated the route in reverse, travelling from Alert Bay to the Fin Island Station near Hartley Bay – with very different results. During the survey we documented and identified 98 individual humpback whales and four habitat hotspots. We will continue these surveys from year to year to determine whether there is a pattern with regard to location and time of year for the increased sightings in August.

We completed 23 marine surveys in the main research area throughout the Kitimat Fjord system. While our sightings were very low during the first half of the season, as was well documented by both land-based and marine surveys,

Photo by Michael Scholl

Photo by Yoann Vidoz

in September the numbers increased significantly, although only deeper into the fjord system past Hartley Bay towards Klemtu. This is a trend we have noticed in previous years and it was the topic of a paper called 'The Whale Wave'. Now, however, we are seeing that the number of sightings deep in the fjords is on the increase whereas the number of whales seen in Squally Channel towards Caamano Sound is decreasing.

To date we have identified 125 resident humpback whales and seen another 30 that still need to be identified and catalogued. We identified 28 female humpbacks, but only three with calves, and have documented 22 new arrivals (still pending), which will be added to our 2019 catalogue.

During the study period we opportunistically collected prey samples while observing humpback whales feeding to determine the composition of their diet. The samples indicate that the food source was primarily herring and krill. All scale samples taken during bubble-net feeding came from herring. Humpback whales within our research region are commonly observed bubble-net feeding on herring in groups of between one and 14 individuals. During these events we identify each member of the feeding group as well the GPS location of each feed. This information has enabled us to understand the importance of location with regard to bubble-net feeding, as the whales show a definite preference for the slopes of deep fjord systems. They often follow the shoreline and have specific 'hotspots' where they regularly feed. From our identification work we now know that the same nine individual humpbacks have been practising this feeding behaviour together for at least the past decade. We have observed other humpbacks try to join the group and some have been accepted, others not. We are not sure what the prerequisite is to join, but it is obvious when a humpback fails the test as the entire group reacts with tonal blows and robust behaviour until the rejected whale leaves the group. We find it particularly interesting that the bubble-net feeding technique appears to be a behaviour that is learnt and passed on.

We are now seeing that individuals are separating from the main group to develop their own bubble-net feeding groups and are using a distinct call type that is heard only during this foraging display. We can analyse how this call type is changing over time from group to group, demonstrating a specific dialect in particular whales and groups. All these calls are recorded with a hydrophone and portable recorder and are added to a database with the identification of each individual whale. With this library of call types and individual humpback identifications, the NCCS will eventually have an acoustic fingerprint for each whale that participates in bubble-net feeding. The number of individuals observed bubble-net feeding has increased from nine in 2006 to 62 in 2018. Humpback whales that do not participate in bubble-net feeding use other techniques such as lunge feeding, tail flicking or feeding at depth.

The number of fin whales identified this season was extremely low at only 16. The total has yet to be finalised, but there was definitely a decrease, for unknown reasons.

We saw and photographed 35 northern resident orcas. Although this population of 309 orcas remains stable, the southern resident population is at an all-time low of 74 and has been listed as Endangered. During the summer of 2018 a female known as J35 carried her deceased calf for 17 days on her back, above the surface. This brought worldwide attention to the dire situation of this population due to a lack of Chinook salmon and the stress of marine traffic that surrounds the whales daily. It also demonstrated the strength of the resident orcas' family bond.

We also saw and photographed 36 transient orcas during the 2018 season, which indicates that this population is doing very well along the entire coast of British Columbia. During our marine survey on 21 August we photographed T069A2, the juvenile we rescued after it had stranded on a large rock while in pursuit of a seal in July 2015. It was a great relief to see that this whale had survived the ordeal and appeared extremely healthy, displaying robust behaviour.

COLLABORATIONS

The NCCS has been working with the Marine Education and Research Society to complete a single catalogue of humpback whales throughout British Columbia. This has involved the cooperation of First Nation communities along the coast, as well as members of the whale watching community, who have shared

FIGURE 14: The dotted square box shows the location of the NCCS hydrophone network and the Fin Island Research Station. The proposed tanker route that has recently been approved runs directly through it.

with us their identification photographs of humpbacks. With more than 2,000 whales and six catalogues to compare, this has become a Herculean task. Our goal is to have the first draft of the catalogue completed by the end of February 2019. The conclusion of this task is made even more urgent since the north coast's humpback population is either declining or some of its members are being displaced to other locations along the coast of British Columbia.

We spent two weeks at OrcaLab, another land-based whale research station along the coast of British Columbia that also uses hydrophone technology. From this location we were able to document a large number of northern resident orcas that are often seen near our own research area close to Hartley Bay. The purpose of this stay was to build a long-term collaboration between OrcaLab and the NCCS so that we can get a better understanding of the travel routes and habitat use of resident orcas between northern and southern British Columbia. During the 2019 season we will develop this partnership by combining land-based survey methods, following the same protocol and effort. This will enable our research teams to compare how the northern and southern resident orcas behave under different habitat stresses, especially with regard to marine vessel traffic and ambient noise.

The NCCS will participate in a workshop with other NGOs operating hydrophone networks in British Columbia to establish a platform we can all work from to ensure that the same methods are being used to collect data and to build an open-access database for academic purposes. We are also working with the University of Victoria and OrcaLab to develop a platform for university students working on their Masters, PhD or post-doc that will give them access to our database and to two research stations to empower their efforts as the next generation of marine conservationists.

THE CONSERVATION IMPACT, REGIONAL SIGNIFICANCE AND SCIENTIFIC IMPORTANCE OF OUR WORK

On 2 October 2018 the government of British Columbia announced that 'The LNG Canada project will see a pipeline carrying natural gas from Dawson Creek in north-eastern BC to a new processing plant on the coast in Kitimat. There, the gas will be liquefied for overseas export.' The route used by tankers to carry the natural gas to the Pacific Ocean and thence overseas would be directly through the research area of the NCCS and in line of sight of the new Fin Island Research Station (see figure 14).

The work of the NCCS has become extremely important for the protection of the whales that depend on these waterways daily for both foraging and social interaction. The baseline data collected by the NCCS, both visual and acoustic, will be used for mitigation purposes relating to marine traffic and the potential effect it will have on these whale populations. Our 2019 drone project will be of great importance with regard to the health of whale species within our research area. All information will be shared with the First Nation and research communities of British Columbia through our collaborative efforts to protect this important, nutrient-rich habitat for whales.

Photo by Janie Wray

Photos by Janie Wray

PRESENTATIONS & PUBLICATIONS

From the deck of the Fin Island Research Station we presented to 16 ecotourism groups that were travelling through the Great Bear Region. The presentation focused on the culture of whales and what we can do to protect them.

Photo by Jenn Dickie

PRESENTATIONS

• IEEE Oceans Conference | Kobe (Japan), 2018
Title: Automated monitoring and analysis of marine mammal vocalisations in coastal habitats.

• YOUMARES | Conference for young marine researchers, Germany, September 2018
Title: Ecological niche modelling of humpback mother–calf pairs on northern British Columbia feeding ground.

• Acoustical Society of America | Victoria BC, November 2018
Title 1: Acoustic versus visual monitoring of cetaceans in coastal habitats.
Title 2: Localising bio-acoustic signals with long-baseline hydrophone arrays.

• 26th Annual Marine Mammal Symposium | University of British Columbia, 24 November 2018
Title: Localising whale calls with hydrophone arrays in northern British Columbia.

PEER-REVIEWED PUBLICATIONS 2018/2019

• Hendricks B, Keen EM, Wray JL, Alidina HM, McWhinnie L, Picard CR. 2018. Automated monitoring and analysis of marine mammal vocalisations in coastal habitats. *IEEE Oceans*.

• Hendricks B, Wray J, Keen EM, Alidina H, Gulliver TA, Picard CR. Submitted. Real-time localisation of whales in coastal fjords. *Journal of the Acoustical Society of America*.

• Keen EM, Hendricks B, Wray JL, Alidina HM, McWhinnie L, Picard CR. 2018. Integrating passive acoustic and visual monitoring of cetaceans in coastal habitats. *Proceedings of Meetings on Acoustics* 35: *010002*.

• Keen EM, Wray J, Pilkington J, Thompson KL, Picard CR. 2018. Distinct habitat use strategies of sympatric rorqual whales within a fjord system. *Marine Environmental Research* 140: 180–189.

• Wray J, Keen EM. In prep. Calving rate decline in humpback whales (*Megaptera novaeangliae*) in northern British Columbia. *Marine Mammal Science*.

RESEARCH PROJECTS 2019

The NCCS welcomes Eadin O'Mahony, who will be working with us on her Masters/PhD through the University of St Andrews.

DRONE PROJECT

We propose to gather blow (exhale) samples of humpback whales, using cutting-edge drone technology to collect valuable DNA without inducing stress to the animals. The DNA will be analysed over the next two years to unveil mysteries such as patterns of relatedness across various groups of humpbacks that are observed year after year feeding together in northern British Columbia's deep fjords. This area is thought to be visited by two differing groups of humpback whales. The first, appearing in May, feeds predominantly by bubble-net feeding, while the second arrives much later in the year and uses various other foraging techniques. The social structure of these segregated feeding groups is completely unknown and we would like to find out firstly whether the feeding groups are composed of family members closely related to each other, and secondly whether the use of the habitat (for example, the feeding technique used) depends on levels of relatedness between individuals within groups and between different groups. We will also use these samples to determine whether a female humpback is pregnant and will look for stress hormones and microbiomes that help fight disease and digest food – all baseline data that are essential when investigating population changes.

The use of drones to collect what is essentially whale snot (hence the coined term 'SnotBot') and the subsequent sequencing of the DNA found in it is a new method that is proving to be an extremely successful, cost-effective and non-stressful alternative to the more common method of taking biopsy samples. Collectively we have the expertise to collect scientific material for peer-reviewed publication and generate outreach through this project, and thus make an impact on the protection of these charismatic whales. In addition to answering important scientific questions, we intend to disseminate the results to several stakeholders. We will host interactive workshops with the local First Nation communities of Gitga'at, Kitasoo and Heiltsuk and plan to communicate the results of this study via short film clips, photography and articles. Film footage captured from a drone

Photo by Janie Wray

that shows humpback whales leaping straight into the air will make a powerful impact, catching the attention of a broad and global audience.

With drone technology we will also produce images that will enable us to determine the size and growth rate of individual humpback whales. This will add a completely different dimension to our research and our ability to understand cetacean biology and health.

HYDROPHONE PROJECT

The project's postdoctoral researchers Ben Hendricks and Eric Keen are developing tools to track the movements of vessels and whales and simultaneously analyse the whales' behavioural responses to the presence of marine vessels. They are also developing visualisation tools that show shipping and whales in real time and are working on means to analyse interactions with shipping and compute strike risk metrics. The knowledge generated by their research will contribute to the management of the area and to developing a shipping plan that reduces collisions between marine vessels and whales. The tools and findings from this work will empower the Gitga'at to effectively manage shipping traffic impacts in their territory.

SHORT-TERM OUTCOMES (2019–2021)

- Primary research to acoustically detect, locate and track whales from hydrophones is completed and used with visual surveys and behavioural response studies to understand the local response of whales to marine vessels and increased traffic.
- Risks to whales from increased shipping are quantified and preliminary recommendations to reduce and mitigate risks to whales is published by the NCCS in partnership with WWF and the Gitga'at First Nation for further discussion with the federal government and industry.
- Industry and government are engaged in a process of brokering evidence-based solutions that will contribute to the development of locally developed shipping measures and marine area protections in Gitga'at Territory.

MEDIUM-TERM OUTCOMES (2022–2025)

- Underwater noise impacts on whales from marine vessel traffic in Gitga'at Territory are effectively managed; the management plan is recognised by government and development proponents so that existing and increased marine vessel traffic does not hinder the recovery of whales (i.e., does not impair habitats used by whales for feeding, resting and socialisation).
- Co-managed protected areas and the use of other spatial protection tools in the Territory demonstrate how shipping can be effectively managed within protected areas and other ecologically sensitive marine ecosystems.
- Advocacy and the generation of knowledge about the impacts of vessel noise will catalyse strong processes to create protective measures (including noise guidelines, environmental quality objectives and industry best practices), supported by indigenous communities, government and industry.

LONG-TERM OUTCOMES (2025–2029)

- What is learnt from this project is scaled upward and outward.
- Risks from shipping activities to marine biodiversity are recognised, understood and mitigated at regional and national scales.
- Advocacy that is founded on an evidence-based approach connects indigenous communities and conservation NGOs to government decision-makers; Transport Canada and Fisheries and Oceans Canada are engaged in ocean conservation initiatives to mitigate the impacts of shipping; environmental policies and guidelines and the election and budget cycles reflect those efforts.
- Canada develops and implements new evidence-based regulations for marine environmental quality pursuant to its Oceans Act; and improves the implementation of the Species At Risk Act to protect marine mammals effectively from shipping impacts, based on new data and mitigation strategies.

OTHER INITIATIVES

The NCCS will continue to work with Fisheries and Oceans Canada on the Entanglement Scar Project, taking the lead to ensure that as many cetaceans as possible are photographed during the 2019 season. Signs of scar damage seen

Photo by Janie Wray

in these photographs will enable us to determine if a whale has been entangled in fishing gear. We believe that these results will influence measures to be taken to ensure that whales do not need to suffer the prolonged death of entanglement. With such a drastic increase in the abundance of humpback whales along the coast of British Columbia, entanglement has increased in parallel. Because the ability to go for months without food has evolved in humpbacks, for these majestic mammals entanglement means a drawn-out period of suffering.

Our internship programme will continue and our helpers will add to the collection of cetacean sightings data from our land-based platforms. With the assistance of hydrophone, drone and identification methods already in place, we will increase efforts to identify bubble-net feeding call types and understand the social dynamic of this display.

The NCCS will continue to collect data from its land-based stations, both visually and acoustically, and from its local and British Columbia-wide marine surveys, and will use these data to advocate for the creation and management of high-quality marine protected areas that include acoustic protection.

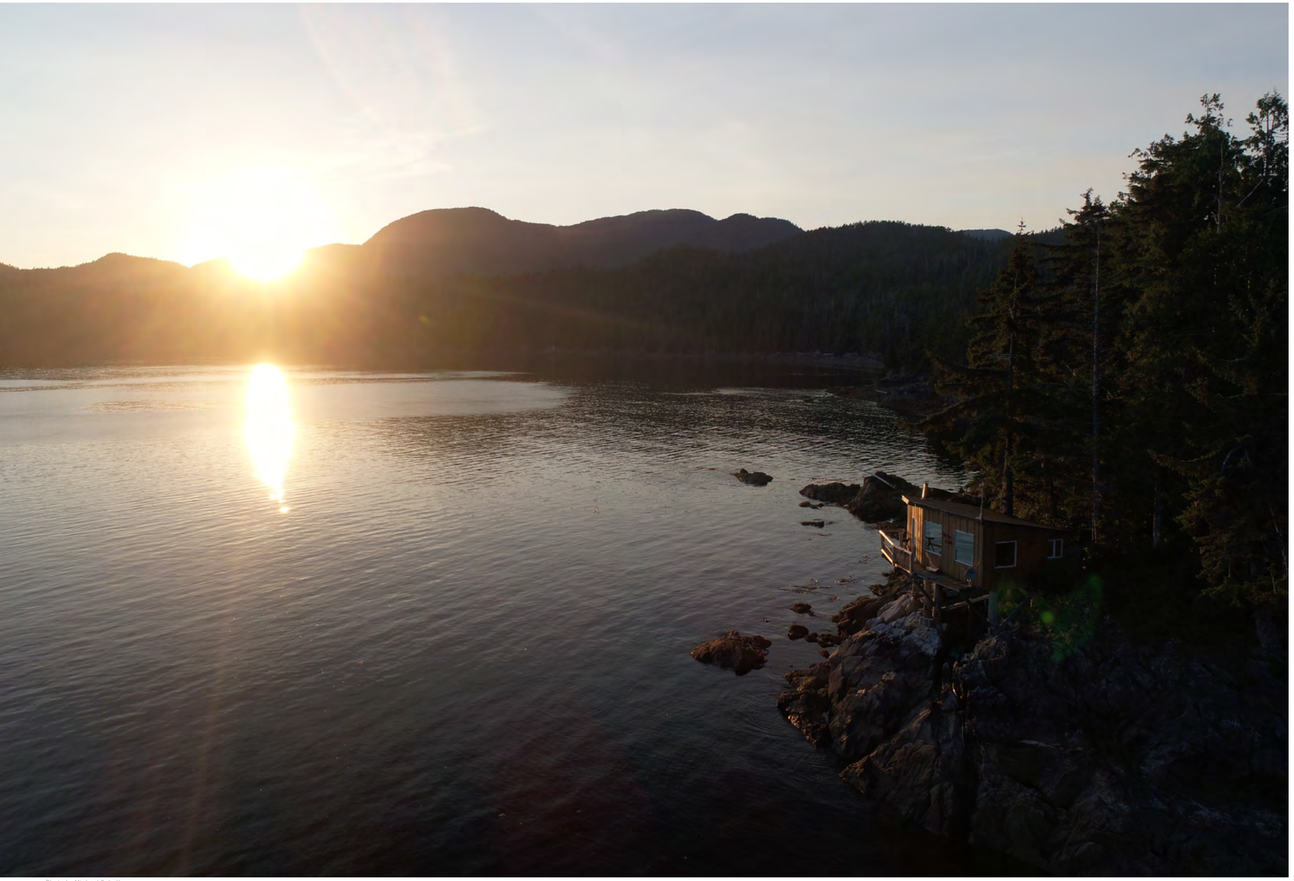


Photo by Michael Scholl

FORWHALES.ORG

CETACEA LAB 2018 | HERMANN MEUTER

Together with the Gitga'at First Nation and the NCCS, and with funding from the Save Our Seas Foundation, Cetacea Lab conducts crucial research along one of the most remote sections of the British Columbia coast. Its historic dataset is considerable, encompassing 16 years of land-based and boat-based sightings data that are extremely valuable in that they enable the Gitga'at First Nation to make informed decisions about how they want their territory to be managed in the future. The non-profit work of Cetacea Lab would be impossible without the generous support of the Save Our Seas Foundation. We value our partnership and are looking forward to continuing to work together to help make Gitga'at territory a safe and prosperous area for whales.

WHALE POINT

Hermann Meuter

The volunteer season at Cetacea Lab started on 8 May, when young adults from Canada, Italy, Holland, Germany, France, the UK and the USA arrived. Until 30 September, 17 volunteers helped Cetacea Lab to function on a daily basis. Due to my wedding to Christa in mid-July, the season was divided into two parts, the first ending on14 July and the second starting on 1 August. The Wall Islets out-camp was manned from early June until mid-July and then again from early August to the end of August.

Funding through Canada Summer Jobs and the Gitga'at Field Technician initiative enabled us to employ two young Gitga'at members throughout the summer. Looking to the future of Cetacea Lab, trying to spark serious interest in marine biology among young Gitga'at First Nation adults is an extremely important part of our work.

Davide Lelong, a young Italian, spent the summer months at Cetacea Lab using new and historic data to complete his MSc degree. His focus was the seasonal change in humpback whale feeding calls within our research area.

Since December 2018 Cetacea Lab has been working under the guidance of the Pacific Whale Society (PWS). This newly formed non-profit organisation comprises members of the Gitga'at First Nation and its work will reflect the values and vision of the people in whose territory we conduct our research. Among their goals is the long-term survival of cetaceans within the waters of the Gitga'at people, a goal that Cetacea Lab will help them to realise. A new research vessel, a 6.7-metre (22-foot) aluminium centre-console boat that is perfect for whale ID work and extremely capable in challenging sea conditions, has been made available to the PWS.

OBSERVATIONS

Climate change is becoming more and more obvious in the Great Bear Rainforest. The most immediate effects are rising seawater temperatures and reduced rainfall throughout the summer, and both will have lasting negative impacts that are poorly understood at this time. Reduced rainfall for as long as three to four weeks results in significantly lower creek levels, which increases the

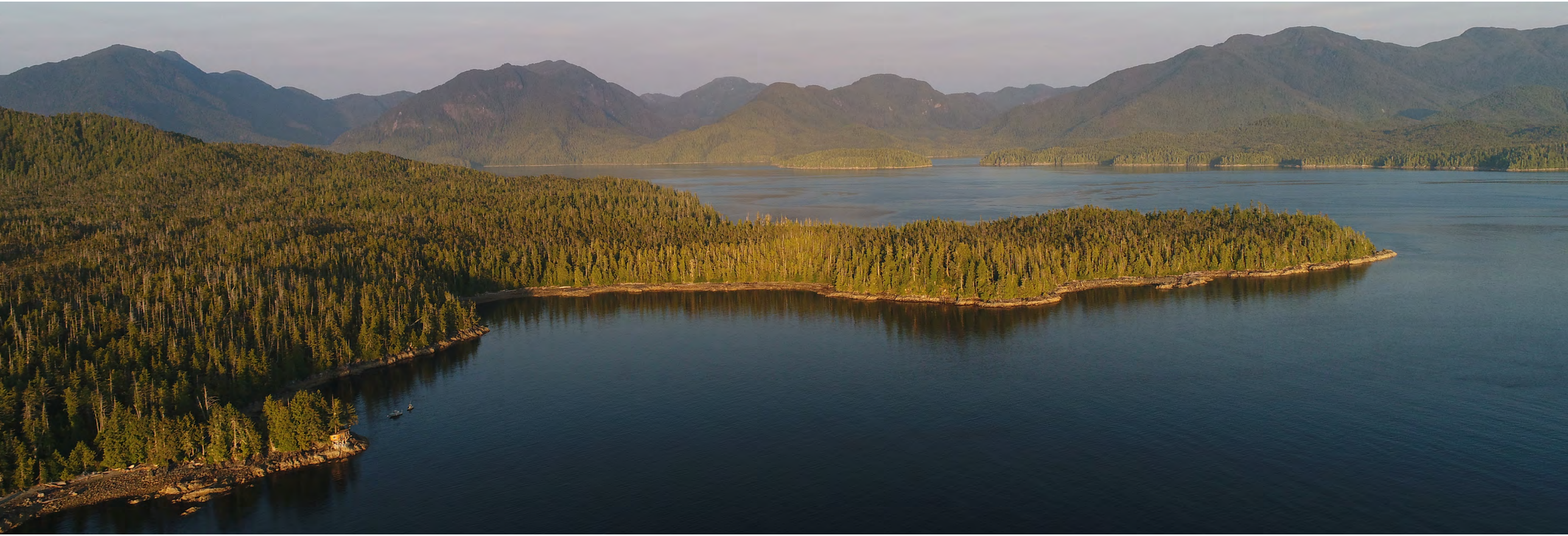


Photo by Michael Scholl

stress on migrating salmon in the river and results in decreased spawning success. Since salmon is the keystone species on this coast, major negative impacts on its populations will affect all wildlife that depend on them. There were so few salmon along the entire coast in 2018 that for the first summer in modern history no commercial salmon fishing took place within Gitga'at territory. This is a major concern to coastal First Nations, as they depend on salmon as a staple food for their nutritional needs.

The lack of rainfall has an impact on Cetacea Lab's ability to function in that we depend on water for drinking and electricity. To compensate for drier summers we need to increase water storage facilities and our use of other renewable energy sources, such as wind and solar.

The orca Springer (A73) spent almost two weeks in the vicinity of Gil Island with her two calves in late spring/early summer. No other matriline has spent so much time so close to the lab before and we hope that we will witness this again in 2019. Springer spent most of her time with A56, who is her cousin and usually travels with the A35s.

In the 2018 season we observed an overall increase in the number of northern resident orcas in Whale Channel and Campania Sound. Given the low abundance of all salmon species, we were surprised to record this increase of 25% in resident orca sightings from land-based observations at Cetacea Lab: 165 orcas were sighted in 2018 compared to 132 in 2017. Perhaps it was a good sign for the area, as the orcas were observed foraging for much of the time they spent in Whale Channel. Groups of the A clan continue to be those most often identified, both visually and acoustically.

Large groups of up to 15 humpback whales were seen feeding on schooling fish in upper Campania Sound during daylight hours and for days on end in August and September. The waters surrounding Ashdown Island seem to be becoming an increasingly important feeding area for resident humpbacks.

A lower than usual number of new mother/calf pairs for the resident humpback whale population is being recorded annually. This needs to be monitored in the long term. We have not been able to establish a reason: the

Photos by Hermann Meuter

FIGURE 15: WALL ISLETS SIGHTINGS 2018

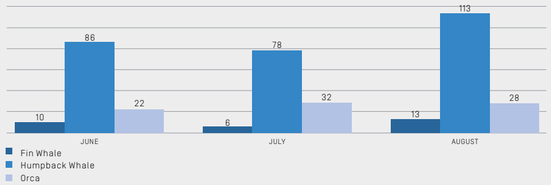
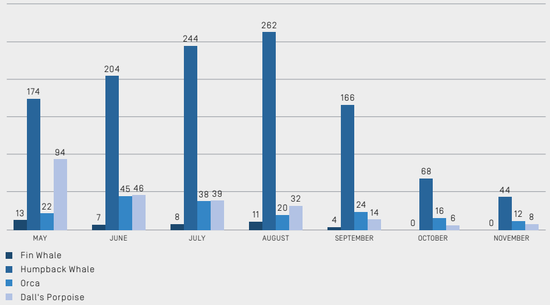


FIGURE 16: CETACEA LAB SIGHTINGS 2018



decrease may be related to food availability or to the size of the population in the habitat, or perhaps the survival rate in the calving areas was lower than usual.

There have been more recordings of fin whale pulses on the Cetacea Lab hydrophone. Fin whale pulses are very low frequency, just within a human's hearing range, and very powerful. Humpback and fin whales have been sharing this habitat peacefully throughout the summer months since 2006 and, for the first time last summer, we heard both species vocalise together in lower Whale Channel. It sounded as though they were communicating with each other, but we have no proof of that (see figures 15 and 16).

2019–2020

The 2019 season started promisingly with the sighting of the A34s, a well-known matriline of northern resident orcas, in Douglas Channel in early January. They looked very energetic and healthy and all members of the family were accounted for.

Two new hydrophone stations will be installed in the coming season: at Jenkinson Point in Verney Passage, an important habitat for humpback whales in fall; and on the west side of Ashdown Island to cover the underwater world of Campania Sound and lower Squally Channel.

The volunteer programme at Cetacea Lab will continue and young people from the Gitga'at First Nation will be employed by the PWS, thanks to Canada Summer Jobs and the Field Technician initiative. Davide Lelong will begin his PhD project.

We will continue to share whale sightings and data with the Gitga'at First Nation, Fisheries and Oceans Canada, the NCCS and others. We will also attend meetings to ensure that we have a strong voice in the creation of marine protected areas in Gitga'at territory.

We would like to thank the Save Our Seas Foundation for its generous support for the North Coast Cetacean Society in protecting this coast for whales. We are extremely grateful for this opportunity to work with your organisation, which enables us to open our doors to many students from around the world as well provide essential data that enable First Nation communities along the entire coast to play a vital role in the conservation of its whales.

Thank you from the BC Whales team!

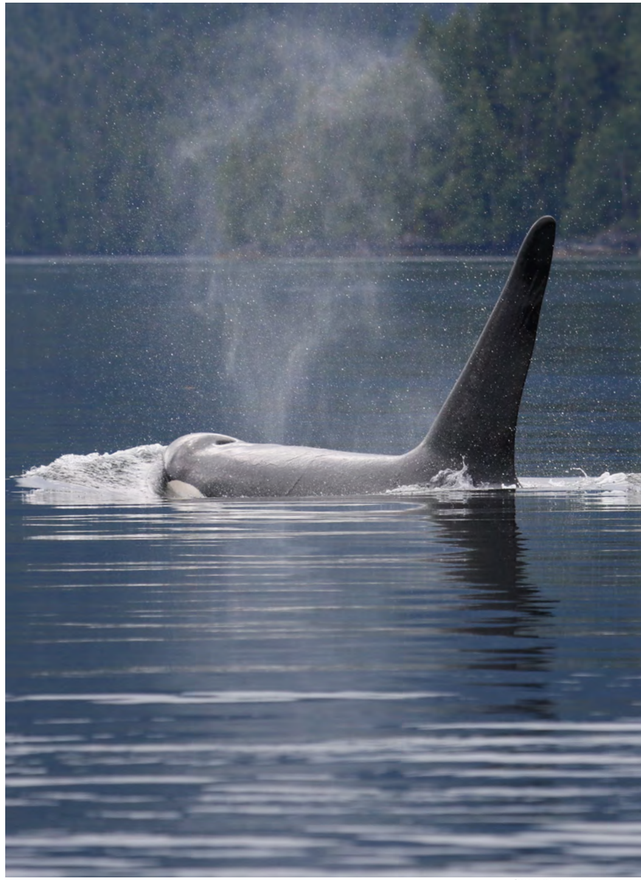


Photo by Hermann Meuter

Photo by Michael Scholl

Photo by Michael Scholl

Photo by Hermann Meuter

Photos by Hermann Meuter

Photo by Janie Wray

THE ACOUSTIC TRACKING ARRAY PLATFORM

PAUL COWLEY

Photo by Paul Cowley

Paul Cowley

2018 PROGRESS AND HIGHLIGHTS

BACKGROUND

South Africa's Acoustic Tracking Array Platform (ATAP), managed by the South African Institute for Aquatic Biodiversity (SAIAB), is a large-scale acoustic receiver array that was established to facilitate the large-scale and long-term monitoring of acoustically tagged marine animals. The SAIAB and its collaborating partners maintain the nationwide network of receivers and the SAIAB manages the data downloaded from the network, passing on to researchers the information about their tagged animals. In this way, the ATAP provides a sustainable, cost-effective means for local researchers to gather movement data on their tagged animals. It also fosters broader collaboration at both national and international levels.

The ATAP array spans some 2,200 kilometres (1,370 miles) of the southern African coastline, with 16 monitoring sites situated between False Bay (Cape Town) and Ponta do Ouro on the Mozambique border. In addition, 21 estuaries throughout the region are equipped with moored receivers. In its current format the array design enables researchers to address a number of key questions pertaining to animal movement. These include estuarine–marine connectivity, inter-estuary connectivity, bay-scale movements, movements in relation to marine protected area (MPA) boundaries, large-scale annual migrations, trans-boundary movements and a host of ecological aspects, such as spawning aggregation dynamics and predator–prey interactions. Since its inception in 2011, the ATAP has witnessed steady growth in terms of the number of species and individuals tagged. To date approximately 1,000 individuals from more than 35 species have been tagged, with considerable focus on estuarine-dependent fishery species; large sharks such as white, bull and broadnose sevengill sharks; and, more recently, batoids (guitarfish and stingrays). Many of the deployed tags on the sharks and rays have a battery life of up to 10 years, which in time will yield unprecedented insights into the habits of these animals that can be used for improved management and conservation.

INFRASTRUCTURE

The ATAP is an infrastructure platform consisting of moored acoustic receivers at focal monitoring sites around the southern African coastline. Since it represents a long-term monitoring programme, a level of equipment refurbishment must be maintained in the event of equipment losses and/or failure. Over the years the SAIAB has secured telemetry hardware through a partnership with the global Ocean Tracking Network (OTN) project, capital equipment grants from the National Research Foundation and funds from smaller independent research projects. More recently, it has also acquired funding from the Department of Science and Technology (DST)-funded Shallow Marine and Coastal Research Infrastructure initiative, which was established to develop an array of instruments and physical research platforms around the coast of South Africa that would collect reliable long-term data for scientific research. During 2018 this initiative forged a strong collaboration with the South African Environmental Observation Network (SAEON) and collectively the SAIAB and SAEON secured 34 new Vemco VR2-AR acoustic receiver/release units and an additional nine Vemco VR2W acoustic receivers valued at approximately $260,000.

As an equipment-rich platform, the ATAP can count on its sustainability being safe for the next two to three years. In addition, it is now also able to entertain short-term loans to researchers to increase the success of their localised projects. Several equipment loans were implemented during 2018.

A further development on infrastructure is that Vemco (the manufacturer of the receivers and transmitters) is prepared to offer the ATAP partners a discount on purchases over the next two years. The terms and conditions of this agreement will be finalised early in 2019.

INTERNATIONAL LINKAGES

The ATAP is a partner of the Canadian-based global OTN (*www.oceantrackingnetwork.org*) and Dr Paul Cowley (ATAP manager) is a member of the OTN's International Scientific Advisory Committee (ISAC), while Dr Taryn Murray (ATAP data scientist) is a member of its Data Management Committee.

'To date approximately 1,000 individuals from more than 35 species have been tagged, with considerable focus on estuarine-dependent fishery species; large sharks such as white, bull and broadnose sevengill sharks; and, more recently, batoids (guitarfish and stingrays)'

The ATAP is also a partner in a new initiative called the European Telemetry Network, which recently had a proposal accepted by the European Cooperation in Science and Technology that will facilitate Europe's position in the global arena of large-scale aquatic telemetry networks.

The ATAP supports a number of collaborative projects with international partnerships. These include the OCEARCH white shark project, telemetry projects in False Bay (led by Dr Alison Kock) and Mossel Bay (Dr Enrico Gennari) and a new project in northern Mozambique (Dr Nigel Hussey). In early 2019 Dr Neil Hammerschlag will start a project in the De Hoop MPA (Western Cape).

The ATAP's international standing is gaining recognition as a mature cooperative telemetry network and the platform is mentioned in several international publications. These include OTN's 'First 10 Years' review document, a review paper on telemetry in Europe (Abacasis et al. 2018), a paper on the outcomes of the OBIS-Event-Data workshop on animal tagging and tracking (Benson et al. 2018) and a paper on Australia's continental-scale acoustic tracking database (Hoenniger et al. 2018).

MPA RESEARCH

Acoustic telemetry provides a powerful tool to evaluate the benefits of MPAs and the ATAP supports projects within several MPAs in southern African waters. Firstly, two projects recently funded by the African Coelacanth Ecosystem Programme (ACEP; an initiative run by the SAIAB) are being conducted in MPAs. One involves investigating connectivity between MPAs in KwaZulu-Natal, and researchers from the Oceanographic Research Institute have already tagged 20 catface rockcods in the Pondoland and St Lucia MPAs. The second project will be conducted in the Tsitsikamma National Park on resident reef fish species. The SAIAB's research on estuarine-associated fishery species has also expanded its objectives by deploying six receivers in the De Hoop MPA to assess connectivity between it and the neighbouring Breede River estuary. In 2019, the De Hoop MPA will also be the focus of a study on juvenile

Photo by Taryn Murray

Photo by Paul Cowley

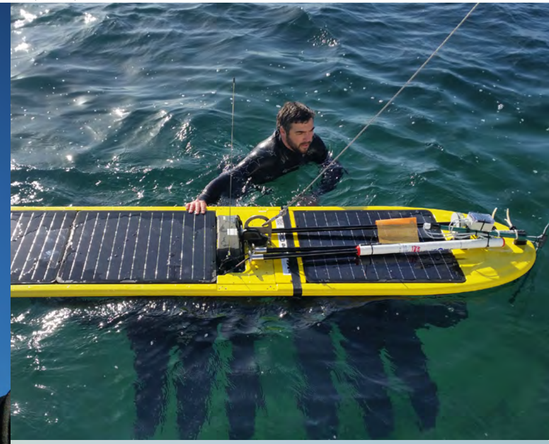


Photo by Paul Cowley

hammerhead sharks by Dr Hammerschlag, whose research team will be deploying an additional nine receivers to complement the ATAP's six receivers that were recently installed at this site.

Telemetry research at the border between South Africa and Mozambique has achieved several successes and on a recent field trip the research team tagged the 100th animal at this study site in the Partial Marine Reserve at Ponta do Ouro. The research aims to evaluate trans-boundary movements and interactions between a number of top predators (sharks and reef fish) and is currently strengthening collaboration with Dr Nigel Hussey, who has a project at Vamizi near the Mozambique/Tanzania border.

SOSF-SPONSORED TRANSMITTER ALLOCATIONS

Although funding for transmitter allocations was not received from the Save Our Seas Foundation (SOSF) in 2018, the ATAP continues to monitor the progress of the projects that previously received this support. In 2017, 20 V16 transmitters were awarded to Tamlyn Engelbrecht, a PhD candidate working on broadnose sevengill sharks. Her work is progressing well. Progress reports have also been received from the two recipients of the 2016 tag awards, who each received 10 tags. The project on giant guitarfish under the leadership of Stuart Dunlop (Oceanographic Research Institute, Durban) achieved early success and the ATAP sponsored an additional 10 transmitters for this project. Catches of giant guitarfish are seasonal (summer) and the team will finish tagging its animals (n=20) during the 2018–2019 summer. By November 2018 two additional animals had already been tagged. The other supported project was on soupfin sharks by Meaghen McCord (South African Shark Conservancy). By the end of 2017 Meaghen and her team had managed to tag only four soupfins, despite numerous attempts. Hence, they requested to rather work on spotted gully sharks and during 2018 they tagged six of this species. The ATAP recently awarded an additional five tags to this project so that it could continue to tag gully sharks.

Photos by Paul Cowley

Photo by SAIAB

Photos by Paul Cowley

CONFERENCES, WORKSHOPS, DATA REPORTS AND SCIENTIFIC PAPERS

ATAP TAGGING FIELD TRIPS

Over the past few years ATAP researchers have been attending a number of beach fishing competitions, which provide an opportunity to tag additional animals, particularly the large stingrays. During 2018 the researchers managed to tag 13 duckbill rays, four diamond rays and five blue stingrays, as well as a further two smooth-hound sharks in Algoa Bay. In addition, 40 more estuary-associated fishery species were tagged, with a focus on investigating connectivity between the Breede River mouth and the De Hoop MPA in the Western Cape. Lastly, during a field trip to Mozambique at the end of 2018, our research team tagged four blacktip sharks, one tiger shark, one bull shark, one hammerhead shark and our first spotted eagle ray. Overall, 75 new animals were tagged in 2018.

CONFERENCES AND WORKSHOPS

2018 was a quiet year for conferences compared to 2017. However, a number of significant workshops and meetings were attended that specifically profiled the ATAP. These included:

1. IODE/OBIS-Event-Data Workshop on animal tagging and tracking (Oostende, Belgium, 23–26 April 2018). Workshop Reports, 282. UNESCO, 24 pp. Paul Cowley gave a presentation on the ATAP programme.

2. Shark Biodiversity Management Plan Workshop (Cape Town, 18–19 June 2018). Paul Cowley gave a presentation titled 'Insights into the coastal movements and mortality of selected sharks and rays equipped with acoustic transmitters'.

3. Movement Ecology of Marine Organisms Workshop. A training workshop for 20 PhD and post-doc candidates from around the world (Cape Town, 10–13 September 2018). Paul Cowley gave a presentation titled 'Fish movements: Insights from acoustic telemetry'.

4. OTN Data Management Committee Meeting (Halifax, Canada, 22–23 October 2018). Matt Parkinson attended the annual meeting and presented the ATAP's annual report at the meeting.

5. The SAIAB's Scientific Advisory Committee Meeting (Grahamstown, 14 November 2018). Taryn Murray gave an overview presentation on the ATAP.

6. 1st African Bio-acoustics Community Conference (Cape Town, 2–7 Dec 2018). Paul Cowley gave a special session presentation titled 'Trials, tribulations, successes and opportunities of establishing a national network of acoustic receivers'.

DATA REPORTS

During 2018, the ATAP received 28 requests for data reports from its stakeholders/beneficiaries, a significant increase on the 11 requests made in 2017. The increasing trend for data requests provides testimony of data maturity and we anticipate that in the near future a number of publications will result from the data currently being collected. Furthermore, we predict that the ATAP will get considerable exposure next year due to the hosting of the South African Marine Science Symposium (South Africa) and the 5th International Conference on Fish Telemetry (Norway) in 2019.

SCIENTIFIC PAPERS

The publication of scientific manuscripts that expose the ATAP platform is slowly progressing. One paper making use of ATAP data was published this year:

Murray TS, Cowley PD, Bennett RH, Childs A-R. 2018. Fish on the move: connectivity of an estuary-dependent fishery species evaluated using a large-scale acoustic telemetry array. *Canadian Journal of Fisheries and Aquatic Sciences* 1–15.

EDUCATION AND OUTREACH

The ATAP engages with the public in many different ways. It once again hosted an interactive exhibition during the annual SciFest Expo in Grahamstown

'Telemetry research at the border between South Africa and Mozambique has achieved several successes and on a recent field trip the research team tagged the 100th animal at this study site in the Partial Marine Reserve at Ponta do Ouro'

in 2018, which was attended by thousands of young school learners. At our exhibit we also hosted interns from Oceans Research and the 'Keep Fin Alive' campaign to expose the vulnerability of sharks to overexploitation. In December the ATAP management team once again hosted students (mainly from historically black universities) from around South Africa at a Summer School in Port Alfred, Eastern Cape. The aim of the Summer School is to provide the students with hands-on experience in acoustic telemetry field techniques and introduce them to the research methodology. During the Summer School, students witnessed a mock acoustic tag implantation on an anaesthetised fish, were shown how to initialise and deploy acoustic receivers, actively took part in some manual tracking and were exposed to acoustic telemetry datasets and methods of data analysis.

ACKNOWLEDGEMENTS

The ATAP's acoustic telemetry hardware has been secured from the Ocean Tracking Network (OTN) project, National Research Foundation capital equipment grants and the Shallow Marine and Coastal Research Infrastructure. Running expenses and costs linked to servicing the hardware are provided by the SOSF and ACEP. Collectively, the support from these organisations has allowed for the successful establishment and running of a significant marine science platform that has gained an international reputation. We are extremely grateful to all our sponsors and will endeavour to acknowledge their contributions whenever possible.

Photo by Paul Cowley

Photo by Taryn Murray

Photo by Paul Cowley

Photos by Paul Cowley

PROJECT LEADER PROFILES – SUMMARY

AN INTRODUCTION TO OUR PROJECT LEADERS WHOSE PROJECTS ARE A CONTINUATION FROM THE PREVIOUS YEAR(S) AND WERE FUNDED DURING 2018. THEIR COMPLETE PROFILES ARE AVAILABLE IN PREVIOUS ISSUES OF OUR ANNUAL REPORT AS WELL AS ON OUR WEBSITE.

RIGERS BAKIU

BEGINNING OF SHARK CONSERVATION IN ALBANIAN TERRITORIAL WATERS BY PERFORMING FISHERIES SURVEY AND SENSITISING COMMUNITIES
ALBANIAN CENTER FOR ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT
2017–2018
ALBANIA
Research, Conservation
Shark and rays

Although Albania has an extensive coastline, very little is known about the country's elasmobranchs. Rigers will collect catch data from fishers and aquaculture workers and encourage authorities to protect these vulnerable species. He will also engage with coastal communities to sensitise them to the plight of Albania's sharks.

RAMÓN BONFIL

CONSERVATION AND ECOLOGICAL RESEARCH OF SMALLTOOTH AND LARGETOOTH SAWFISHES IN MEXICO
OCÉANOS VIVIENTES AC
2017–2018
MEXICO
Research, Conservation
Sawfish

Sawfishes are among the ocean's most endangered species and until very recently they had never been studied in Mexico. Ramón is using new technologies and a multidisciplinary approach to find and eventually protect Mexico's smalltooth and largetooth sawfishes.

Photo by Ramón Bonfil

EVAN BYRNES

HOME RANGE SCALING IN LEMON SHARKS (*NEGAPRION BREVIROSTRIS*) THROUGH ONTOGENY: TESTS OF BIOENERGETIC MECHANISMS
MURDOCH UNIVERSITY
2017–2018
BIMINI, BAHAMAS
Research
Lemon shark (*Negaprion brevirostris*)

Does body size influence how much energy a shark needs? Evan is investigating how this is linked to the home range size of lemon sharks, and how they use their habitat.

DHARMADI

SAWFISH STATUS IN INDONESIA
KEMENTERIAN KELAUTAN DAN PERIKANAN/ MINISTRY OF MARINE AFFAIRS AND FISHERIES
2017–2018
INDONESIA
RESEARCH, CONSERVATION
SAWFISH

Indonesia is home to the highest diversity of sharks and rays in the world, including endangered sawfishes. Dharmadi will run a baseline study to assess where sawfishes can be found and how many are left. He will also establish a network of sawfish allies and raise awareness about these enigmatic fishes among local communities.

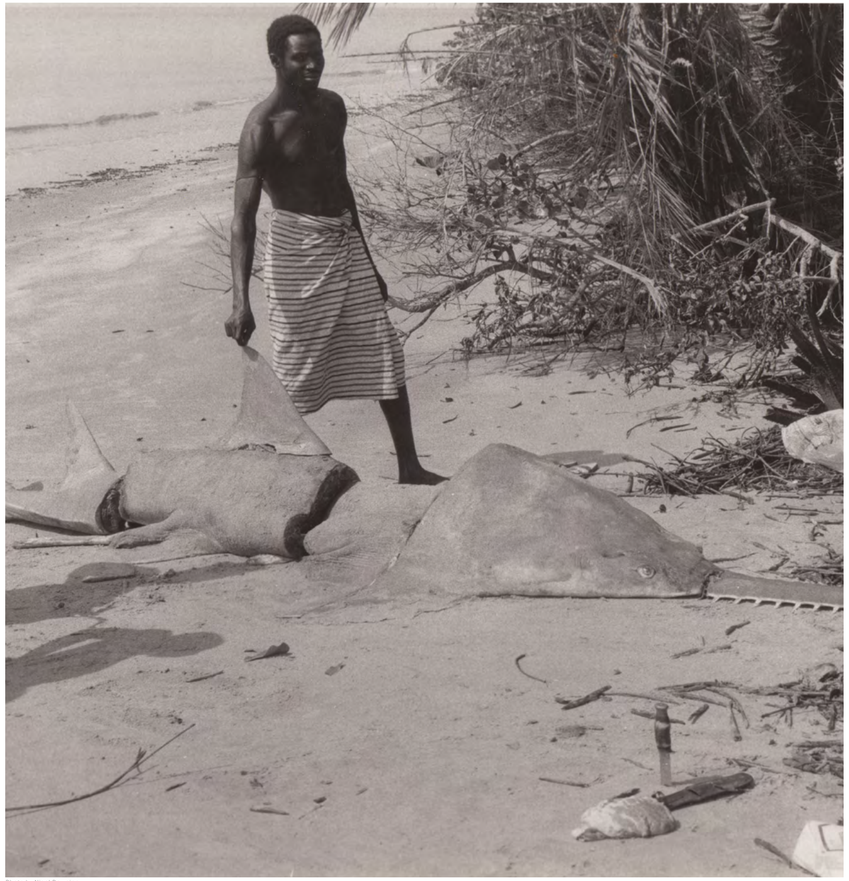


Photo by Nigel Downing

NIGEL DOWNING

STATUS OF SAWFISH IN THE CASAMANCE RIVER, SENEGAL, WEST AFRICA
HENLEY ON THAMES, OXFORDSHIRE, UNITED KINGDOM
2017–2018
SENEGAL
RESEARCH, CONSERVATION
SAWFISH

In the 1970s, Nigel discovered a treasure trove of sharks and rays that were using the Casamance estuary in Senegal as a nursery ground. He also found an abundance of sawfishes. More than 40 years on and every indication is that the sawfishes in the region are all but extinct. Nigel is going back to find out if those indicators are right.

CHANTEL ELSTON

THE ECOLOGY OF STINGRAYS IN ST JOSEPH ATOLL, SEYCHELLES
SOSF D'ARROS RESEARCH CENTRE
2014–2018
ST JOSEPH ATOLL, SEYCHELLES
RESEARCH
MANGROVE STINGRAY (*HIMANTURA GRANULATA*), COWTAIL STINGRAY (*PASTINACHUS SEPHEN*), PORCUPINE STINGRAY (*UROGYMNUS ASPERRIMUS*)

St Joseph Atoll is a special place in the remote Indian Ocean. It's home to numerous stingray species, including cowtail, mangrove whiptail and porcupine rays. Chantel is investigating how many of these animals there are, what they eat, where they live and how they move.

DEAN GRUBBS

HABITAT USE, RESIDENCY AND POPULATION GENETICS OF THE ENDANGERED SMALLTOOTH SAWFISH OFF ANDROS ISLAND
FLORIDA STATE UNIVERSITY RESEARCH FOUNDATION
2015–2018
ANDROS, BAHAMAS
RESEARCH, CONSERVATION
SMALLTOOTH SAWFISH (*PRISTIS PECTINATA*)

Sawfishes are rapidly disappearing from our seas, so when a healthy population was discovered off Andros Island in The Bahamas, the area became a very important place. Dean aims to understand this rare community of sawfishes in order to protect them.

DYLAN IRION

ESTIMATING THE ABUNDANCE OF THE WHITE SHARK IN SOUTHERN AFRICA WITH AN INTEGRATED POPULATION MODEL
OCEANS RESEARCH
2017–2018
SOUTH AFRICA
RESEARCH
GREAT WHITE SHARK (CARCHARODON CARCHARIAS)

Dylan aims to bring together several photo-ID datasets in a massive collaboration of white shark researchers throughout South Africa. He will combine the data with information collected by acoustic receivers to arrive at the first reliable estimate of abundance for great whites in southern Africa.

MABEL MANJAJI MATSUMOTO

ELASMOBRANCH BIODIVERSITY MONITORING AND ASSESSMENT IN SABAH, NORTHERN BORNEO
UNIVERSITY MALAYSIA SABAH
2016–2018
SABAH, MALAYSIA
RESEARCH, CONSERVATION
SHARKS AND RAYS

In Sabah, Malaysia, access to the ocean is easy for researchers – and fishers. The area is also home to at least 95 species of sharks and rays. Mabel is visiting local fish markets to discover important information about these animals and how they are being exploited.

Photo by Michael James Sealey

EVA MEYERS

DISCOVERY OF AN ANGELSHARK NURSERY AREA IN THE CANARY ISLANDS
BIODIVERSITY AND CONSERVATION RESEARCH UNIT, UNIVERSITY OF LAS PALMAS DE GRAN CANARIA
2015–2018
CANARY ISLANDS, SPAIN
RESEARCH, CONSERVATION
ANGEL SHARK (*SQUATINA SQUATINA*)

Although they grow to be 2.5 metres long, angel sharks are notoriously difficult to spot. They are flat, perfectly camouflaged – and also rare. Eva is learning about one of the few remaining populations of these enigmatic creatures.

JEANNE MORTIMER

COMMUNITY MONITORING OF NESTING SEA TURTLES AT D'ARROS AND ST JOSEPH, SEYCHELLES
SOSF D'ARROS RESEARCH CENTRE
2013–2018
D'ARROS ISLAND AND ST JOSEPH ATOLL, SEYCHELLES

Research, Conservation, Education
Turtles

The beaches of D'Arros Island and St Joseph Atoll are very important places for mother sea turtles to come and lay their eggs. Jeanne is training Seychellois monitors to observe nesting turtles and collect data about them.

LAUREN PEEL & GUY STEVENS

MOVEMENT PATTERNS, TROPHIC ROLE AND ECOLOGY OF REEF MANTAS IN THE D'ARROS MARINE PROTECTED AREA
AUSTRALIAN INSTITUTE OF MARINE SCIENCE I SOSF D'ARROS RESEARCH CENTRE I THE MANTA TRUST
2013–2018
D'ARROS ISLAND AND ST JOSEPH ATOLL, SEYCHELLES

Research
Reef manta ray (*Manta alfredi*)

There is a very lucky population of manta rays that lives at D'Arros Island in the Seychelles. These mantas not only live in a relatively pristine habitat, but are also safe from fishing. This gives researchers a unique opportunity to learn about how these intriguing animals live when they are free from human influence.

NICOLE PHILLIPS

COMPARISON OF LEVELS OF GENETIC DIVERSITY IN HISTORIC AND CONTEMPORARY SAWFISH POPULATIONS
UNIVERSITY OF SOUTHERN MISSISSIPPI
2017–2018
WORLDWIDE

Research, Conservation
Sawfish

Not only the most distinctive feature of a sawfish, the prehistoric-looking saw also contains vital information. By analysing samples from around the world, Nicole is investigating the genetic health of largetooth and green sawfishes and will estimate how much genetic diversity was lost during the declines sustained by these species.

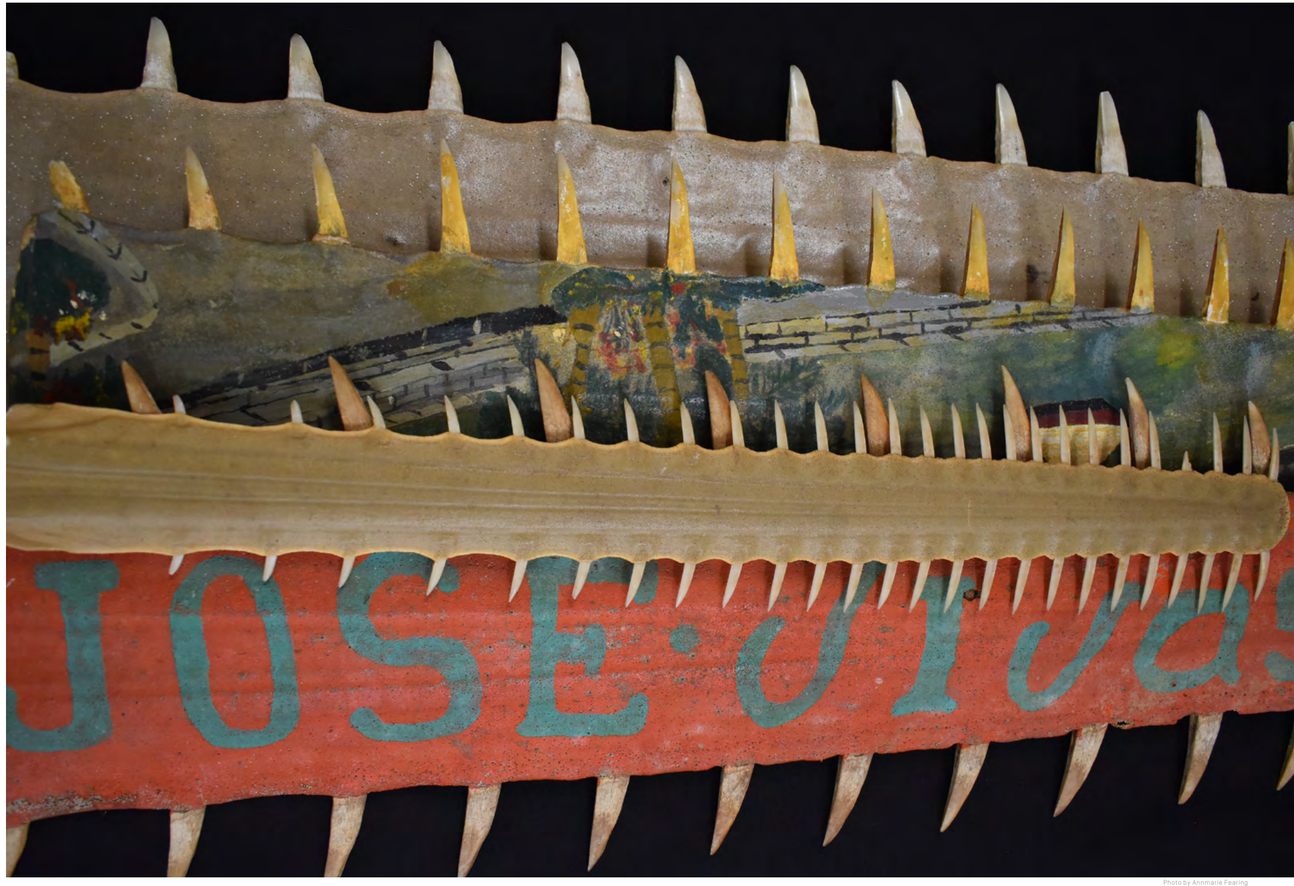


Photo by Annmarie Fearing

NICK PILCHER

IMPACT OF EXTREME CLIMATIC CONDITIONS ON REPRODUCTIVE BIOLOGY OF ENDANGERED SEA TURTLES IN IRAN
MARINE RESEARCH FOUNDATION
2017–2018
IRAN
RESEARCH, CONSERVATION
GREEN TURTLE (*CHELODIA MYDAS*)

The gender of sea turtles is determined by temperature, so climate change could have a catastrophic impact! If the sand is too warm, we get too many females. Nick is studying turtles in the Arabian Gulf, where temperatures are already so extreme that they mimic what many parts of the world are predicted to look like in the future.

MARIANNE PORTER

MIGRATION MECHANICS – UNDERSTANDING SWIMMING KINEMATICS OF A MARINE APEX PREDATOR
FLORIDA ATLANTIC UNIVERSITY
2017–2018
USA
RESEARCH, CONSERVATION
BLACKTIP SHARK (*CARCHARHINUS LIMBATUS*)

Every year thousands of blacktip sharks migrate along the coast of South Florida. Marianne will film the aggregation with drones and then use her knowledge of engineering and physics to understand how the animals move. This is the first time that shark-swimming kinematics will be studied in the wild!

Photo by Kim Bassich

GREGG POULAKIS

USING ENVIRONMENTAL DNA TO DETECT SMALLTOOTH SAWFISH IN CURRENT AND HISTORICAL NURSERY SITES
FISH & WILDLIFE FOUNDATION OF FLORIDA, INC.
2017–2018
USA
RESEARCH, CONSERVATION
SAWFISH

Gregg will use environmental DNA (eDNA), a scientific method that marine biologists have only recently begun to employ, to track sawfishes in Florida. He will determine whether they still use the same nursery areas that they used in the past and learn about their range and whether that range is expanding.

COLIN SIMPFENDORFER

SOSF GLOBAL SAWFISH SEARCH
JAMES COOK UNIVERSITY
2017–2018
WORLDWIDE
RESEARCH, CONSERVATION
SAWFISH

In order to protect the five species of endangered sawfishes, we need to know where they can still be found today. Colin will work with sawfish experts around the world to undertake a global sawfish survey using environmental DNA (eDNA).

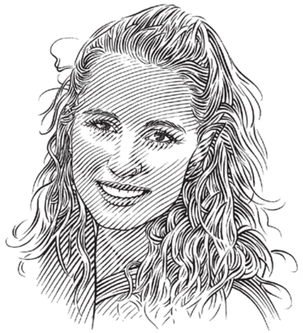
Photo by Madie Cooper

DANIELA VILEMA

CHARLES DARWIN FOUNDATION – GALÁPAGOS MARINE EDUCATION PROGRAMME
CHARLES DARWIN FOUNDATION
2017–2018
GALÁPAGOS ISLANDS, ECUADOR
EDUCATION
SHARKS AND RAYS

The Galápagos archipelago is the sharkiest place in the world! This year Daniela and her team will continue their work to conserve the sharks of the Galápagos by encouraging local communities to protect these wonderful species through a marine ambassador's education programme.

Photo by Michael Scholl



ORNELLA WEIDELI

HABITAT AND RESOURCE PARTITIONING OF JUVENILE SHARKS AND THEIR ROLES IN REMOTE COASTAL ECOSYSTEMS
SOSF D'ARROS RESEARCH CENTRE I CRIOBE I EPHE
2014–2018
ST JOSEPH ATOLL, SEYCHELLES
RESEARCH
BLACKTIP REEF SHARK (*CARCHARHINUS MELANOPTERUS*), SICKLEFIN LEMON SHARK (*NEGAPRION ACUTIDENS*)

Sharks don't look after their pups, but they do choose a safe place to give birth. Ornella studies young blacktip reef and sicklefin lemon sharks in St Joseph's lagoon to see how they get along while growing up together.

KEVIN WENG

D'ARROS AND ST JOSEPH AS A REFUGE FOR THE ENDANGERED HUMPHEAD WRASSE IN SEYCHELLES
VIRGINIA INSTITUTE OF MARINE SCIENCE, COLLEGE OF WILLIAM & MARY
2017–2018
SEYCHELLES
RESEARCH
HUMPHEAD WRASSE (*CHEILINUS UNDULATUS*)

The Endangered humphead wrasse is an iconic coral reef fish that is overfished through much of its range. Kevin and Andrew are assessing whether D'Arros Island and St Joseph Atoll may be a refuge for this fish in the Seychelles.

ANDREW GRAY

WILLIAM WHITE

INVESTIGATION OF THE STATUS OF SAWFISHES (PRISTIDAE) IN PAPUA NEW GUINEA
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL ORGANISATION
2017–2018
PAPUA NEW GUINEA
RESEARCH, CONSERVATION
SAWFISH

Sawfishes have vanished from much of their historical range, but reports from Papua New Guinea suggest that it might be one of the few remaining sawfish strongholds. With help from local students, Will hopes to identify where the animals can still be found and how they fit into the local culture and economy.

Photo by Sirachai Arunrugstichai

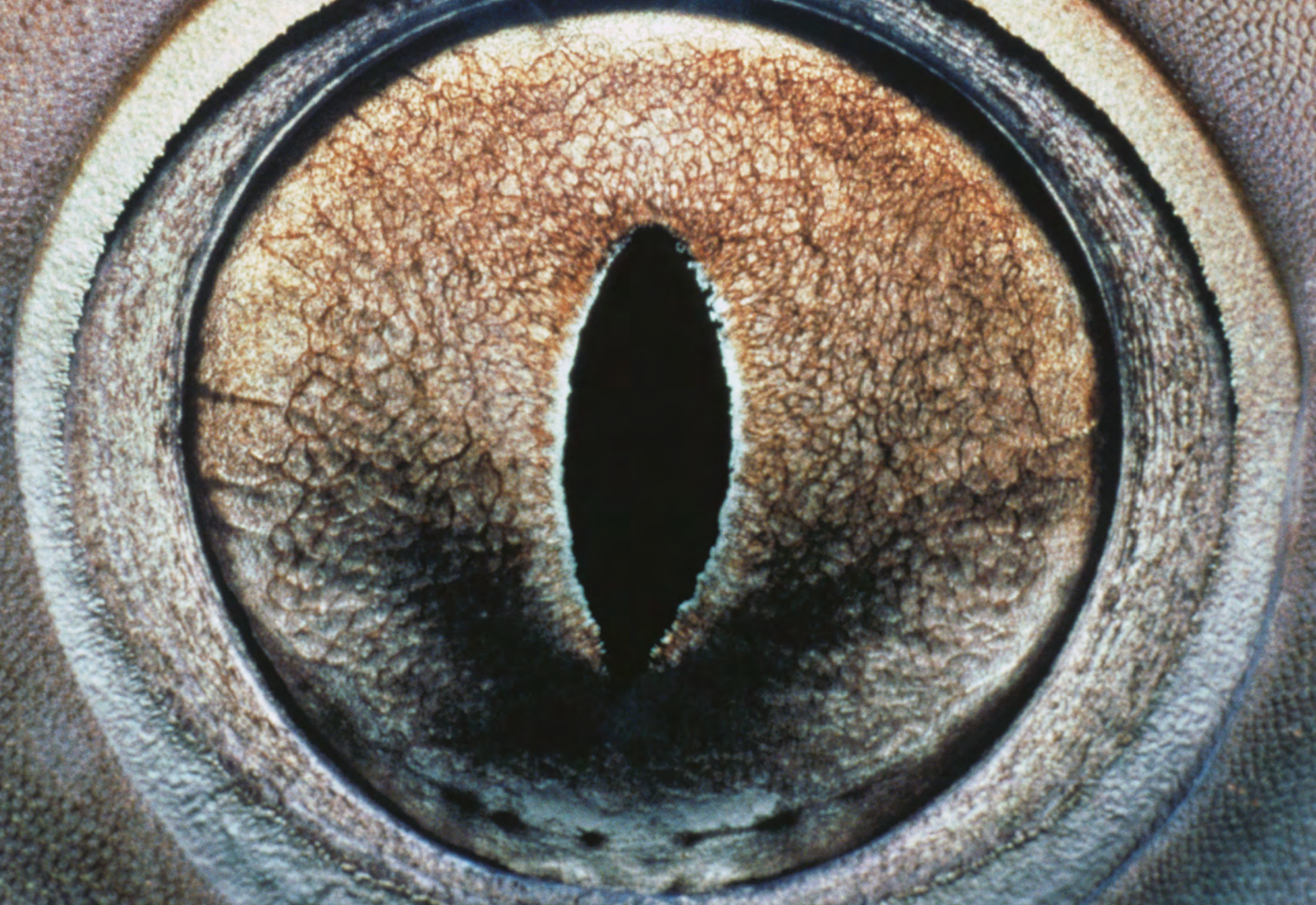
BARBARA WUERINGER

TROPHIC POSITION AND ECOLOGICAL ROLES OF EURYHALINE ELASMOBRANCH PREDATORS
SHARKS AND RAYS AUSTRALIA PTY LTD
2015–2018
CAPE YORK PENINSULA, NORTH QUEENSLAND, AUSTRALIA
RESEARCH, EDUCATION, CONSERVATION
SAWFISH

Northern Australia is one of the last strongholds for largetooth sawfish and it is an important home for other endangered species too. Barbara is investigating the role of sawfish within the ecosystem and working with citizen scientists to raise awareness about this critical habitat.

SOSF TEAM

OUR TEAM CONSISTS OF A PASSIONATE GROUP OF PEOPLE WHO ARE DEDICATED TO MARINE CONSERVATION. OUR CORE OPERATIONS ARE HANDLED BY A SMALL NUMBER OF PEOPLE LOCATED IN VARIOUS OFFICES AROUND THE WORLD.



SCHOLL MICHAEL | CHIEF EXECUTIVE OFFICER

Michael is the chief executive officer of the Save Our Seas Foundation, which allows him to merge decades of experience in science, conservation and education and his lifelong passion for conserving sharks and the oceans.

Born in land-locked Switzerland along the shores of Lake Geneva, Michael's love for the ocean transcended his personal geography. He attended the University of Lausanne in Switzerland and graduated from the University of Aberdeen in Scotland with a BSc in zoology.

His initial field experience with sharks began in 1995 at the Bimini Biological Field Station in The Bahamas. He then spent the next decade studying the population and ecology of white sharks around Dyer Island in South Africa. In 2002, he founded the White Shark Trust to support research, education and conservation projects focused on white sharks.

His genetic, tagging and fin-printing studies were integral to discovering a link between South African and Australian white shark populations. This work was a major factor in the decision to list white sharks on CITES in 2004.

Michael's research and conservation efforts have been featured in numerous television documentaries produced by the likes of BBC, National Geographic and Discovery Channel, as well as publications such as *Science*, *Nature*, *BBC Wildlife Magazine*, and *Africa Geographic*. In 2006, Michael co-authored *South Africa's Great White Sharks* (Struik Publishers) with photographer Thomas P. Peschak.

Michael taught bilingual high school and IB level biology, mathematics and physics classes in Lausanne, Switzerland, and worked for South African explorer Mike Horn on the Pangaea Expedition, assisting Young Explorers worldwide to establish environmental and social projects.

BRUYNDONCKX NADIA | EXECUTIVE ASSISTANT AND SCIENTIFIC ADVISOR

Nadia is a doctor in biology who joined the team of the Save Our Seas Foundation in spring 2013. Based in Geneva, she works with Michael Scholl as an executive assistant and scientific advisor.

Animals and nature have fascinated Nadia since her childhood so it was a natural progression for her to study biology to better understand the wonders of the animal kingdom. For her PhD she researched the conservation and co-evolution of bats and parasites using several molecular tools. Bats, she established, are fascinating animals that can help to explain the role of scientists and make people sensitive to conservation and other environmental issues. Having completed her own PhD, Nadia became the coordinator of a doctoral programme, organising courses and workshops for PhD students in ecology and evolution. In 2012 she took over the administration of a biology department, dealing with finances and human resources.

A field biologist familiar with unpopular animals, Nadia also has solid expertise in administrative management. But it was while qualifying for her advanced diver certificate that she became sensitive to the vulnerability of the oceans and the importance of preserving them. After several years in science and administration, she decided to use her diverse skills to help to promote the conservation and protection of marine environments.

FOWLER SARAH | SCIENTIFIC ADVISOR

Sarah has a first class joint honours degree in zoology and marine zoology from the University College of North Wales, an MSc in conservation from University College London and 30 years of professional experience as a marine biodiversity conservation expert. She has worked in various capacities for government departments, national and international NGOs and a biodiversity consultancy. Having been appointed to the IUCN Shark Specialist Group in 1991, she chaired it for many years and is now its vice-chair for international treaties.

Sarah founded the European Elasmobranch Association and its UK member, the Shark Trust (and is a trustee of the latter). She was appointed Officer of the Order of the British Empire for services to marine conservation in 2004, and a Pew Fellow in Marine Conservation in 2005. She became principal scientist for the Save Our Seas Foundation in 2011.

SOSF STAFF

GRUBBS DEAN | SCIENTIFIC ADVISOR

Dr Dean Grubbs is a fish ecologist with interests in the biology of exploited and poorly studied estuarine and marine taxa. Much of his research addresses specific gaps in biological knowledge necessary for the management and conservation of coastal and deep-water sharks and rays. Dean specialises in the use of fishery-independent surveys to study population dynamics and the drivers of distribution patterns of fishes and to facilitate studies of life histories, reproductive biology, trophic ecology and systematics. Dean has also tagged and released more than 10,000 sharks representing over 40 species during the past 25 years. He employs a variety of tagging and telemetry techniques to examine movement, migration and patterns of habitat use and to delineate essential and vulnerable habitats for exploited, threatened or poorly studied species.

Dean is a native of Florida and his early years spent fishing and exploring the waters of the north-eastern Gulf of Mexico led to an early interest in marine biology. He received Bachelor's degrees in marine science and biology from the University of Miami and a doctoral degree in Fisheries Science from the College of William & Mary's Virginia Institute of Marine Science. Dean was a post-doctoral researcher and faculty member at the Hawaii Institute of Marine Biology before moving to Florida State University (FSU) in 2007. He is a member of the IUCN Shark Specialist Group, the National Oceanographic and Atmospheric Administration (NOAA) Office of Protected Resources' Smalltooth Sawfish Recovery Team and NOAA's SouthEast Data Assessment and Review Advisory Panel for Highly Migratory Species. Dean is currently the associate director of research at the FSU Coastal and Marine Lab, where he mentors graduate and undergraduate students and maintains an active research programme on the ecology of deep-water and coastal fishes. His research has been featured in many television documentaries, including National Geographic TV, National Geographic Wild, Discovery Channel and the US Public Broadcasting System.

CHIN ANDREW | SCIENTIFIC ADVISOR

Dr Andrew Chin is a fisheries scientist whose work focuses on shark and ray biology and ecology, and how the information from this research can be translated into conservation and sustainability. Specifically, Andrew is interested in how fishes use coastal and marine habitats and how patterns of use affect their vulnerability to pressures such as fishing, habitat loss and climate change. His recent research spans the life history and biology of sharks by means of tagging and acoustic telemetry, as well as risk assessment. As an applied scientist, Andrew is also very interested in how fishes, sharks and rays interact with people and how their populations can be managed, as well as in impacts on their populations.

Andrew grew up in South-East Asia but currently lives in Queensland, Australia, where he received his PhD from James Cook University. He has a diverse marine background, having worked as a marine biologist in the tourism industry and as an education officer in a public aquarium. He also spent 10 years working at the Great Barrier Reef Marine Park Authority, the Australian federal agency charged with protecting the Great Barrier Reef. In 2017, Andrew launched SharkSearch Indo-Pacific, an effort that blends formal research, citizen science and public outreach, and aims to develop a scientifically robust shark diversity checklist and conservation account for every country and territory in the Pacific by 2022. He is also one of the founders of the Oceania Chondrichthyan Society and a member of the IUCN Shark Specialist Group.

STEVENS GUY | SPECIAL MOBULIDAE ADVISOR

Guy has always been fascinated by the natural world, especially life under the sea. He progressed through school and university with this in mind, graduating from the University of Plymouth in 2002 with a degree in marine biology and coastal ecology. After university he moved to the Maldives to work as a marine biologist and in 2005 he founded the Maldivian Manta Ray Project (MMRP) to help protect the country's manta population through active research and education. Guy's conservation efforts in the Maldives have led to the creation of several Marine Protected Areas (MPAs) at key manta aggregation sites. For six years his MMRP work in the region was funded and supported by the Save Our Seas Foundation (SOSF). In 2011 Guy went on to found the Manta Trust. The mission of this UK-registered charity is to advance the worldwide conservation of mobulid rays and their habitat through robust science and research and by raising awareness about them and providing education, influence and action. With a vision of a world in which manta and mobula rays thrive within a globally healthy marine ecosystem, the trust now has projects in 16 different countries.

The SOSF also supports various other mobulid ray research and conservation projects globally. As a leading expert on the science and conservation of mobulid rays, Guy has a role within the Foundation to advise it on such projects so that an effective conservation strategy for these increasingly vulnerable species is realised.

Guy completed his PhD thesis on the 'Conservation and Population Ecology of Manta Rays in the Maldives' at the University of York in the UK and wrote the reference book *Manta: the Secret Life of Devil Rays*.

SOSF STAFF

KUBICKI STEFAN | IT AND WEB OFFICER

Stefan grew up in North Dakota, about as far away as it's possible to get from the coast in the USA. He first developed a fascination with sharks and the underwater world thanks to nature documentaries and well-worn issues of *National Geographic*. He began his career as an analyst at a UN-based NGO in New York before moving to London, where he worked as a web developer and advisor to several startup companies. He joined the Save Our Seas Foundation in 2010. Aside from his work for the foundation, Stefan is an award-winning filmmaker whose films have screened at festivals around the world.

SOSF COMMUNICATION | KALK BAY | WESTERN CAPE | SOUTH AFRICA

SCHULTZ JADE | CONTENT MARKETER AND SOCIAL MEDIA MANAGER

From a young age when she and her family would go on holiday to nature reserves and the seaside, Jade has felt a very strong connection to the natural world and a great appreciation for its overwhelming beauty. With time however, she realised that this was a view few others shared. Having experienced in particular how little other people know about the wonders of the ocean, she became acutely aware that they know even less about the dangers that the marine realm faces.

With a background in marketing and media experience, Jade understands that the media is extremely powerful when it comes to spreading a message and raising awareness – and, in fact, in today's digital world it is an invaluable conservation tool. She believes that the knowledge and experience that she is able to bring to the Save Our Seas Foundation's Conservation Media Unit, together with the passion and dedication of the other team members, can and will make a positive difference in the mindset of the public – and, ultimately, the health of our oceans.

SOSF D'ARROS RESEARCH CENTRE | D'ARROS ISLAND AND ST JOSEPH ATOLL | AMIRANTES | SEYCHELLES

DALY RYAN | RESEARCH DIRECTOR

As a child growing up along the coast of South Africa, Ryan spent every spare moment surfing, diving and exploring the shoreline and rock pools of South Africa. After gaining a Bachelor's degree in zoology and ocean and atmosphere science from the University of Cape Town, he completed his Master's degree in marine biology at Rhodes University, South Africa. Between 2010 and 2015 he led studies on the ecology and migration dynamics of bull sharks and tiger sharks in southern Mozambique. The work on bull sharks earned him his PhD from Rhodes University in 2014. Ryan's current research interests include marine conservation, shark ecology, migration and behavioural patterns, predator–prey interactions and the habitat use and aggregation dynamics of keystone teleost species.

KEATING DALY CLARE | PROGRAMME DIRECTOR

Clare's affinity for the ocean comes as a surprise to some people. She spent her childhood exploring forests and streams in her native Minnesota in the USA, far from the tidal pools and ocean creatures that usually draw people to the ocean. But soon after her first scuba dives in the shallow waters of the Caribbean, she realised that salt water was indeed the cure for anything. Before her starter career as a scuba instructor, Clare completed a Bachelor's degree in business and economics at Colorado College in the USA. She then went on to teach diving in Thailand and the Philippines before moving to Mozambique to embark on a research project studying bull sharks and later tiger sharks. While working as a shark research assistant, Clare also conducted research on the sustainable financing of marine protected areas in southern Mozambique, which earned her a Master's degree in commerce from Rhodes University. Her current research interests include marine protected areas, conservation finance and seabirds, as well as the migration and behavioural patterns of marine species.

SOSF SHARK EDUCATION CENTRE KALK BAY | WESTERN CAPE | SOUTH AFRICA

YELD HUTCHINGS ELEANOR | EDUCATION CENTRE MANAGER

Dr Eleanor Yeld Hutchings currently works for the Save Our Seas Foundation, managing the Shark Education Centre in Kalk Bay, South Africa. She is also the specialist marine biologist presenter for the award-winning South African television documentary series *Shoreline*, which completed two seasons exploring the coast of South Africa.

Eleanor gained her PhD from the Marine Biology Research Centre, University of Cape Town. Her research was on the parasites of a number of endemic South African shark species, focusing on the discovery and description of several species new to science, the transmission of blood parasites and the ecology of parasite communities with potential for application in the assessment of fisheries stock.

Demonstrating a special affinity for connecting civil society with the marine environment, Eleanor in the past has managed WWF-South Africa's People and the Coast programme and, with a tourist guide certificate for marine and coastal tourism, has run a specialist company guiding tours of the marine environment. She is a qualified scuba diver (both commercial and PADI Rescue level) and dive/boat skipper, and she is kept level-headed by trail-running in the Table Mountain National Park. She lives with her husband and son in the seaside village of Kommetjie.

METCALF CLAIRE | FACILITIES ADMINISTRATOR

Raised in various small West Coast fishing and mining towns of South Africa and Namibia, with parents whose free-range approach to parenting meant lots of time outside exploring beaches, Claire is a firm believer in the power of experiential education in moulding future generations to become effective conservationists.

Claire joined the Save Our Seas Foundation Shark Education Centre in May 2016 after almost eight years with Liberty Life Financial Services as a franchise business support administrator. With a diploma in administration and legal studies from Montrose Business College in Cape Town, in her role as the facilities administrator she brings a high level of organisation and structure to the dynamic working environment that is the Shark Education Centre. She is enjoying every minute of the varied opportunities this role brings and, in addition to seeing to facilities maintenance and administration, she has become a vital part of the team, joining school groups as they learn about, explore and appreciate the ocean. She has also made it her personal mission to convince the education centre's resident puffadder shysharks to eat their food.

With a family that has earned – and continues to earn – its income almost entirely from the sea, Claire has a vested interest in the conservation of the oceans for current and future generations. She believes that she is in exactly the right place to be able to contribute to this.

SOSF SHARK EDUCATION CENTRE
KALK BAY | WESTERN CAPE | SOUTH AFRICA

MILLAR PAUL JAMES | EDUCATOR

As an educator and conservationist whose own fascination with the marine world began with surfing and diving around Cape Town, Paul believes that initiating or growing people's experience, knowledge and appreciation of our oceans has a vital role to play in protecting our natural world. In between chasing swells up and down the coast of South Africa and enjoying the icy waves of local surf spots, he squeezed in some terrestrial time at the University of Cape Town, studying environmental and geographical science and education.

Paul draws on his significant experience in schools and environmental education when running the SOSF Shark Centre's programmes. His classes welcome the range of strong opinions inevitably encountered when educating people about sharks.

MAYIYA ZANELE | ASSISTANT EDUCATOR

Zanele was born in the northern part of South Africa's Eastern Cape. As a young girl she enjoyed cooking very much, so when she completed her matric she decided to make hotel and catering management her career. In March 2008 she started working for the Save Our Seas Foundation (SOSF) as a housekeeper at the Shark Education Centre. As well as carrying out her housekeeping duties, she assisted with the bookshop and showed the public around the centre. In June 2009 she joined Alison Kock on the research boat to Seal Island in False Bay and there she saw a great white shark for the first time in her life. By the end of that trip she had fallen in love with the sea and decided to become an educator so that she can pass on her enthusiasm to the upcoming generations of South Africans.

Although she enjoyed her job during those years, she told herself that one day she would fulfil her dreams. Her previous duties at the centre were the steps of the ladder that enabled her to get where she is today. The experience that she gained by showing the public around the centre, reading marine books and helping with school groups helped her a lot. Getting an opportunity to teach young people about marine life makes her very proud, in particular because most South African children, especially those who grow up in townships and rural areas, do not have a direct connection to nature or the ocean. After the training that she did during the probation period in her new role as assistant educator, Zanele explained, 'I can truly say that to achieve success you have to believe in yourself, have a vision and work hard because there were so many challenges during the training, like presenting in front of big school groups.' But through hard work she's made it.

OSMAN WISAAL | EDUCATION COORDINATOR

Wisaal graduated from the University of Cape Town with a Master's degree in science, specialising in applied marine science. Her subsequent career path took her from WWF South Africa's Sustainable Seafood Programme (WWF-SASSI) to the Council for Scientific and Industrial Research (CSIR), where she was involved with strategic environmental assessments in support of national strategic integrated projects that further the country's development goals. She is passionate about sustainability and how to live in harmony with nature.

Wisaal has a keen interest in projects that contribute to the development of communities. Since 2016 she has been teaching maths and science to high school students at an under-resourced school in Mitchell's Plain, a suburb of Cape Town. Her aim is to help students to grasp new learning concepts, as well as to contribute to their holistic development as they navigate their life path. The challenge is to make learning fun and relevant to the student, using whatever tools are available.

Wisaal lives with her husband and cat in the seaside suburb of Muizenberg. At weekends they enjoy the beautiful Cape Town outdoors: cycling, gardening, hiking, surfing or having a braai (barbecue) at home.

SOSF STAFF

SOSF SHARK RESEARCH CENTER | NOVA SOUTHEASTERN UNIVERSITY, OCEANOGRAPHIC CENTER, FLORIDA, USA

SHIVJI MAHMOOD | DIRECTOR

Mahmood is professor of marine science at Nova Southeastern University's (NSU) Oceanographic Center in Florida and a director of the SOSF Shark Research Center. He received his undergraduate degree in biological sciences at Simon Fraser University in Canada, his Master's from the University of California, Santa Barbara, and his PhD from the University of Washington. He has been a faculty member at NSU since 1993 and a director of the SOSF Shark Research Center since 2010.

Mahmood credits his lifelong fascination with biology to growing up in Kenya, where he was routinely exposed to African wildlife and undersea environments as a child and teenager. His interests in marine science in particular were boosted when as an undergraduate student he assisted one of his professors with kelp-bed ecology research in a pristine part of British Columbia. That experience proved transformative, leading to a career in marine and conservation science and education.

In addition to leading the research and education programmes of the shark research centre, Mahmood directs the Guy Harvey Research Institute, emphasising collaborative projects between the two entities to achieve larger and more impactful research and conservation outcomes. He specialises in integrating laboratory genetics-based and field-work approaches to study and solve problems pertaining to the management and conservation of sharks and rays, billfishes and coral reef ecosystems.

Mahmood's work consistently receives worldwide attention. His research developing rapid DNA forensic methods to identify shark body parts is being used by US and other national fisheries management agencies to reduce the illegal fishing of threatened species. This work is also on exhibit at the Smithsonian Museum's Sant Ocean Hall in Washington, D.C. and his team's research discoveries have been widely reported in the national and international media.

DODGE RICHARD | DIRECTOR

Having conducted research on coral reefs worldwide, Dr Richard E. Dodge is a recognised authority on reef ecosystems. With expertise involving reef ecology and ecology, he is also the author of many publications in scientific literature. His interests include the study of natural and man-induced impacts on coral reefs from factors including climate change, ship groundings and oil spills with their related mitigation, pollution and sedimentation; coral skeletal growth and sclerochronology; coral reef restoration; reef mapping and assessment; and Habitat Equivalency Analysis.

Richard gained a BA degree from the University of Maine in 1969 and an MPhil and PhD in geology and geophysics from Yale University in 1973 and 1978. He is dean of the Nova Southeastern University Oceanographic Center as well as executive director of the center's National Coral Reef Institute, which is dedicated to providing management research outcomes on reef monitoring, assessment and restoration.

SOSF ISLAND SCHOOL SEYCHELLES
MAHÉ, SEYCHELLES

VEL TERENCE | PROJECT ADVISOR AND EDUCATOR

Before joining University of Seychelles in 2015 as a science laboratory technician and a field lecturer for BSc environmental science students, Terence Vel spent 16 years as a laboratory technician in various secondary schools. Twenty-one years ago he became a founder of Wildlife Clubs of Seychelles and during this time has managed the organisation's projects and coordinated environmental programmes in 40 schools on Mahé, Praslin and La Digue.

In 2000 he worked as a technician on a project called 'Avian ecosystems in Seychelles', which was funded by the Global Environment Facility and implemented by the former BirdLife Seychelles. The project involved two distinct phases: in the first, ecological research was carried out on a number of the Seychelles' Inner Islands to investigate their biology and conservation potential; during the second, endemic Seychellois birds were translocated from certain islands to others that were more suitable.

In 2008 Terence embarked on studies for a diploma in environmental education and social marketing at the University of Kent's School of Anthropology and Conservation. This led him to The Darwin Initiative Rare Pride Campaign to work on a project called 'Investing in island biodiversity: restoring the Seychelles paradise flycatcher'. The project was based on La Digue Island and aimed to translocate a small population of birds on Denis Island.

Terence also conducts outreach programmes that focus on marine education for youth groups from the community.

SOSF STAFF

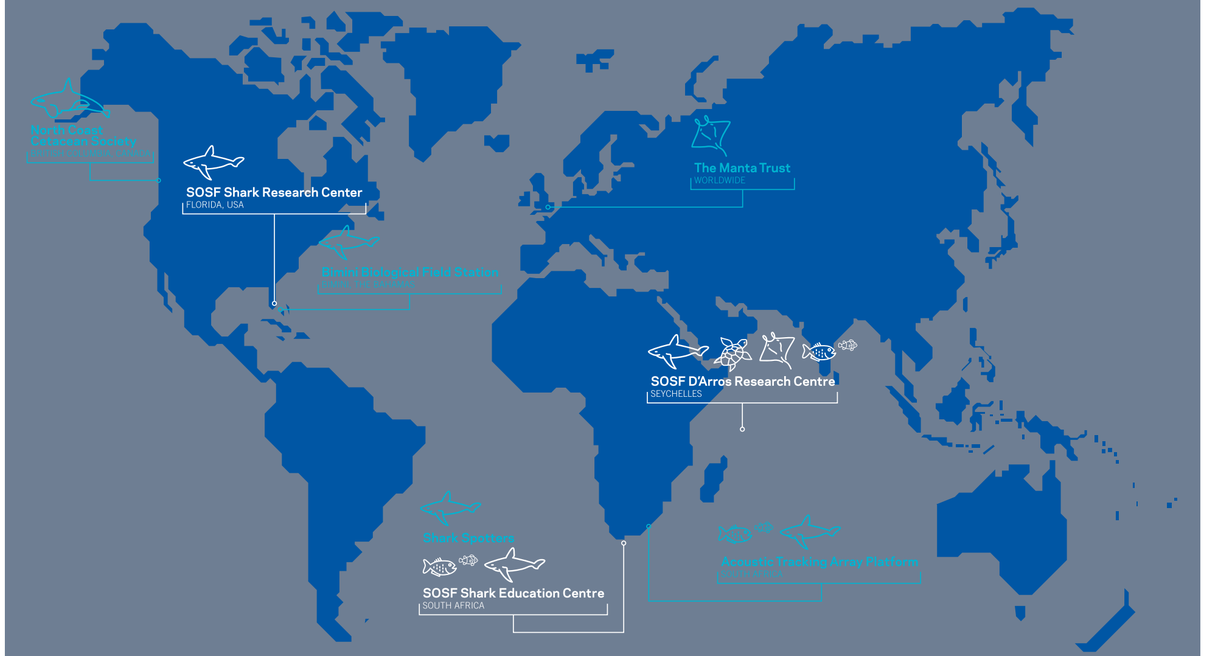
FUNDING SUMMARY

A SUMMARY OF ALL THE PROJECTS FUNDED
BY THE SAVE OUR SEAS FOUNDATION
DURING 2018

Photo by Jeffrey Rotman | BlueProtos

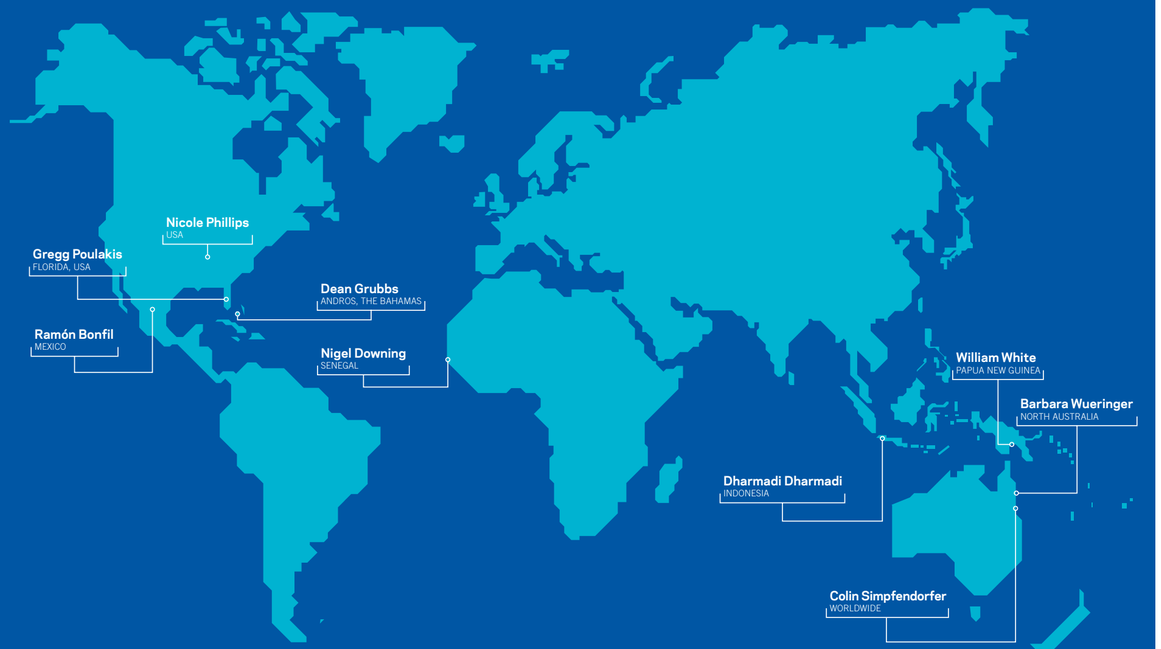
2018 SOSF CENTRES & PARTNERS

save our seas foundation



2018 SAWFISH PROJECTS

save our seas foundation



2018 PROJECTS

save our seas foundation

SOSF CENTRES

SOSF Headquarters – Geneva, Switzerland | Scholl Michael

SOSF D'Arros Research Centre – D'Arros Island and St Joseph Atoll, Les Amirantes, Seychelles (328) | Daly Ryan & Daly Clare

SOSF Shark Education Centre – Kalk Bay, Western Cape, South Africa (105) | Yeld Hutchings Eleanor

SOSF Shark Research Center – Nova Southeastern University (NSU), Oceanographic Center (OC), Dania Beach, Florida, USA (157) | Shivji Mahmood

SOSF PARTNERS

Shark Spotters – Finding a balance between recreational water user safety and white shark conservation (149) | Waries Sarah, Kock Alison & Sikweyiya Monwabisi

Cetacea Lab – Identifying critical habitat for killer whales in northern British Columbia (217) | Wray Janie & Meuter Hermann

The Acoustic Tracking Array Platform ATAP – A nationwide marine science platform (227) | Cowley Paul

Bimini Biological Field Station Foundation – Elasmobranch research, education and conservation in Bimini, Bahamas (260) | Gruber Samuel & Guttridge Tristan

The Manta Trust – A global strategy and action plan for the long-term conservation of mobulid rays (291) | Stevens Guy

SOSF SPONSORSHIPS

Award – Eugénie Clark Award at the Shark International conference – June 2018 | João Pessoa, Brazil (335) | Grubbs Dean

Student Travel Grant and Keynote Speakers – European Elasmobranch Association (EEA) Scientific Conference – October 2018 | Peniche, PT (228) | Hood Ali

Sponsorship – University of the Seychelles | Seychelles (338) | Terence Vel

FUNDED PROJECTS

A: ALL SOSF PROJECTS FUNDED IN 2018
IN ALPHABETICAL ORDER OF THE PROJECT TITLE

Angel Shark Project (344) Meyers Eva

Beginning of shark conservation in Albanian territorial waters by performing fisheries survey and sensitising communities (374) Bakiu Rigers

Charles Darwin Foundation – Galápagos marine education programme (387) Vilema Daniela

Community monitoring of nesting sea turtles at D'Arros Island and St Joseph Atoll, Seychelles (256) Mortimer Jeanne

Comparison of levels of genetic diversity in historic and contemporary sawfish populations (381) Phillips Nicole

Conservation and ecological research of smalltooth and largetooth sawfishes in Mexico (375) Bonfil Ramón

Elasmobranch biodiversity monitoring and assessment in Sabah, northern Borneo (343) Manjaji Matsumoto Mabel

Estimating the abundance of the white shark in southern Africa with an integrated population model (378) Irion Dylan

Finprinting – An international white shark photographic identification catalogue system (310) Scholl Michael

Habitat use, residency and population genetics of endangered smalltooth sawfish off Andros Island (302) Grubbs Dean

Home range scaling in lemon sharks (*Negaprion brevirostris*) through ontogeny – tests of bio-energetic mechanisms (402) Byrnes Evan

Impact of extreme climatic conditions on reproductive biology of endangered sea turtles in Iran (382) Pilcher Nick

Investigation of the status of sawfishes (Pristidae) in Papua New Guinea (388) White William

Migration mechanics – understanding swimming kinematics of a marine apex predator (383) Porter Marianne

Movement patterns, trophic role and ecology of reef mantas in the D'Arros Marine Protected Area (230) Peel Lauren & Stevens Guy

Sawfish status in Indonesia (376) Dharmadi

Status of sawfish in the Casamance River, Senegal, West Africa (377) Downing Nigel

Trophic position and ecological roles of euryhaline elasmobranch predators (309) Wueringer Barbara

Using environmental DNA to detect smalltooth sawfish in current and historical nursery sites (384) Poulakis Gregg

B: ALL SOSF PROJECT FUNDED IN 2018
SORTED BY CATEGORY AND IN ALPHABETICAL ORDER OF THE PROJECT TITLE

KEYSTONE GRANTS – CONTINUATION

Angel Shark Project (344) Meyers Eva

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The ecology of stingrays in St Joseph Atoll, Seychelles (288) Elston Chantel

Photo by Michael Scholl

The Save Our Seas Foundation team at the annual meeting of the scientific advisors in November 2018 in Gerani, Rethymno, Crete, Greece. From left to right: Dean Grubbs, Andrew Chin, Michael Scholl, Sarah Fowler and Nadia Bruyndonckx.

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