THE SAVE OUR SEAS FOUNDATION MAGAZINE

saveourseas

FALSE BAY | SHARKS | REEF FISH

CHRIS LOWE
Professor of marine biology at California State University, Long Beach, where he runs its Shark Lab. Chris studies the movement, behaviour and physiology of sharks, rays and gamefishes.

JORIS VAN ALPHEN
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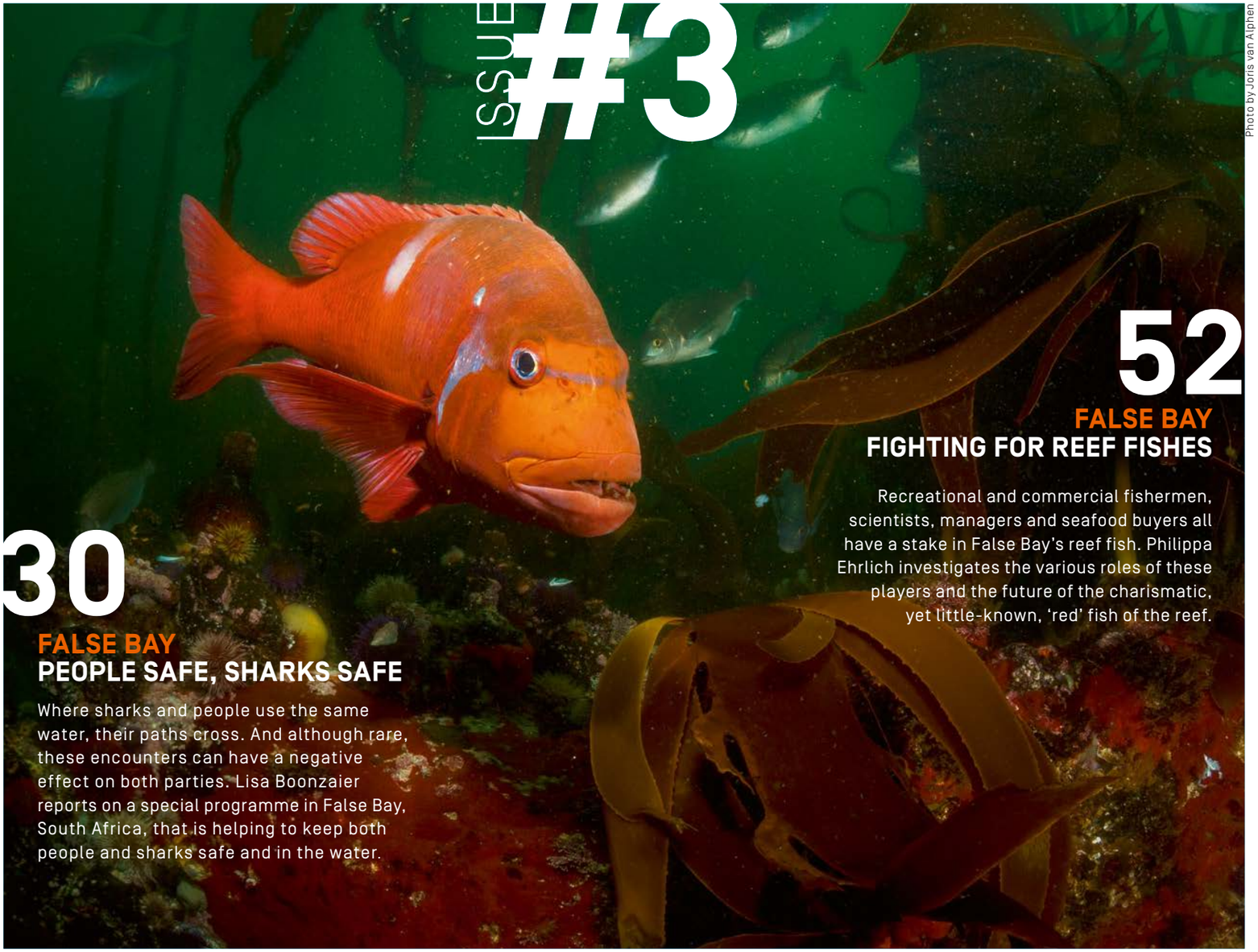
JEREMY STAFFORD-DEITSCH
Author and photographer. Jeremy is well known among shark enthusiasts and scientists for his book *Shark – A Photographer's Story.* He is now working with the SOSF on a book that will celebrate 25 years of the Bimini Biological Field Station.

MAC STONE
Natural history and conservation photographer from Gainesville, Florida. Mac is an Associate Fellow of the International League of Conservation Photographers and his first book, *Everglades: America's Wetland,* was published in 2014.

Iconic great white shark breaching (front cover) while chasing seals around Seal Island, False Bay, South Africa
Photo by Chris Fallows

Nine-year-old Laila Ntlantlu fishing (back cover) from the Kalk Bay harbour wall, South Africa
Photo by Joris van Alphen



ISSUE #3

Photo by Joris van Alphen

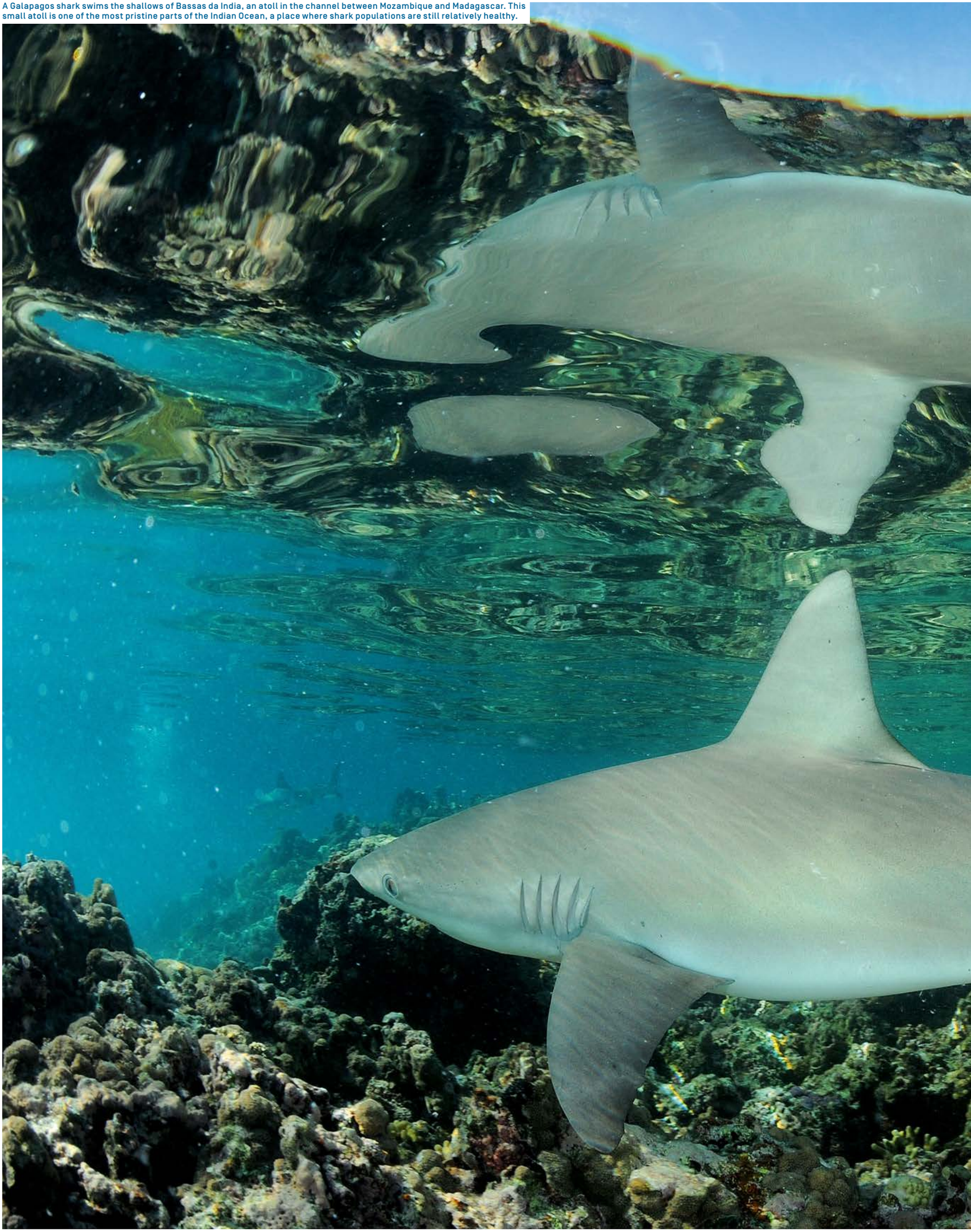
Photo by Dan Beecham | Danah Divers

'As long as there are people who care, we can and will make a difference.'

THE FOUNDER | SAVE OUR SEAS FOUNDATION

Armed with a small spear and the light of a kerosene lantern, many fishermen of the Danajon Bank in the Philippines eke out a living by spearing fish at night. Most of the fish are smaller than the average human hand, clearly indicating how heavily overfished this once productive region is.

A Galapagos shark swims the shallows of Bassas da India, an atoll in the channel between Mozambique and Madagascar. This small atoll is one of the most pristine parts of the Indian Ocean, a place where shark populations are still relatively healthy.



A humpback whale bubble-net feeding in the Pacific Ocean off Canada's Great Bear Rainforest. When using this feeding technique, humpback whales coordinate their movements, blowing veils of bubbles to encircle and concentrate their fish prey before gulping them up.

Hanifaru Marine Protected Area in the Maldives is thought to be the location of one of the largest aggregations of manta rays anywhere in the world. As such, it promises tourists an opportunity to swim with dozens of mantas. Scores of visitors arrive each year hoping to witness the mantas' seasonal feeding frenzy.


PETZL
PIONEER
BHEAD
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edit-orial

The most influential role models we have growing up are unequivocally our parents, through their genes and the environment they create for us. Then, as the world expands around us, we look up to other people who will act as figureheads throughout our lives. For me, a passion for the oceans originated from Jacques-Yves Cousteau's influence and a fascination for sharks was sparked by a few people who recognised their plight long before it made headlines. Dr Eugénie Clark, affectionately known as 'the Shark Lady', was one of these pioneers. She passed away at the honourable age of 92 on 25 February 2015, leaving not only an incomparable legacy in shark research and conservation, but an inspiration for everyone who is currently helping to dispel the effects of *Jaws* and better understand these 'magnificent and misunderstood' creatures, as described in the title of an article she wrote for *National Geographic* Magazine in 1981.

When I met last Genie, in January 2013, she still had the unique and fresh energy that helped sharks worldwide for more than 60 years. Her office was the best shark museum in the world, filled with photographs, reference books and memorabilia of all kinds. I am very proud that Dr Eugénie Clark was one of the Save Our Seas Foundation's honorary scientific advisers, and I know that her heritage will continue in current and upcoming chondrichthyan researchers worldwide.

The current issue of the *Save Our Seas* magazine is once again a celebration of the present. Our main feature is about False Bay, at the south-western tip of South Africa, and showcases the results of the first Marine Conservation Photography Grant we held in 2014. Our two winners, Mac Stone and Joris van Alphen, have explored and documented the intricate relationship between humans and endangered fishes in this incredible ecosystem. We also take a closer look at the relationship between science, the media and the public to better understand the importance of balance in conservation news. And, to honour shark research and legacies further, we celebrate the 25th anniversary of the Bimini Biological Field Station with its founder, Dr Samuel Gruber.

I hope that the stories presented in these pages will continue to inspire future generations of scientists, conservationists and educators.

Michael C. Scholl
Chief Executive Officer
Save Our Seas Foundation

Photo by Michael Scholl

WHERE WE WORK 2015

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 160 projects in more than 40 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

AFRICA

1 Indian Ocean Sea Mounts | Paul Clerkin

MADAGASCAR
2 Sharks | Frances Humber
3 Sawfishes | Ruth Leeney

MOZAMBIQUE
4 Tiger Sharks | Ryan Daly
5 Sharks & Rays | Isabel da Silva

SEYCHELLES
6 SOSF D'Arros Research Centre | Rainer von Brandis
7 SOSF Island School Seychelles | Abi March
8 Bonefish | Paul Cowley
9 Manta Rays | Guy Stevens
10 Sharks | Ornella Weideli
11 Stingrays | Chantel Elston
12 Turtles | Jeanne Mortimer

SOUTH AFRICA
13 SOSF Shark Education Centre | Eleanor Yeld Hutchings
14 Shark Spotters | Sarah Waries
15 ATAP | Paul Cowley
16 BRUVS | Lauren De Vos & Colin Attwood

17 Smoothhound Sharks | Simo Maduna
18 Southern Right Whales | Katja Vinding-Petersen
19 White Sharks | Alison Kock

SUDAN
20 Sharks | Igbal Elhassan

WEST AFRICA
21 Manatees | Lucy Keith Diagne

OCEANIA

22 Student Travel Grants | Oceania Chondrichthyan Society (OCS) Conference

AUSTRALIA
23 Batoids | Barbara Wueringer
24 Sawfishes | Barbara Wueringer
25 Whale Sharks | Lara Marcus Zamora
26 White Sharks | Lauren Meyer

US INCORPORATED UNORGANIZED TERRITORY
27 Sharks | Darcy Bradley

AMERICAS

28 Student Travel Grants | American Elasmobranch Society (AES) Conference
29 Conference live-tweeting (AES) | David Shiffman

BAHAMAS
30 Bimini Biological Field Station | Tristan Guttridge & Samuel Gruber
31 Sawfishes | Dean Grubbs
32 Sharks | Derek Burkholder
33 Sharks | Stephanie Buhler
34 Socio-economic Study | Michael Scholl

BELIZE
35 Deep-sea Sharks | Ivy Baremore

CANADA
36 CetaceaLab | Janie Wray & Hermann Meuter
37 Killer & Humpback Whales | Diana Chan

COSTA RICA
38 Mangrove Habitats | Alex Tilley & Juliana López-Angarita

ECUADOR
39 MPA Rangers' Training | Daniela Cruz
40 Sharks | Euan Harvey

PANAMA
41 Sharks | Erin Dillon

USA
42 SOSF Shark Research Center | Mahmood Shivji
43 Mobulids | Nerea Lezama-Ochoa
44 Sharks | Andrew Nosal
45 Sharks | David Shiffman
46 Sharks | Katherine Lyons
47 Sharks | Neil Hammerschlag

EUROPE

48 Student Travel Grants | European Elasmobranch Association (EEA) Conference

PORTUGAL
49 Devil Rays | Ana Sobral

SPAIN
50 Angel Sharks | Eva Meyers

UNITED KINGDOM
51 Mako Sharks | David Sims

ASIA

INDIA
52 Sharks | Dipani Sutaria

JAPAN
53 Hammerhead Sharks | Austin Gallagher
54 Sharks Socio-economic Study | Mareike Dornehege

MALAYSIA
55 Turtles | Nicolas Pilcher

PALESTINE
56 Giant Devil Rays | Mohammed Abudaya

PHILIPPINES
57 Mobulid Rays | Shannon Arnold

WORLDWIDE

58 SOSF Conservation Media Unit | Lisa Boonzaier
59 The Manta Trust | Guy Stevens
60 Manta Genetics | Emily Humble & Jane Hosegood
61 Mobulid ID Guide | Daniel Fernando
62 Ray Conservation | Nick Dulvy
63 Sharks Share Global | Madeline Green
64 White Shark Finprinting Software | Michael Scholl

Photo by Dan Beecham | Danah Divers

Photo by Dení Ramírez-Macías

Elusive in the Eastern Pacific

It is the largest of the sharks and is found in all tropical seas, yet the whale shark remains enigmatic. There are still many mysteries about the behaviour and ecology of this gentle, plankton-eating giant. In the Pacific Ocean, there are whale shark research programmes in Taiwan, the Philippines, Mexico and the Galapagos. In the Eastern Pacific specifically, though, the species is poorly understood. Nevertheless, it is known to migrate very long distances – thousands of kilometres. And although the presence of whale sharks off the coast of Peru has been confirmed since 1955, until now these animals have not been studied. Dení Ramírez-Macías has been researching whale sharks off the west coast of Mexico – and in other parts of the world – for more than 10 years. Now she's moving south to Peru. Dení would like to know whether the two countries' whale sharks are the same individuals that are simply moving between different habitats. But finding out isn't going to be easy; in six months she and her colleagues have seen only two whale sharks. This is despite receiving reports from local fishermen of a whale shark aggregation site.

Through her project, funded by the Save Our Seas Foundation during 2014–2015, Dení aims to do baseline research on whale sharks in Peru to determine basic information such as seasonality, abundance and population structure – information crucial for conservation action. Monitoring the population is critical for appropriate management and to determine whether whale sharks have the potential to be a tourist attraction and offer an alternative livelihood for the fishing community.

PITCAIRN ISLANDS: TO BE THE WORLD'S BIGGEST MARINE PROTECTED AREA

Located in the southern Pacific Ocean and more than 5,000 kilometres from the nearest continent, the four Pitcairn Islands are home to about 50 people and more than 80 marine species. Earlier this year, the UK took a step towards protecting the Pitcairn marine environment and claiming the title of having the largest marine protected area (MPA) in the world.

In its 2015 budget, the UK government announced its intention to establish a vast MPA at the islands. It has been proposed that the protected area will cover 99% of the islands' waters (834,000 square kilometres), which will be largely closed to fishing. There are caveats to this announcement, however, as the designation of the reserve will depend on procedures for effective enforcement being devised. 'The government intends to proceed with the designation of an MPA around Pitcairn. This will be dependent upon reaching agreement with NGOs on satellite monitoring and with authorities in relevant ports to prevent landing of illegal catch, as well as on identifying a practical naval method of enforcing the MPA at a cost that can be accommodated within existing departmental expenditure limits,' reads the 2015 Budget.

Monitoring and enforcement in such a large reserve will be a real challenge and the UK government is working with the Pew Charitable Trusts and the Bertarelli Foundation to develop a satellite monitoring system that will detect illegal fishing in real time. However, this still leaves the challenges of catching and then penalising the offenders.

Regardless of the drawbacks, this is an exceptional opportunity to see a large piece of marine area protected, as only a small fraction of the ocean is currently contained within MPAs.

Photo by Tony Probst

Going down...

The mysterious lifestyle of Greenland sharks makes them incredibly difficult to follow. Peter Bushnell and John Steffensen have been studying these animals since 2011 and it was only recently that they found a way to track them. On their latest expedition they employed a new tagging method that provides ground-breaking insights into not only where, but also how deep Greenland sharks go.

How do you track a shark that lives in the depths, often beneath ice floes, in the northernmost reaches of the planet where the sun glares for weeks in summer but doesn't emerge at all in winter? SPOT tags, which rely on GPS, work perfectly for animals like white sharks that come to the surface; PSAT tags, which estimate geographic position by measuring depth, time of day and light intensity, are effective at locations closer to the equator. Neither, however, is suitable for Greenland sharks. Since beginning his research, Bushnell has tagged 20 Greenland sharks, but the only locations he has been able to pinpoint were the exact sites where the PSATs were deployed and where they popped up after three to nine months. To discover where the sharks go and whether populations on the eastern and western sides of Greenland are mixing, he needs more detailed information about their movements.

In May 2014 he flew from Indiana to Greenland for another tagging expedition and this time he had a new plan. Instead of fitting each shark with a single tag that would result in only one usable data point, he used what he terms the 'breadcrumb technique'. By attaching four tags to each shark and programming them to release at six-week intervals, he would be able to get a much better idea of where the shark had travelled over the six-month period. The breadcrumbs provided valuable and interesting data – and one result that came as quite a surprise. At least one, if not two, of the tags on each shark released prematurely. This was not a malfunction, but rather an issue of depth: the tags have a safety feature that causes them to release at a depth of 1,800 metres.

This sheds new light on the dark world of Greenland sharks and means that all four of the tagged animals probed at least 1,800 metres down into the bathypelagic or 'midnight' zone. Another deep diver, the great white, has been recorded at 1,200 metres, while the Portuguese shark, the deepest dwelling of all shark species, has been fished at 2,700 metres. The ocean's deepest diver recorded so far, Cuvier's beaked whale, can plummet to almost 3,000 metres.

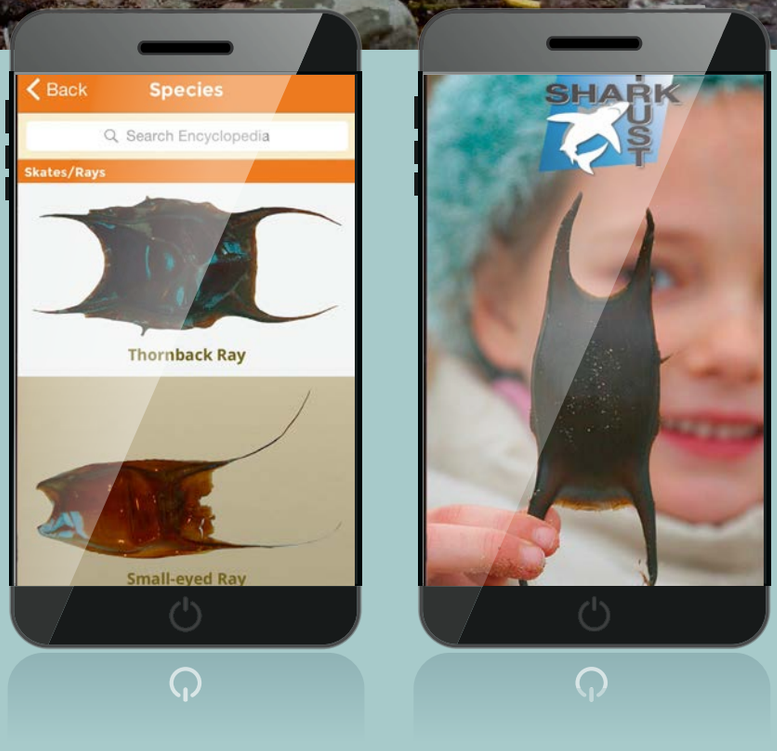
Photo by Julius Nielsen

Photo by SG Haywood | The Shark Trust

Great Eggcase Hunt App

The Great Eggcase Hunt ID guide is now available at your fingertips! If you're strolling along the beach and discover a mermaid's purse (the eggcase of a shark, skate or ray), you can use the new Shark Trust app to identify what you've found, learn about the species it came from and report your find.

This citizen science project has been running for 12 years and its database now contains more than 74,000 records, all of which help to piece together a picture of shark, skate and ray species diversity and distribution around the British coast. The new dedicated smartphone app provides tips on how to find eggcases, information about egg-laying sharks, skates and rays, a step-by-step identification tool and a recording form that enables you to upload photos and record the GPS location. Although the ID guide is for British species, if you're eggcase hunting further afield, then please still report your finds. The app is currently available for Apple devices and an Android version will be launched soon.



GREAT BEAR LIVE

Along a quiet part of Canada's Pacific coast, a few hundred kilometres north of the busy streets of Vancouver, bears, moose and caribou roam in verdant rainforests that are criss-crossed by rivers in which salmon run under the watchful gaze of bald eagles. Here, in narrow, rocky ocean channels, swim endangered orcas, humpback whales and other marine mammals.

It is also here that at least 14 major industrial oil and gas projects have been proposed. If even only some of these projects were to be approved, there would be a dramatic increase in shipping traffic in the region, which has been fortunate to escape large-scale human interference until now.

This year, Diana Chan of Pacific Wild is embarking on a mission to bring this world and its whales to the public eye – literally. Her goal is to use remote HD cameras to study and highlight the Great Bear Rainforest's cetaceans. And by live-streaming the camera feeds on-line, she hopes to facilitate an education programme and build strong support for the region. One camera has already been deployed, but Diana plans to set up many more. Keep an eye on pacificwild.org!

Photo by Ian McAllister | Pacific Wild

FESTIVAL CINEMAR

Artwork by Felipe Caro

The first-ever 'Festival CineMar' was held in Bogotá, Colombia, in early December 2014. The film festival showcased some of the incredible biodiversity found in the world's oceans and highlighted the richness of Colombia's own marine realm. The event was hosted by the Talking Oceans Foundation.

Films were screened at Maloka Museum, an interactive science centre in the capital city. Talking Oceans held two cinema nights at which 12 films were screened. Afterwards, the audience was invited to ask questions of a panel of experts that comprised a fisherman from an isolated community, two university professors, an environmental lawyer and leading Colombian marine scientists. The last event of the week was a children's workshop about sharks.

'We brought the oceans to the public eye in Bogotá, and were encouraged by many to repeat the festival in 2015, or take it on the road to other Colombian cities,' says Alex Tilley, the director of Talking Oceans. The foundation has decided to expand the event to include other forms of art and expression in the future. It will take place again around World Oceans Day in 2016 as 'Festival-Mar' or Festival of the Sea.

AIRING

A great white shark swims in the Pacific near the tiny island of Guadalupe, off the Baja California peninsula.

Photo by Morné Hardenberg | Atlantic Edge Films

SOON

OCEAN VIEW

For the past two years a team from the BBC's Natural History Unit has been travelling the world to create the ultimate wildlife trilogy about sharks. These extraordinary yet misunderstood fish were filmed using the latest high-definition and high-speed camera technology.

The first of the three films looks at the great diversity of sharks and what makes them such superior predators. To do this, the BBC team videoed more than 30 species of sharks and rays in dozens of locations, including the bizarrely named tassled wobbegong and the epaulette shark, which can walk!

The second film reveals the secret lives of sharks and rays, recording everything from courtship and mating to the remarkable ways they navigate and the surprising relationships they have developed with other organisms. The team filmed shark courtship, baby sharks developing and even shark teeth cleaning!

The final instalment shows the extraordinary work of shark scientists across the world, including Save Our Seas-funded project leaders working in The Bahamas, South Africa and the USA. Demian Chapman, who is studying oceanic whitetips, explains that sharks, as top predators, are vital to the health of ocean ecosystems. Alison Kock has been studying where sharks go and how they find their prey in False Bay, South Africa, where great whites share the water with surfers and swimmers. David Ebert has discovered 24 new shark species and he thinks there could still be many more to find. These are the people uncovering the secrets of sharks and helping to secure their future.

This new series, narrated by Paul McGann, aims to change everything you thought about sharks, revealing all aspects of their lives and showing them to be intelligent, social and complex creatures.

BBC earth

Photo by Michael Scholl

What does your 'office' look like?

Our Cetacea Lab office is built on stilts over water on the rocky shoreline of a small bay on Gil Island, British Columbia. There are more windows than walls and they give us a beautiful 180-degree view of the ocean to the south, east and west. The room is filled with identification dorsal and fluke photos of orca, humpback and fin whales. We have two desks with computers: one is used to monitor four hydrophones by means of spectrograms, the other for data entry. Radio receivers and speakers on a large cedar shelf enable us to listen to the rest of the hydrophone stations. A sliding door leads onto a deck, on which two spotting scopes are set up to look for whales. The view from the deck is of the ocean and coastal mountains.

Describe the first time you saw an orca in the wild.

I was in a kayak, paddling for the first time, when a pod of orcas passed directly underneath us. They were so close we could make out their black and white markings as they glided by. My first thought was how graceful and gentle these creatures of the sea are. I didn't feel afraid, even though they were much larger than the kayak I sat in – just present and aware that in this moment my life had completely changed.

You've been listening to whales for more than 10 years. Do you feel like you're learning a new language?

I feel like I'm learning many new languages, each one unique to each species of whale and to each season. Whales communicate in a way that humans may never truly understand and I love that this mystery still surrounds their behaviour. I know that if we want to even come close to understanding this language, we will need to think way, way 'out of the box'.

What does the SOSF–Cetacea Lab partnership mean for you and your work?

The SOSF supports the work of Cetacea Lab in an extremely remote location along the north coast of British Columbia, which has given tremendous insight into the habitat use of orca, humpback and fin whales. This data will help us in our goal to have this area designated a marine protected area for whales and for this we are proud of, and grateful for, our partnership with the SOSF.

What achievement in the history of the Cetacea Lab are you exceptionally proud to have been a part of?

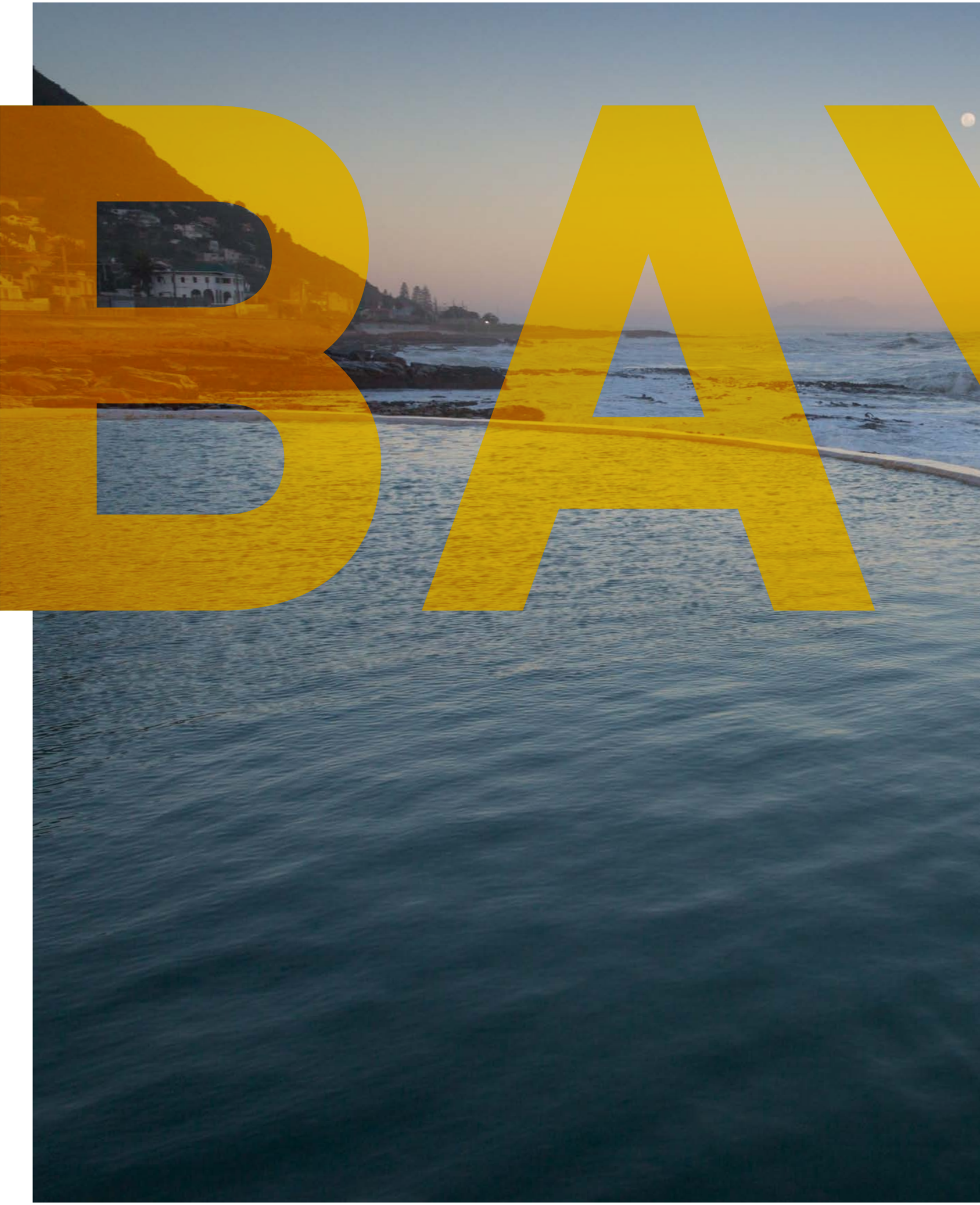
We are extremely proud of our relationship with the First Nations and how we have inspired their interest in playing a role in whale research and as guardians within their own territory. This complements our role of bringing to the attention of the world the importance of this area for whales – and all the other inhabitants of the Great Bear Rainforest.

FROM THE FIELD

A short interview with Janie Wray


EAT

Photo by Mac Stone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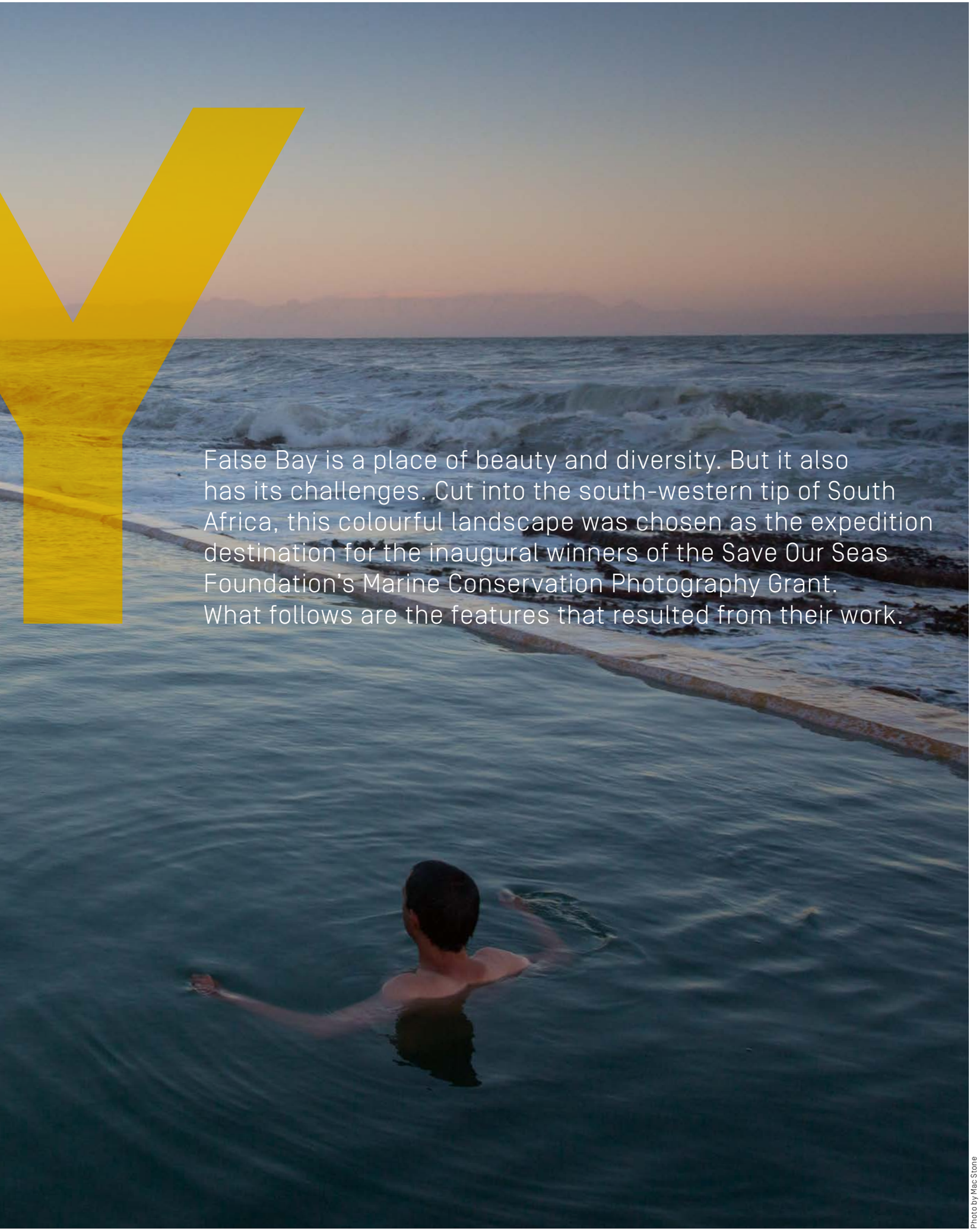


False Bay is a place of beauty and diversity. But it also has its challenges. Cut into the south-western tip of South Africa, this colourful landscape was chosen as the expedition destination for the inaugural winners of the Save Our Seas Foundation's Marine Conservation Photography Grant. What follows are the features that resulted from their work.

Photo by Mac Stone

Surfer Dave Kennedy waits for a wave amid the tangles of kelp in the temperate waters of South Africa's False Bay. Surfers in the bay understand that they share the watery wilderness with a number of shark species.

people parks

safe

A cluster of shark incidents and some outside-the-box thinking sparked a unique programme that is beneficial on so many levels. Lisa Boonzaier describes how it works.

Photography by Mac Stone

Although False Bay is famed for its great white sharks *Carcharodon carcharias,* there are many other species that call these waters home, including the pyjama shark *Poroderma africanum.* Endemic to the coastal waters of South Africa, pyjama sharks cruise the rocky bottom in search of prey.

Urban zones along the coast of False Bay are growing by the day – and bringing people and sharks closer to one another. Muizenberg, possibly the world's most popular destination for beginner surfers, offers consistent breakers but it is also an area where sharks frequently hunt for schools of fish in summer.

A centuries-old practice: trek-net fishermen deploy a large seine net in the breakers to target schooling fish. In summer they frequently encounter sharks like this bronze whaler *Carcharhinus brachyurus*, but they release them unharmed back into False Bay.

Shark Spotters have begun to provide an innovative non-lethal and sustainable means of keeping swimmers and sharks safe by setting up an exclusion net off the popular Fish Hoek beach every day.

In the waters of False Bay, where the Atlantic Ocean curls around the south-western tip of Africa, marine life abounds. Gouged into this far corner of the South African coast, partly encircled by the Cape Peninsula and gaping southwards, False Bay has lush kelp forests, rocky reefs and sandy shores. A diversity of plants and creatures inhabit these realms and provide an assortment of food to the animals that feed on them. Throughout the bay, marine creatures and plants from the bottom of the food web through to its apex together play out the struggle of life and death, and have done so for millennia.

Just adjacent to this exceptional marine environment lies a more recently established but equally diverse community: the metropolis of Cape Town with its mishmash of urban areas and mix of people. Rounding the coast of False Bay from west to east, you will see the rugged mountainous wilderness of Cape Point; South Africa's largest naval base in Simon's Town; bustling upmarket towns like Kalk Bay; one of the best surfing beaches in the world at Muizenberg; and the sprawling and seemingly endless plains of informal housing, fishing harbours and the high-rise buildings of Strand that taper off into the holiday homes of seaside towns towards Cape Hangklip. All this on just 110 kilometres of coastline.

Together, almost four million people live in Cape Town, abutting the shores of False Bay. With this varied coastline right on their doorstep, Capetonians are not wont to stay on land, and scores of bathers, surfers, fishermen, kayakers, kite-boarders and divers are in the water year-round. This proximity of people and wildlife, while picturesque and exciting to imagine, can be problematic.

There are thousands of marine species, including 27 sharks, that play an important part in the balance of life in the bay, but in the minds of people there is one that overshadows them all: the great white shark. Even in the 1920s, the white shark population in False Bay was recognised as exceptional and the area's shark abundance is almost unrivalled elsewhere. But what conditions support this profusion of white sharks? Seals, for starters. A consistent and abundant supply of them gives these marine giants – even though they are not yet fully adult – an ideal refuge to grow up in before they disperse into the wide ocean. 'They're not going to ignore a food source like this!' says Cape Town-based marine biologist Dr Alison Kock. False Bay's Seal Island, a small rocky outcrop east of Muizenberg, is home to the second largest breeding colony of Cape fur seals in South Africa and the white sharks that live here make up the second largest aggregation of the species. This means the area is one of the most vital for white sharks anywhere in the world.

Because of the close relationship between predator and prey, the behaviour of the sharks in the bay reflects the breeding cycle of the seals. 'From November to January [summer], the male seals arrive and set up their harems. They mate in deeper water and the females give birth on the island,' says Kock, a project leader funded by the Save Our Seas Foundation who has been working with False Bay's sharks for more than 15 years.

False Bay hosts the world's largest aggregation of resident broadnose sevengill sharks *Notorynchus cepedianus*. They are frequently targeted by fishermen but are also a major tourism draw for divers want to swim with these ancient denizens of the deep.

'At this stage, the pups are only drinking [milk] from their moms, they are not yet going into the water and supplementing their diet with fish. So they are not available to the sharks.' At the onset of winter in about April, however, the seals' seemingly languid lifestyle is disrupted. This is when white sharks start spending most of their time near the island, and it's no coincidence that this is also when the naive pups begin venturing into the shallows. At about four months old, the young seals are inexperienced and the sharks capitalise on their vulnerability. Winter in False Bay is the season of breaching, when four-metre-long, 1.5-tonne sharks launch themselves completely out of the water in pursuit of seals.

By the time spring rolls around again, though, the young-of-the-year seals are not so young any more. They have wised up, and they know how to avoid being eaten. The sharks move off and the cycle begins anew.

This dance of predator and prey, life and death, plays out within a few kilometres of the False Bay shore. But where do the sharks go when they aren't at the island? This question was answered only a couple of years ago when research showed that white sharks in the bay, while present year-round, spend their time differently depending on the season. In winter, both male and female sharks hang out around Seal Island; in summer, though, males disperse along the South African coast while females move closer to shore. Summer is a time when other sharks and fish – such as yellowtail – are also inshore, providing another primary food source for the white sharks. Critically, this finding means that during the busiest time of the year for Cape Town's beaches, white sharks and people are using the same space, and inevitably – although rarely – their paths cross.

Generally, close interactions between beach-goers and sharks do not end well for either party. While the first record of a shark fatality in False Bay is from 1900, it was a cluster of shark incidents during the 2000s that set in motion the process that would determine how the current balance between humans and sharks would play out.

Among this cluster of incidents were some that resulted in the loss of limbs and the loss of lives, including one in 2006 that left Achmat Hassiem, an aspiring professional soccer player, without his lower right leg. Hassiem and his brother were both in the water at the time, taking part in a life-saving exercise when the shark approached. 'To be honest, there is a very fine line between being scared and being amazed, and I think I was kind of on both sides,' says Hassiem. He survived, but others were not so fortunate. Of the five serious shark incidents in False Bay between 2003 and 2006, two were fatal.

In response to this series of incidents, the City of Cape Town convened a meeting of specialists to decide how to deal with the situation. Among the suggestions was the option to kill the area's sharks, a tactic used in other parts of the country. One of the participants at the meeting was Alison Kock. Although now recognised as among the foremost marine biologists and shark experts in the country, then she was just starting out as a scientist – and so was

When great white sharks move inshore in summer in the wake of schools of fish, they come in closer to water users.

Donnie Felix, a Shark Spotter, watches the waters off St James. By coordinating via radio with a spotter on top of the mountain, he alerts swimmers to shark sightings.

any sort of research on False Bay's white sharks. 'At that time, we really knew nothing,' she says. 'All we knew about sharks inshore was that there were the occasional shark bites, and that they used to be hunted for trophies. And that was it.'

At about the same time, the local community launched its own initiative in response to the incidents to try to resuscitate beachfront business. 'After the shark bites people were very scared. They didn't want to come and use the beach', says Sarah Waries, programme manager for the Shark Spotters. The idea for the initiative began with the realisation that the mountains overlooking False Bay's beaches were the ideal place to watch for sharks. 'So Greg Bertish, who was a well-known surfer, and Dave and Fiona Chudleigh, who own one of the surf shops, got together, and they got Patrick Rasta Davids and Monwabisi [Sikweyiya], our field manager now, and they put Monwa on the mountain and Patrick on the beach… and it literally just grew from there.'

A similar system started up in parallel at Fish Hoek, harnessing the keen eyes of fish spotters, who usually detect and communicate the locations of shoals of fish to fishermen. In a progressive move on the City's part, it rejected the idea of a cull and decided to get behind the spotters and formalise the programme. What has resulted is a pioneering venture that is socially and ecologically responsible, and the only one of its kind.

Equipped with polarised glasses, binoculars and two-way radios, the Shark Spotters operate an early warning system by watching for sharks at beaches and surf spots around False Bay 365 days a year. They also deploy and monitor an award-winning shark exclusion net at Fish Hoek – one that's designed not to catch anything, but to act as a barrier. In the 10 years since it began the programme has grown from strength to strength, expanding from one site to eight, a single shark sighting to 1,700 and one spotter to 42 employees. Led by Kock and Waries, it now employs 40 people from previously disadvantaged backgrounds to keep their eyes trained on the waters of False Bay. More than keeping water-users safe, Shark Spotters has helped elevate the lives of people struggling in previously disadvantaged communities, including the sprawling plains of shacks found along parts of False Bay's coast. Hardship, poverty and crime are a daily part of life in these communities; earlier this year, one of the Shark Spotters was murdered while off duty in his community.

Monwabisi Sikweyiya – or Monwa, as everyone calls him – was the first spotter to take up a post watching for sharks. 'Shark Spotters has changed me completely,' he says, pausing. 'Respecting life, the ocean, nature. Educated me more. Because if you don't have respect, in most cases you don't have the knowledge.' After joining the programme he says his life transformed for the good. 'I come from a township where life is lived in the fast lane. [With Shark Spotters] there were no more late nights because I had a job to do the next day, so my lifestyle slowly changed. It has changed me a lot, it's made me

more responsible, taught me to respect life. Life at sea and life around me.' This kind of turnaround is not easily won, but Shark Spotters is successfully changing the lives and perceptions of not only their employees, but also the people they protect.

Monwa recalls, 'When we started, there was very little knowledge among the surfing community at the time. And if there was a shark warning and we got people out the water, it was a matter of 500 people climbing back into their cars and taking off. The beach was quiet.' This progressed to a point where the beach-goers would get out of the water and then start asking the spotter questions. 'Now you're looking at the people who get out of the water waiting by the water, waiting right there for the all-clear sign. And five minutes after the beach has been reopened, you have 500 people back in the water.'

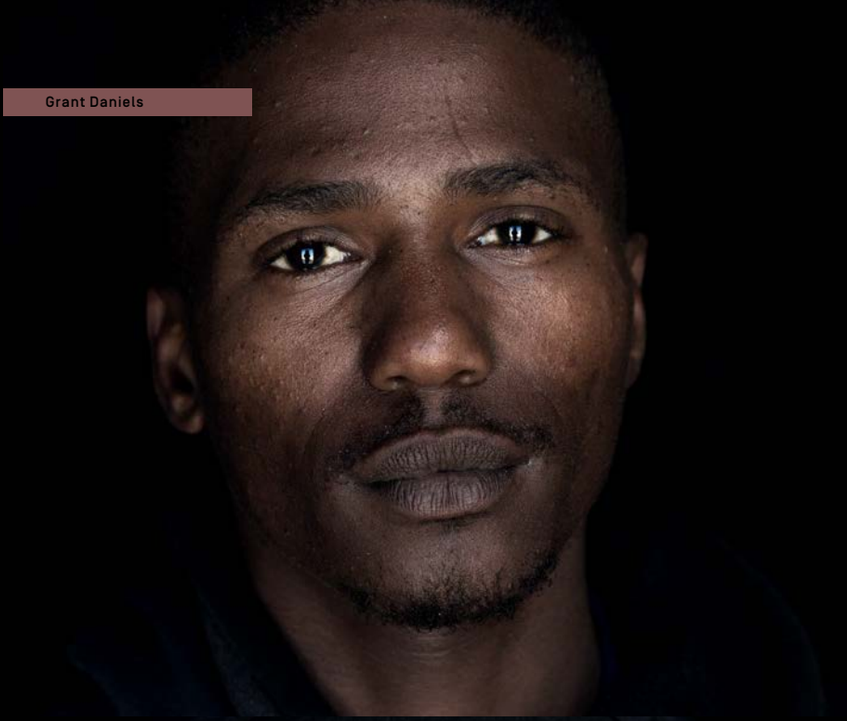
But like any other bather-protection strategy, Shark Spotters is not infallible. Weather conditions, human error and limited capacity present complications. Despite this, the programme remains exceptionally successful and is unique around the world – not only for protecting people, but for protecting sharks. Because without such a programme, lethal options would be on the table.

'[Sharks are] one of the wonders of Cape Town. We have got Table Mountain, we've got great whites, we've got me,' laughs Hassiem, who since he lost his leg has gone on to win a bronze medal for South Africa in 100-metre butterfly at the London 2012 Paralympic Games. 'They really need to be protected, not just around Cape Town, but around the world because of the role they play in our oceans.'

Somehow, in the midst of a cluster of severe shark incidents, Cape Town managed to establish a balance with its marine wildlife. The sharks are still in False Bay, contributing to its diversity, moving in concert with seals and fish, a vital part of the ecosystem. The people are here too, enjoying the beaches, diving in the ocean, surfing its waves. Along the shoreline these two greats of the terrestrial and marine realm meet and coexist under the watchful eyes of the Shark Spotters. 'I have a job,' as Monwa explains it, 'to keep people safe and sharks safe.'

Many of the Shark Spotters live in crowded and impoverished townships outside Cape Town. Funded by the local municipality, local businesses and the Save Our Seas Foundation, the programme provides much-needed jobs and income to under-served communities. Its members wear their branded backpacks and shirts with pride in the communities.


Sibusiso Myeki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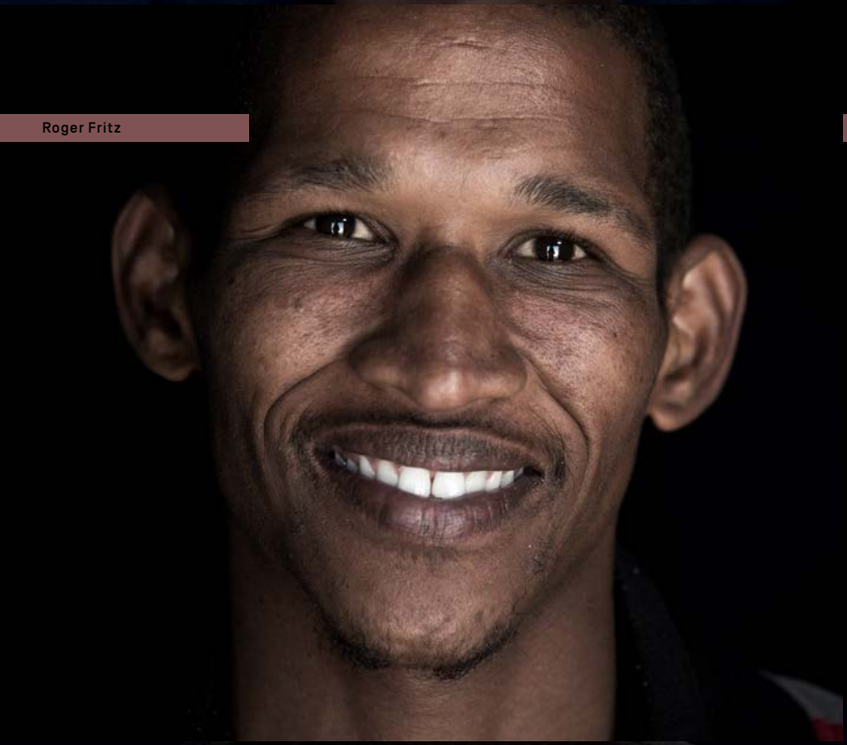
Roger Fritz


Liesel Lott


Steven Bonkolo


Noncedo Kwebana


Marwaan Izaks


Nkosinathi Makanda


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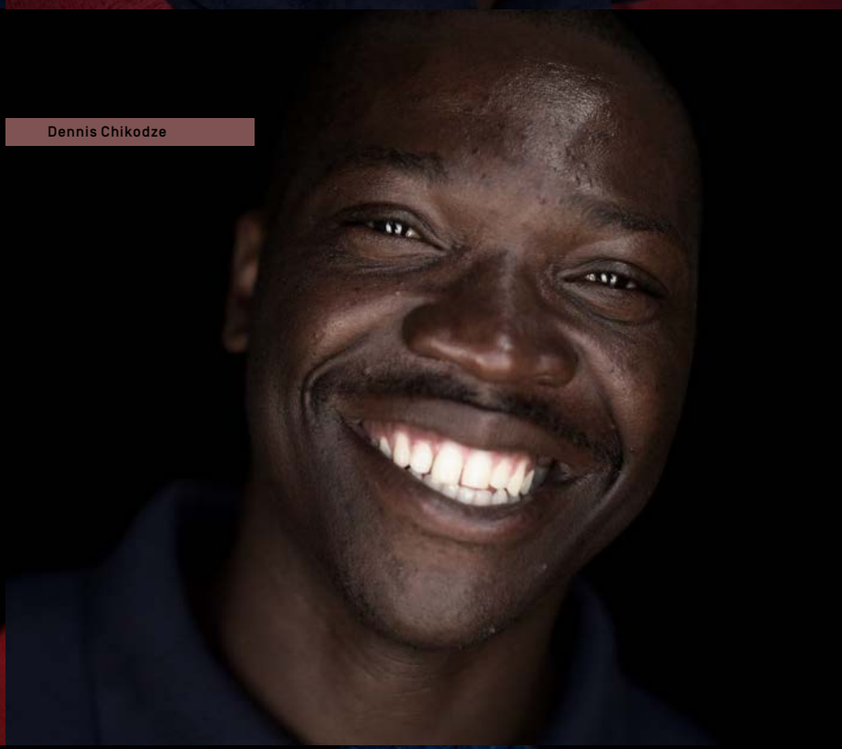
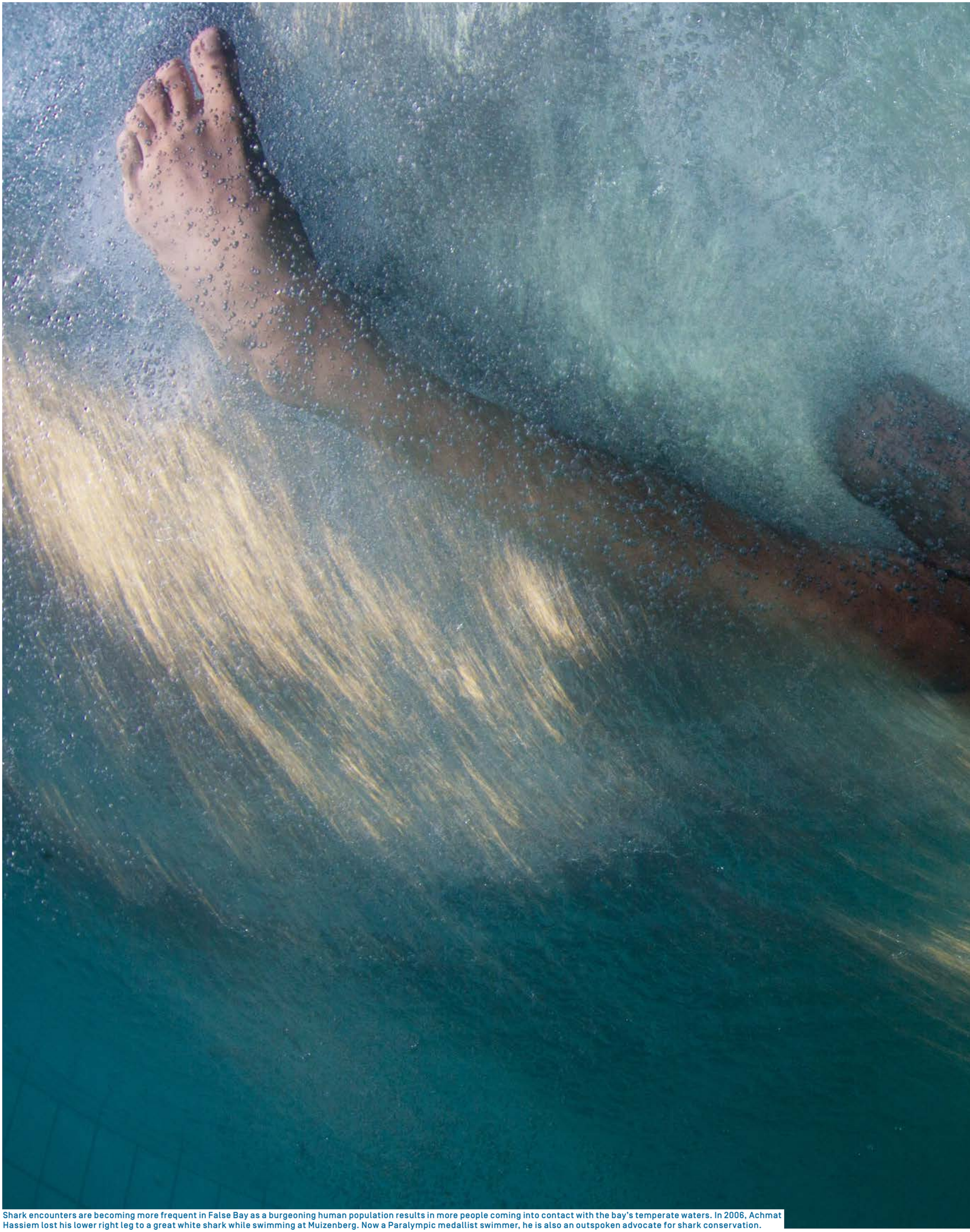

Dennis Chikodze


Simphiwe Mgwabane


Brett Kroukamp



Shark encounters are becoming more frequent in False Bay as a burgeoning human population results in more people coming into contact with the bay's temperate waters. In 2006, Achmat Hassiem lost his lower right leg to a great white shark while swimming at Muizenberg. Now a Paralympic medallist swimmer, he is also an outspoken advocate for shark conservation.

The shy and rarely documented spotted gully shark *Triakis megalopterus* cruises the kelp beds in False Bay. Feeding primarily on crustaceans and squid, this species poses no threat to humans.

A long-boarder paddles alone into a wall of foam on the last breaker at Muizenberg. The Shark Spotter programme gives peace of mind to water users, balancing shark conservation and public safety.

FIGHTING FOR **REEF FISHES**

Red roman *Chrysoblephus laticeps* and hottentot seabream *Pachymetopon blochii* are abundant in the Table Mountain National Park Marine Protected Area. Although South Africa's fishing regulations are far from trouble-free, marine protected areas are proving to be the light at the end of the tunnel for the future of the country's iconic reef fishes and its growing group of fishermen.

In False Bay, South Africa, Philippa Ehrlich learns that protecting the area's critically endangered reef fish species is going to require people – often with different needs and agendas – to collaborate.

Photography by Joris van Alphen

A hottentot seabream speared in Smitswinkel Bay. Spearfishing and hook-and-line fishing are largely responsible for the decline in the resident reef fishes of False Bay.

On a warm summer day in December, 25-year-old Jonathan Lewis (right, green hat) was among many dozens of people gathered to catch reef fishes off Kalk Bay harbour's jetty. By the latest estimate, South African recreational fishermen numbered 900,000 in 2007 – up from 500,000 in 1996.

Skipper Naaim Jacobs and Yaseen Almazon aboard hand-line fishing boat *Kalky's 5*.

Garth Henry ties a fishing line on hand-line fishing boat *Kalky's 5*. Henry has been a fisherman for 16 years.

I pull my face deeper into the hood of my green oilskin and shudder against the icy wind. We are now into our second hour aboard the *Blue Starfish* and are halfway to the mouth of False Bay. It is still pitch dark and in the distance a dim horseshoe of twinkles indicates where the ocean meets the land, reminding me of how vulnerable we are as we slough through this deep, inky bay of invisible life. This is a journey that traditional hand-line fishermen have been making for generations, but it is uncertain how much longer they will be able to continue. South Africa's commercially important line-fishes have been reduced to 10% of past levels. Specifically, populations of bottom-living reef species, which make up 25% of the country's commercial fish stocks, have collapsed.

'My darling, you're shivering. Turn to face the back of the boat.' I am startled by an old fisherman who is sitting just to my right. Most of the crew are playing cards at the back of the boat or sleeping on the bunks below. The old man's name is Yussuf*. He is not one of the crew, but used to skipper his own boat and, despite being in his 70s, he cannot bear to be away from the sea. 'You know, Cape Town has always been a fishing place,' he explains. 'The pioneers of fishing were the Muslim people. Some of them were runaway slaves and some were freed slaves. When they became free they became fishermen.'

False Bay, also known as *'die blou dam'* (the blue dam) to local communities, is a microcosm for what has happened in the rest of South Africa and in other parts of the world. A hundred years ago the bay teemed with life, and fish and fishermen thrived. Then came decades of concentrated exploitation that has decimated fish stocks. And yet, despite shrinking catches and increasing costs, the communities whose culture and livelihood were founded on fishing are still desperately clutching their lines.

As the sun creeps up over the eastern edge of False Bay, we reach the mouth and anchor in the shadow of a series of arrow-shaped peaks. About 16 other vessels surround us. Jacob Saunders*, the most experienced fisherman on the boat, is talking excitedly while he prepares his fishing gear. 'When the fish start to bite, it puts the adrenalin right in you and you want to catch another one and another one.' He throws in his line and almost immediately pulls in a large, shiny fish with long, razor-sharp teeth – a snoek *Thyrsites atun*. He grips the powerful fish under his arm and snaps its neck. Macabrely captivating as it might be, I am not here to learn about the fast-growing and migratory snoek. I am after one of the bay's permanent and grander residents.

Castle Rock, a no-take marine sanctuary that falls within the Table Mountain National Park Marine Protected Area, lies less than a kilometre from where we are fishing. It was declared a sanctuary in 1979 and anyone lucky enough to dive there is likely to meet the aptly named red roman *Chrysoblephus laticeps*. In a temperate ocean of subdued hues, this fish adds a splash of glorious crimson. A roman can grow to a length of 50 centimetres and has powerful jaws and teeth. As one of the greediest and most territorial of the fishes in the bay, this sentry of the reef is extremely vulnerable to desperate line fishermen, but at Castle Rock it is safe, along with legions of other temperate reef species. Schools of blue-black hottentot and galjoen swerve through swaying kelp passages while larger residents, like red steenbras, red stumpnose and John Browns, gawp out from dark caves and cracks between the rocks. The reserve is stuck in a time warp, when 'die blou dam' was still the bay of plenty.

Hand-line fishing boat *Kalky's 5.*

Back at our anchoring point, the south-easterly wind has picked up slightly. I cringe at the bone-chilling crack as another snoek loses its neck and look up to see a red rubber duck roaring towards us. Our skipper Jacob Andrews* is edgy. The boat approaches and he hands over some papers. Uniformed men read through the document carefully before eventually moving on to question another skipper. By now, much to the dismay of the crew, the snoek have stopped biting. The anchor is raised and we move closer to the shore, stopping above a rocky reef. The lines go in and soon a crimson flash breaks the surface and the first red roman of the day is pulled up into the boat.

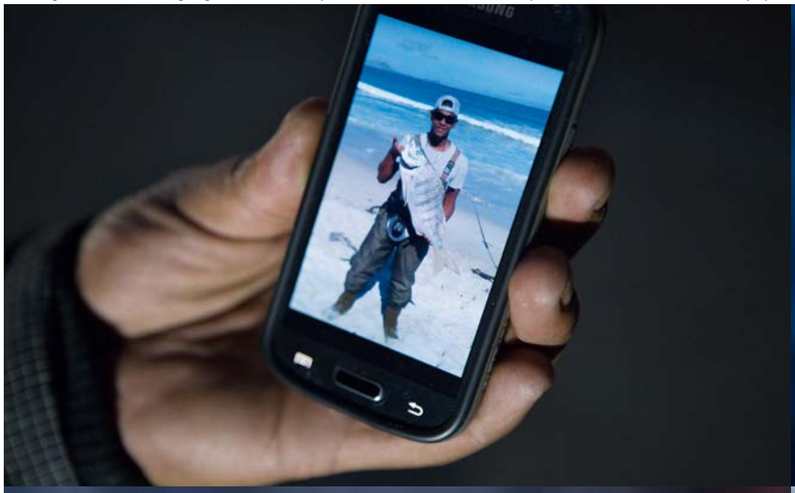
Another rubber duck charges up to us. This time we are expecting it. Photographer Joris van Alphen and I are greeted by local dive operator Steven Benjamin, who is looking bewildered. We thank the fishermen and jump into the inflatable boat. Steve waits until we are a few hundred metres away before he explodes. 'This is mad! There are 16 boats fishing inside the reserve and the patrol boat is watching!' I am shocked when I realise that we are in a stretch of coast known as Paulsberg, which has been a no-take zone since 2004. The patrol team demanded to see papers from every vessel in the area, but did not mention that we were in a reserve and everyone was fishing illegally. In a place where even the law enforcers seem unaware of the conservation rules, the future for reef fishes looks very bleak.

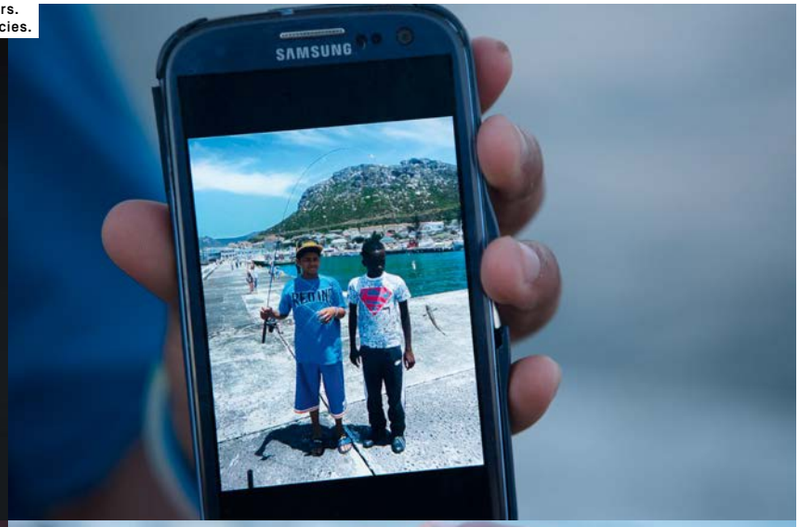
In 2000, South Africa's government declared a conservation emergency and reduced commercial line-fishing quotas by approximately 70%. Additional restrictions were introduced in 2005. Sadly for reef fishes, this was not enough. These endemics are long-lived and slow-growing and differ from resilient pelagics in that their complicated life histories make it very difficult for populations to recover. The red steenbras, a cousin of the red roman, is perhaps in the most precarious state of them all. Old photographs show 50-kilogram red steenbras being hooked out of False Bay in the 1920s, but now even small specimens are rare. These critically endangered fish live for 33 years and have been reduced to less than 5% of their historical population.

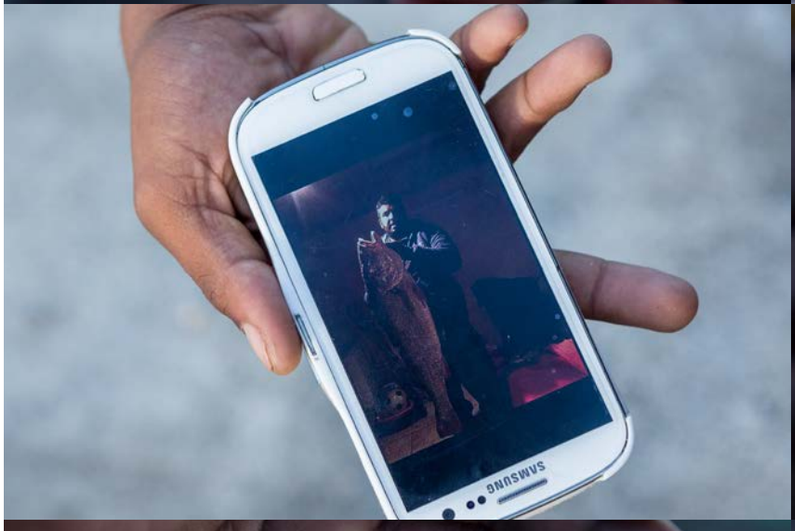
Tension is inherent at every level of South Africa's line fishery where, as resources dwindle, stakeholders become increasingly territorial over their piece of the pie, with negative repercussions for both marine life and people. 'There is no getting away from it, our seas have been plundered. The whole face of fishing has changed. The harbours are dying because there are no fish. The communities are suffering,' explains Paul Joubert sadly. He is a fish wholesaler who used to be a commercial fisherman.

My own conversations with fishermen confirmed these gloomy impressions. Not only are they are struggling to catch enough fish, but questionable government quota systems have meant that many line-fish boats no longer have licences. Crews live with the relentless uncertainty of how much longer they will be able to go to sea. Jacob Andrews is desperate for an alternative. He says he would even be prepared to clean harbours or beaches if the government provided a grant to keep fishermen off the water so that fish stocks could recover. Even Jacob Saunders, whose father was a fisherman for 47 years, does not want his children to fish. 'My dear, times is changing. I tell my son, "If you want to become a fisherman, you do it as a hobby weekends only." For him to become a fisherman in the future it will be very very hard,' he comments grimly.

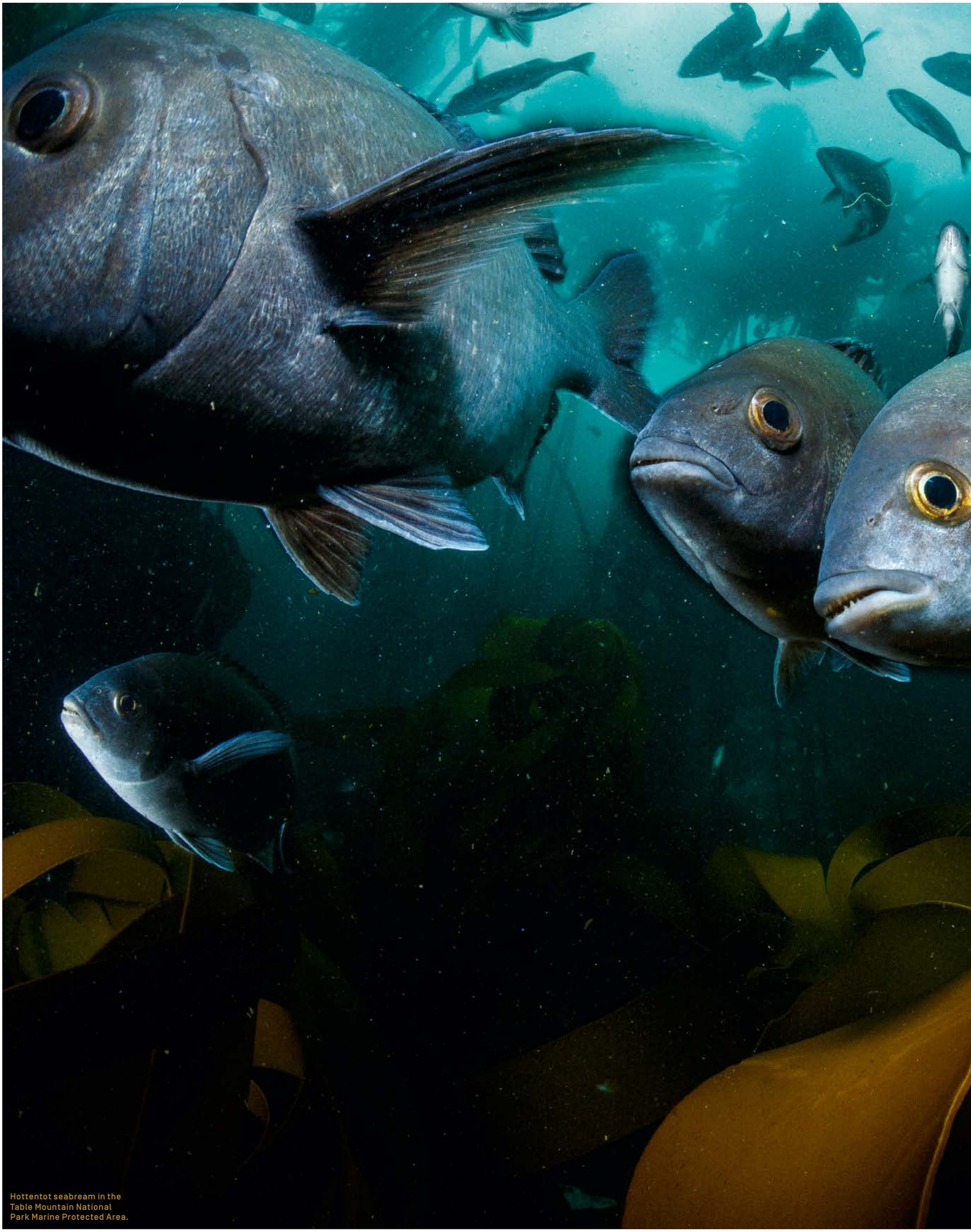
In addition to a fleet of hungry commercial line-fishing vessels, South Africa hosts a legion of recreational fishers. Although it is difficult to gauge their exact impact, scientists hold them responsible for the decline of many species.



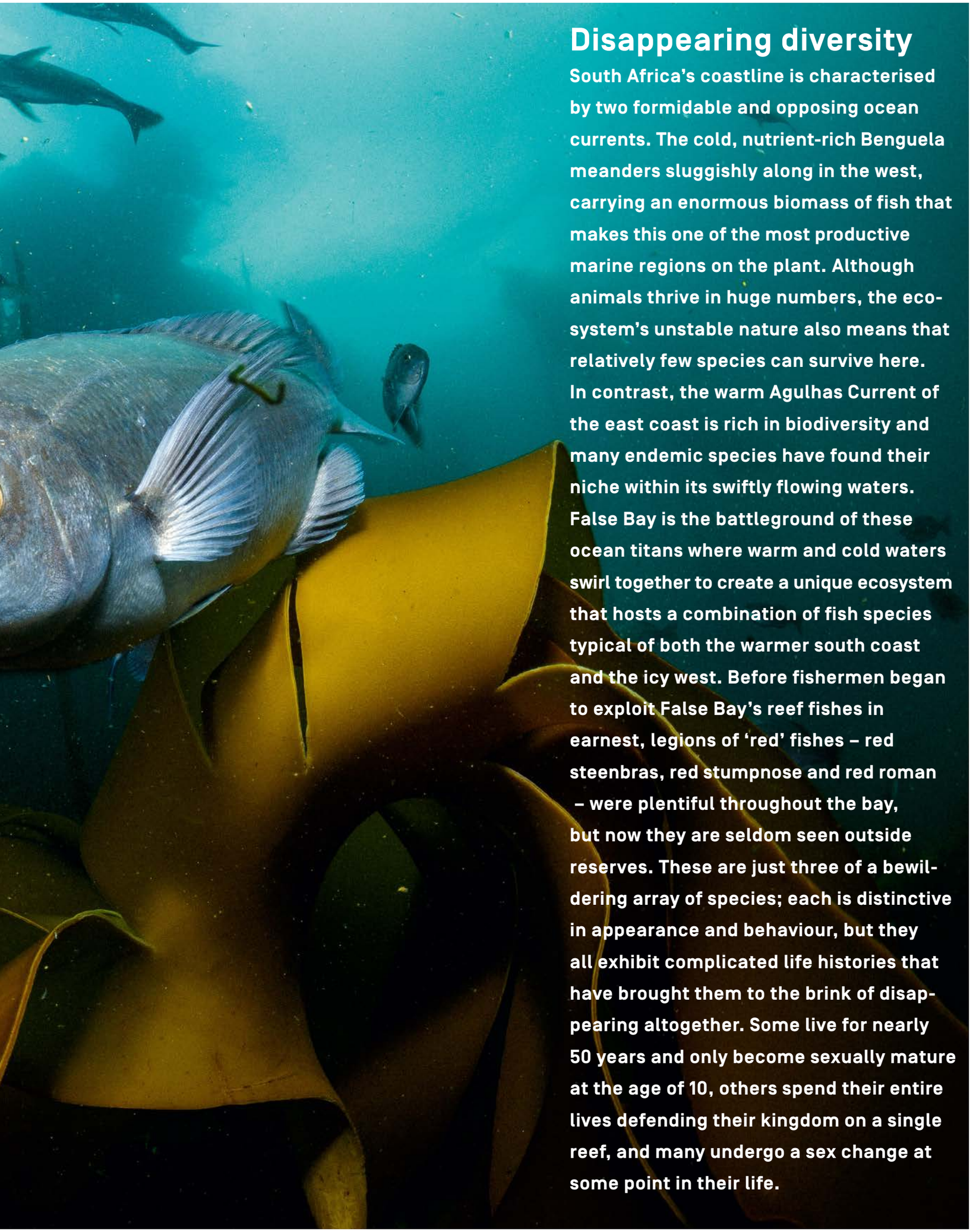




In December 1968, Geoff Fridgeon posed for a photo holding a large white musselcracker *Sparodon dürbanensis* he had caught while spearfishing off Dalebrook beach. A fish of this size would have been close to 30 years old. Forty-six years later Fridgeon stands in the exact same spot holding an enlargement of the photo. Today the species has all but disappeared from False Bay. A white musselcracker can take more than five years to reach sexual maturity, which makes the species highly susceptible to overfishing.



Hottentot seabream in the Table Mountain National Park Marine Protected Area.

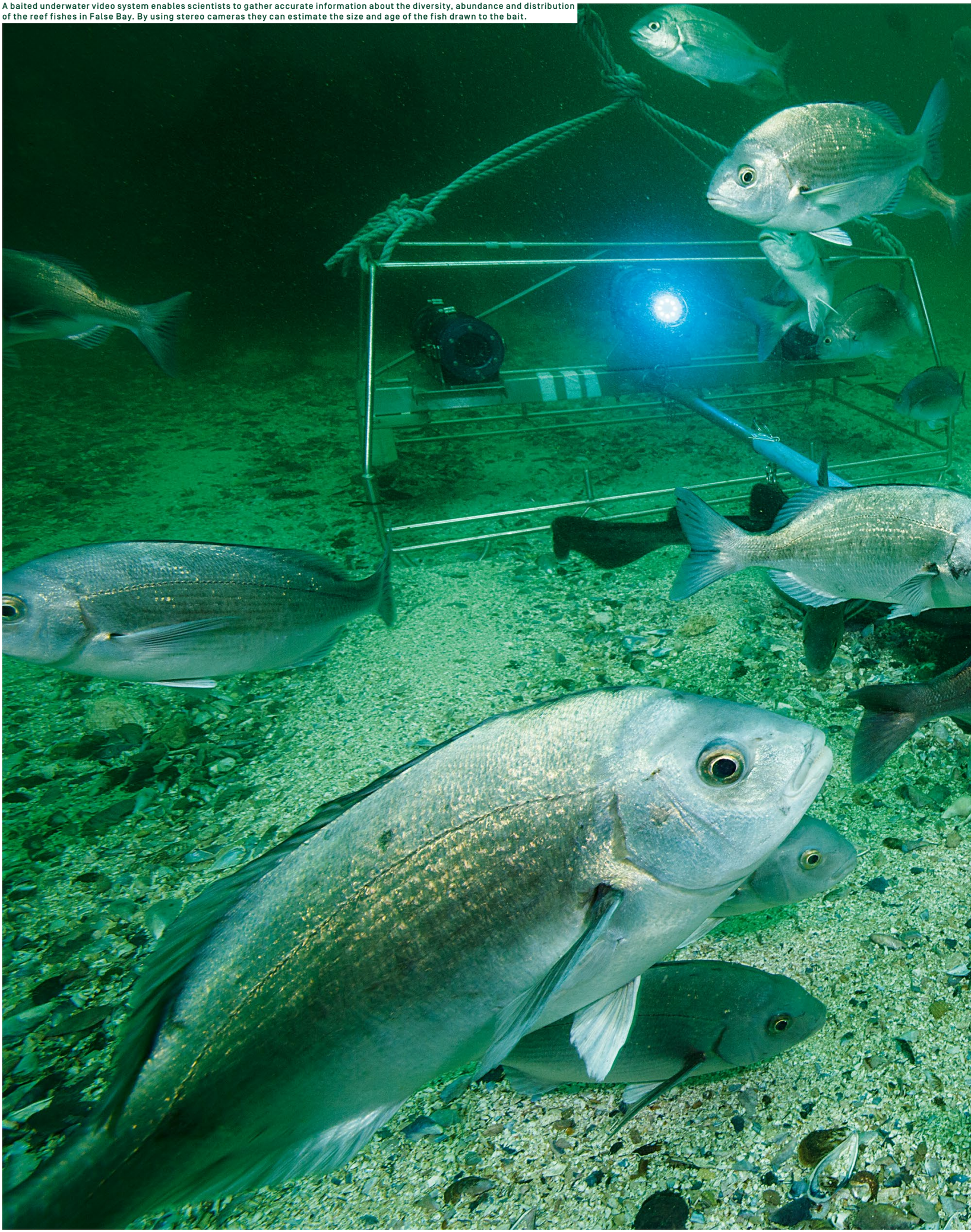


Disappearing diversity

South Africa's coastline is characterised by two formidable and opposing ocean currents. The cold, nutrient-rich Benguela meanders sluggishly along in the west, carrying an enormous biomass of fish that makes this one of the most productive marine regions on the plant. Although animals thrive in huge numbers, the ecosystem's unstable nature also means that relatively few species can survive here. In contrast, the warm Agulhas Current of the east coast is rich in biodiversity and many endemic species have found their niche within its swiftly flowing waters. False Bay is the battleground of these ocean titans where warm and cold waters swirl together to create a unique ecosystem that hosts a combination of fish species typical of both the warmer south coast and the icy west. Before fishermen began to exploit False Bay's reef fishes in earnest, legions of 'red' fishes – red steenbras, red stumpnose and red roman – were plentiful throughout the bay, but now they are seldom seen outside reserves. These are just three of a bewildering array of species; each is distinctive in appearance and behaviour, but they all exhibit complicated life histories that have brought them to the brink of disappearing altogether. Some live for nearly 50 years and only become sexually mature at the age of 10, others spend their entire lives defending their kingdom on a single reef, and many undergo a sex change at some point in their life.

A red roman caught just outside the Table Mountain National Park Marine Protected Area in Smitswinkel Bay. Populations of this seabream have been in decline from overfishing, but show a strong recovery in no-take marine protected areas.

A baited underwater video system enables scientists to gather accurate information about the diversity, abundance and distribution of the reef fishes in False Bay. By using stereo cameras they can estimate the size and age of the fish drawn to the bait.



It is not just law enforcers and fishermen who are responsible for the fate of False Bay's reef fishes. Fortunately, though, when it comes to consumer behaviour the outlook seems more hopeful. 'I used to buy a lot of roman, but I have to follow market trends. My restaurants are all at the high end so they're sort of trail blazers. They don't want that fish, so I can't sell it and I don't buy it,' Paul tells me. Gary Shungking, a local retailer, confirms that he too does not sell reef fishes and on the few occasions that customers ask for roman or red stumpnose, he tries to explain their conservation status. Both these fishes are listed as species to avoid on the Southern African Sustainable Seafood Initiative's (SASSI) responsible consumer guide.

However, there is still a demand. I called 11 fish shops, wholesalers and restaurants to ask if they stock reef fishes and while some were emphatic about their efforts to 'stick to the green list', seven of the 11 said that they stocked roman – and sometimes other threatened reef species – when it was available.

This is something that Lauren de Vos, a PhD student at the University of Cape Town (UCT) finds exasperating. 'People go to pieces for a panda, but they don't have the same empathy for something that has gills. Yet a red stumpnose has an equally interesting story,' she says. Months after my day at sea aboard the *Blue Starfish* I am back in False Bay, this time at the eastern end of the mouth with Lauren and her research crew. It is now mid-afternoon and the strengthening wind has turned the bay into a bubbly, white-flecked bouillabaisse, making it harder and harder to work.

Lauren is using underwater camera systems to create a biodiversity map of the bay. Today she has to get at least

another 10 camera drops done to make this trip worthwhile. We lift the rig and winch it into the air, ready for the next deployment. We release the camera and it breaks through the surface with a large splash, followed by 50 metres of rope all the way to the bottom of the bay. Her cameras work especially well for species that are resident and defend their territory, so they are perfect for reef fishes.

Colin Attwood, an associate professor of coastal fish ecology and fisheries at UCT and Lauren's supervisor, is skippering. 'For fish populations to recover properly you need a moratorium on fishing. Reef fishes recover so slowly that you only need to take a couple of fish off the reef every year and you will stop the recovery,' he explains. 'More areas of False Bay need to be closed to fishing, so a number of reefs need to be identified and shut off – not necessarily permanently, but to allow for recovery.'

If he is correct about these temporary fish recovery zones, Lauren's project could be key for saving False Bay's reef fishes. She hopes to contribute to better spatial planning in the bay by determining where biodiversity is greatest and the relative abundance of different species – including humans. By mapping out who is using the bay and why, she will be able to identify particularly vulnerable ecosystems, as well as potential conflict zones between us and the other animals we share the bay with.

'I'd like to think that False Bay is not beyond repair. It needs a reassessment of how its current MPA network is working, and a deeper look into the level of enforcement is called for,' Lauren explains. After a successful day of field work, we are bouncing our way home. I look towards Paulsberg and wonder where the line fishermen were today. False Bay's reef fishes are lucky to have Lauren on their side, but this is not a fight for conservationists on their own. Her project is part of a larger, complex and highly fraught situation. If red roman are to endure, all stakeholders, from desperate fishermen and under-resourced law enforcers to retailers and consumers, are going to have to take responsibility for the role they play.

Finally, we reach False Bay yacht club and after a long day on a rough ocean, Lauren's positivity is refreshing. 'My personal experience is that the interest and concern in False Bay is higher than I had expected and that's very heartening,' she smiles. The bay may be a sad example of how people have failed the natural environment on which they depend, but if conservationists like Lauren can foster cooperation between the right players, perhaps it could become a blueprint for how things can be done better in the future.

** Editor's note: The fishermen's names and the name of the vessel in this text have been changed to protect identities.*

← A hottentot seabream emerges from kelp in the Table Mountain National Park Marine Protected Area.

↓ Save Our Seas Foundation grantee Lauren de Vos uses baited underwater video systems to create a biodiversity map of False Bay.

With a growing network of marine protected areas, a new generation of South Africans like nine-year-old Laila Ntlahtlu will hopefully see a return of the country's iconic reef fishes to healthy numbers.

Artwork by Annika de Korte

FALSE BAY

SOUTH AFRICA

ANIMALS

1. Snoek
2. Spotted gully shark
3. Yellowtail
4. Red roman
5. Hottentot seabream
6. Pyjama shark
7. Sevengill shark
8. Penguins
9. Seagulls
10. White sharks
11. Cape fur seals
12. Eagle rays
13. St Joseph's shark
14. Bronze whaler
15. Shy shark
16. Dusky dolphins
17. Orcas
18. Red steenbras
19. Bryde's whale
20. Southern right whales

HABITATS

1. Rocky shoreline
2. Kelp
3 Sandy beaches
4. Rocky reef

ACTIVITIES

1. Scuba diving
2. Fishing
3. Shark Spotters
4. Surfing
5. Stand-up paddle-boarding
6. Beach-goers
7. Surf skiing
8. Trek-netting
9. Angling
10. Kite-boarding
11. Sailing
12. Snorkelling

BUILDINGS

1. Cape Point lighthouse
2. Naval base
3. Exclusion net
4. Kalk Bay harbour
5. SOSF Shark Education Centre
6. Shark Spotters information centre
7. Gordon's Bay harbour
8. Cape Hangklip lighthouse

MARINE PROTECTED AREAS

1. Paulsberg Restricted Zone
2. Castle Rock Restricted Zone
3. Boulders Restricted Zone
4. St James Restricted Zone
5. Helderberg Restricted Zone

1 cm = 1.5 km 1:150,000

0 1.5 3 4.5 6 7.5

Seeking san
Sharks in th

ctuary e Seychelles

James Lea and his team are learning about the significance of D'Arros and St Joseph for local shark populations – and how best to protect this critical habitat.

Words by James Lea

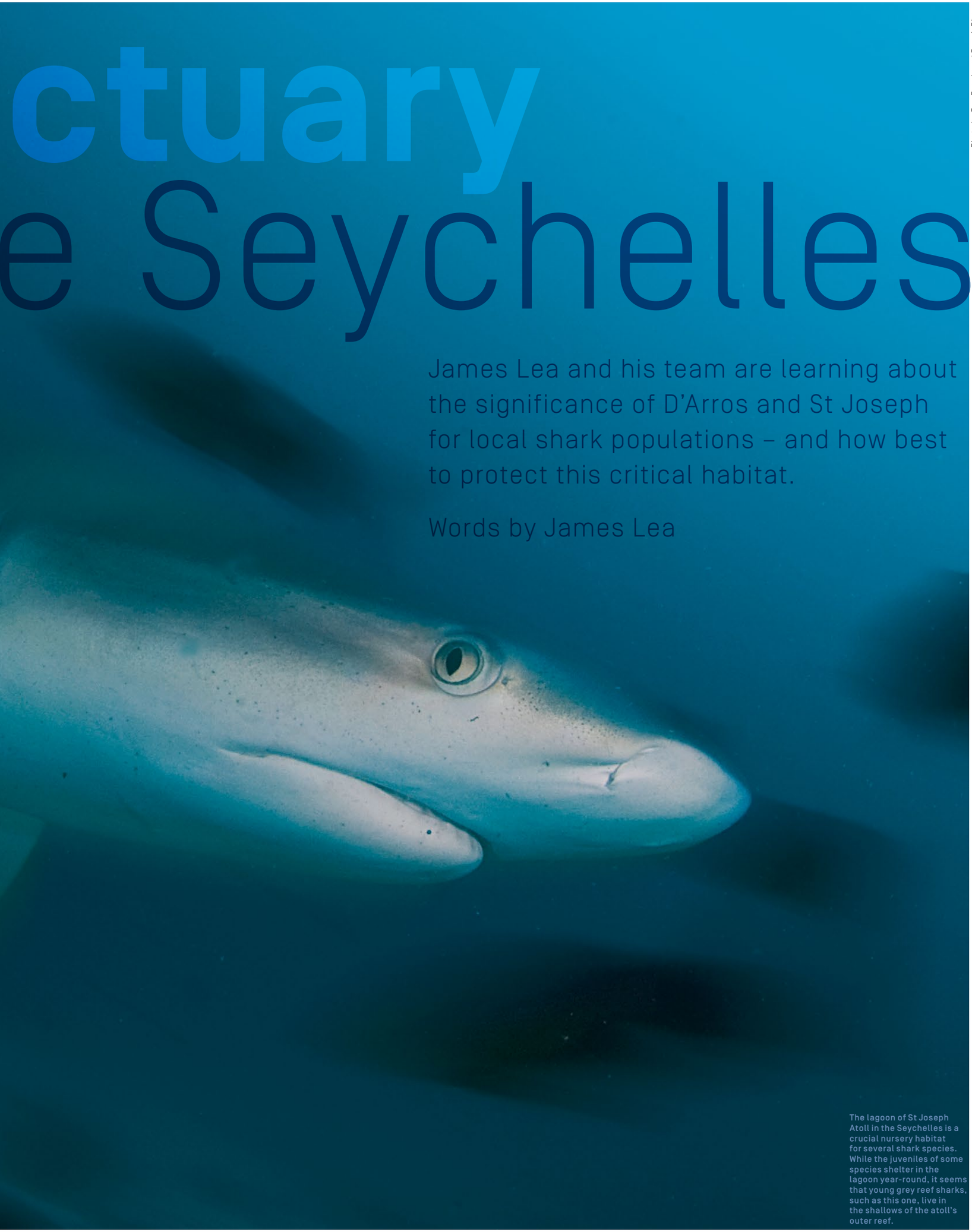


Photo by Dan Beecham | Danah Divers

The lagoon of St Joseph Atoll in the Seychelles is a crucial nursery habitat for several shark species. While the juveniles of some species shelter in the lagoon year-round, it seems that young grey reef sharks, such as this one, live in the shallows of the atoll's outer reef.

More than a thousand kilometres east of Africa, nestled within the vast Indian Ocean, lies a scattered archipelago of granitic islands and coral atolls: the Seychelles. The first recorded landing on the islands was in 1609 by the East India Company, passing by on international trade routes. Back then, the islands must have felt prehistoric, a primordial crucible boiling with life and ruled by ancient leviathans. Giant tortoises ambled across the rugged, harsh terrain and crocodiles lurked in the turbid coastal waters. Even dugongs, the alleged inspiration for mermaids among weary sailors, frequented the mangrove-fringed shallows. Early anecdotes refer to an abundance of large sharks; fishermen were stalked by hammerheads in the harbour, the burgeoning local turtle population was persistently harassed by hungry tiger sharks, and even great whites patrolled the inky depths.

But such abundant life has proved ephemeral in the wake of human settlement. Demand for meat from locals and passing traders has reduced the Seychelles' wildlife to a whispering shade of its former glory: crocodiles are now locally extinct, tortoises survive in only a few isolated spots and dugong sightings compete with a blue moon for frequency. Turtles were also hit hard, vanishing quickly as their meat and eggs were celebrated as local delicacies. But they were afforded full protection in 1994 and now the Seychelles once again hosts some of the largest turtle populations in the Indo-Pacific.

Sharks, however, have received no such reprieve. Traditional fisheries persist, supplying local demand for shark curries and chutneys, and their activities are exacerbated by increasing shark finning that supplies markets in the Far East. The information available suggests catastrophic declines in shark numbers, with larger species proving increasingly rare – the last recorded sighting of a white shark was more than 50 years ago. Without some sanctuary, the outlook is bleak for sharks in the Seychelles.

Yet all is not lost. Some refuges remain, providing piercing glimmers of hope for a broader recovery. One is the World Heritage Site of Aldabra, a large, isolated atoll that is protected from all fishing. It harbours an abundance of sharks, turtles, tortoises – and the last remaining dugongs in the Seychelles. Another is the comparatively small island of D'Arros and the associated atoll St Joseph in the Amirantes. St Joseph contains a shallow lagoon, no more than a few kilometres long, that can be accessed only at high tide. Although modest in size, such an access-restricted lagoon is rare and critical habitat in the Seychelles, providing sanctuary to a whole variety of sharks, turtles and rays, among other marine creatures.

Unfortunately, D'Arros and St Joseph do not enjoy the luxury of protection that Aldabra does, and they continue to suffer fishing pressure. Although the occurrences are uncommon, boats have been recorded finning sharks even within the inner sanctum of the lagoon. This is a grave concern, as predators like sharks are highly valuable not only for ecosystem stability, but also commercially, in fisheries and tourism. Losing predators from an ecosystem can have devastating, unpredictable consequences on community structure, as prey species are released from both the pressure and the risk of predation. In order to appreciate the true value of D'Arros and St Joseph and how to best manage their biological wealth, it is first necessary to understand the behaviour and ecology of their inhabitants.

In August 2012 D'Arros and St Joseph came under the management of the Save Our Seas Foundation (SOSF), with the explicit intention of safeguarding the health and stability of the local marine ecosystem. Just as it's not possible to keep your car running smoothly without some idea of how it works, decisions about managing the marine environment have to be based on an accurate understanding of the ecosystem. Accordingly, the SOSF initiated various projects through the D'Arros Research Centre to study the behaviour and ecology of numerous species around D'Arros and St Joseph, with the ultimate aim of establishing a marine protected area (MPA). Within this broader remit I study the local sharks, which are of particular interest due to their important role as influential predators and the fact that this role is jeopardised by ever-present fishing pressure.

The essence of my work is trying to discover which sharks go where, when and why. It sounds simple but, because of the concealing nature of the marine environment, we do not have even basic information such as this for most shark species. Understanding their movement behaviour is critical for evaluating how effective certain management measures, such as an MPA, might be. So my primary objective has been to track the long-term movements of as many different sharks as possible. This will help develop a comprehensive understanding of how the sharks use the varied habitats around D'Arros and St Joseph, and whether there are any particularly important areas or times on which management efforts should focus.

So how do we find out who goes where, when and why? Logistically, sharks are somewhat difficult to follow and observe, so we have to adopt alternative methods. Fortunately, remote sensing techniques have developed to the point where we can follow the sharks autonomously – we just have to catch them first. This primarily involves a generous amount of patience, and perhaps a few too many biscuits. When a shark is eventually caught (typically interrupting biscuit consumption), the research team and I carefully bring it up to the surface. Once it is alongside our research boat, we roll the shark over onto its back, facing belly up. In this upside-down position the shark enters a trance-like state called tonic immobility, in which it ceases to respond to most stimuli. This biological quirk makes the subsequent work-up significantly easier for us and safer for the shark, as we then implant an acoustic transmitter under its skin.

James Lea has worked with sharks in locations across the Indian Ocean, but he thinks D'Arros Island and St Joseph Atoll could offer a special refuge for sharks. Here he tags and measures a silky shark in the Red Sea.

Photo by Dan Beecham | Danah Divers

Each acoustic transmitter, or tag, continually transmits a unique identification code for up to 10 years, using ultrasonic pings. When the shark has been tagged and had its measurements and gender recorded, we roll it back over so that it can come out of tonic immobility and be released. As the tagged shark then moves around the islands, its unique code will be recorded whenever it passes one of the many underwater acoustic receivers we have deployed around D'Arros and St Joseph and across the Amirantes. When we then download the data from these receivers we can reconstruct the movements to discover where the sharks have been.

In this way, we are currently tracking more than 100 different sharks of various sizes and species, including blacktip reef, sicklefin lemon, grey reef and tawny nurse sharks, among others. To date we have more than two years' worth of track data, which give us unique insight into the sharks' private lives. One of our main discoveries is just how important the coastal habitats of D'Arros and St Joseph appear to be for these sharks. In particular, I can now identify the access-restricted refuge of the St Joseph lagoon as a crucial nursery habitat for several species: juvenile sicklefin lemon, blacktip reef and tawny nurse sharks shelter in the lagoon all year and for several years. The lagoon is an idyllic nursery for young, vulnerable sharks, providing both shelter from predators, because of the access-restricted shallows, and an abundance of prey, such as juvenile reef fish, rays and crustaceans. Although not in the lagoon, juvenile grey reef sharks appear to live just along the shallows of the atoll's outer reef.

This year-round residency of various shark species highlights St Joseph as an invaluable nursery, which may be critical for recruitment into the regional shark populations. In contrast to the tracked juveniles, the adults of most species tend to range more widely. For instance, we have recorded sicklefin lemon sharks moving to other islands up to 80 kilometres away from D'Arros, and adult grey reef sharks seem to range predominantly along offshore reefs.

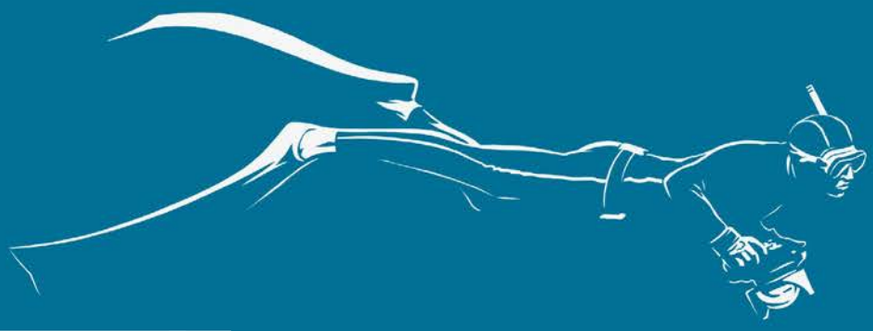
At D'Arros Island, blacktip reef sharks cruise around the shallows. While the number of sharks has declined drastically in other parts of the Seychelles, this island has been able to offer a partial refuge for sharks due to its remoteness.

So how can we use these data to plan and inform potential management strategies? One way is to assess how effective certain MPA designs might be. D'Arros and St Joseph are relatively small and isolated, so it is feasible that an MPA of moderate size could be enforced with relative ease. Aldabra, the World Heritage Site with the most comprehensive protection in the Seychelles, possesses a no-fishing exclusion zone that extends one kilometre from the high-tide mark. Using this as a reference, a similar MPA at D'Arros would provide reasonable coverage of overall shark movements, ranging from 40 to 90%, depending on the species. However, the large reef flats associated with St Joseph mean that a boundary measured one kilometre from high tide would not even cover all of the lagoon, and wouldn't fall far beyond the reef edge. Consequently the sharks, including the juveniles, would continue to cross the boundaries and remain vulnerable to fishing, even within the lagoon.

To combat this, we tried setting the boundaries at one kilometre from the low-tide mark, when the reef flat is exposed, instead of the high-tide mark. Although it's only a small variation in definition, it provides a large boost to the protection afforded: now 70–99% of overall shark movements would be encompassed by the MPA, with all tracked juveniles spending at least 95% of their time within its boundaries. However, the larger sharks tend to range more broadly so they would still be frequently exposed to fishing pressure, a risk starkly realised by the capture of a tagged individual 80 kilometres from D'Arros at the island of Marie-Louise. Consequently, any MPA must be coupled with broader fisheries management strategies, such as catch quotas, size limits and time/area closures, if it is to be effective. There would be limited benefit in protecting juveniles to maturity, just for them to be caught as they start to range more widely.

Our work is ongoing and there is still much to learn, but it is becoming clear that D'Arros and St Joseph play an important role in the nursing of juvenile sharks to maturity and that this role is jeopardised by ongoing fishing pressure. Through the stewardship of the D'Arros Research Centre and the development of an MPA, D'Arros can become a true sanctuary for sharks in the Seychelles: a bastion from which a broader, regional recovery can be seeded, enabling the islands to aspire to their former majesty.

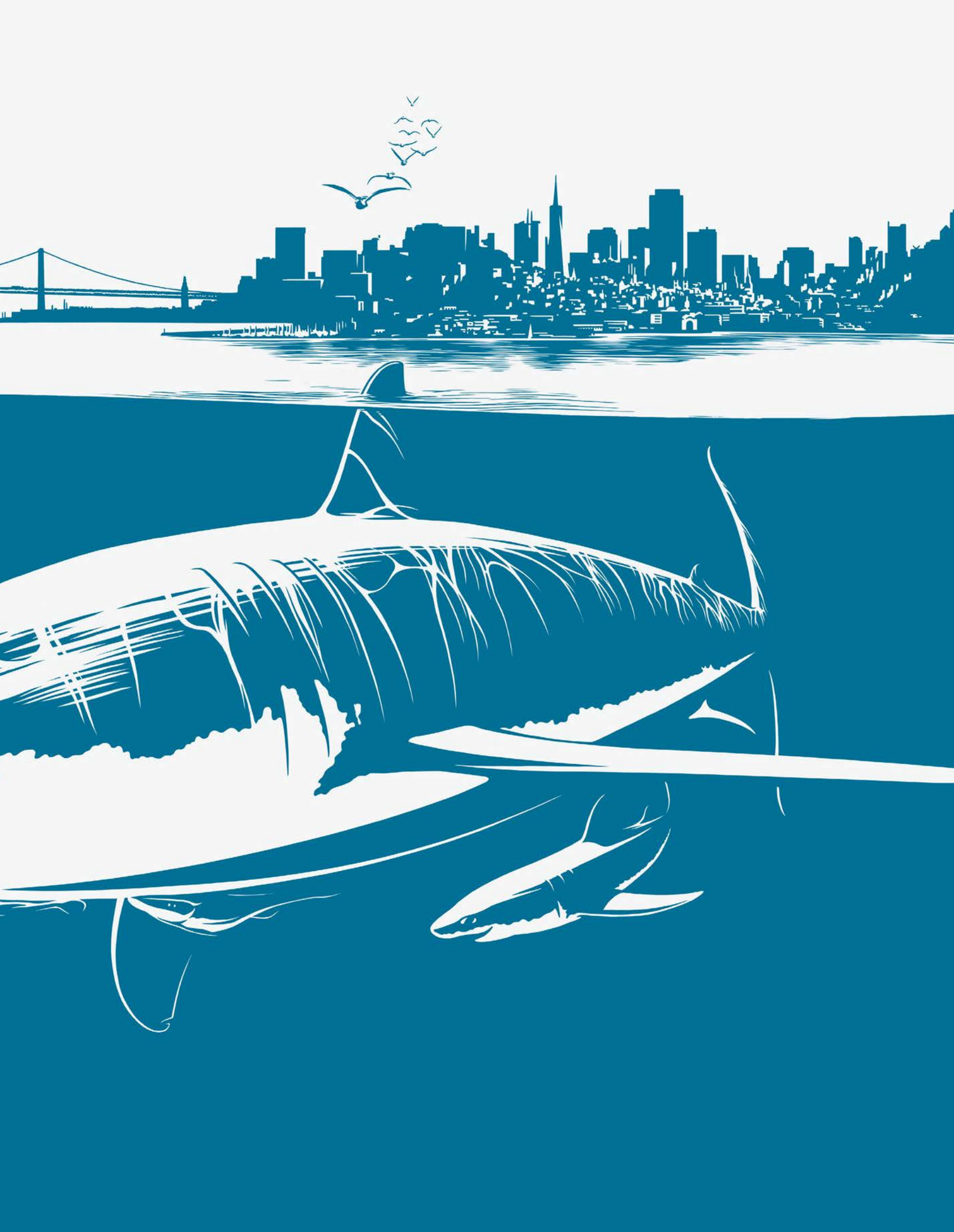
Photo by Byron Dilkes | Danah Divers



Good science & recognising recoveries

Chris Lowe takes a close look at the relationship between science, the media and the public and asks whether 'the-sky-is-falling' science is really the only solution for elasmobranch conservation.

Words by Chris Lowe
Illustrations by Gregory Gilbert-Lodge



The rise of the environmental revolution

A rising human population coupled with a focus on increasing economic growth has resulted in severe impacts on our environment, and the challenges of dealing with these impacts have been battled for decades in many countries, both developing and developed. It was in the early 1960s that scientists like Rachel Carson started sounding the alarm about how pollution, overfishing and the destruction of habitat were greatly affecting our environment and the organisms within it, kicking off what many refer to as the 'environmental revolution'. This brought forth a new form of activism, one that would highlight the largely ignored creep towards loss of ecosystem function and greatly reduced wildlife populations. Some of the impacts on the environment were clearly visible, yet science still needed to generate sufficient concern among the public – and policy-makers – to stimulate change. Thus the relationship between science, the media and the public became further entwined.

A case in point is the fisheries in the USA and abroad, where sharks, rays and skates – collectively known as elasmobranchs – faced many of the same problems that most other targeted favourites, such as cod, swordfish and tuna, faced. Many elasmobranch fisheries in the USA started when fisheries managers encouraged fishers to switch from an already-depleted species to an 'underutilised' one. Because one fisher's trash is another's treasure, most elasmobranch fisheries evolved from being discarded by-catch (trash) to a target (treasure) with the help of new markets. While this strategy helped take pressure off overfished stocks, the distinct lack of basic life-history information for most elasmobranch species led many of these new fisheries down the same path as that of the past – only faster.

By the early 1980s scientists were becoming concerned about rapidly declining catch rates and growing market demand for elasmobranch products. Generating sufficient concern for declining elasmobranch populations was difficult, however, due to a lack of science and the public's perception of sharks as dangerous animals. In addition, the declines occurred during what many consider to have been the nadir of environmental health in the USA (the 1940s to 1990s), a period when there were minimal regulations regarding water or air quality, wetland protection or safeguarding fisheries.

'By 2010 up to 30% of all scientific papers published on elasmobranchs mentioned population declines, regardless of the research topic'

Recognising the problem

It wasn't until the early 1980s that the first studies describing population declines in elasmobranchs and the impacts of overfishing these species came to the scientific mainstream. Between 1980 and 1985, elasmobranch population declines were mentioned in an annual average of 43 scientific papers, the vast majority of which attributed direct or indirect fishing as the primary cause. Unfortunately, by 2010 this trend had greatly increased to more than 240 papers per year. Once again, it was a dedicated group of scientists (Jack Musick, Sonny Gruber, Bob Hueter, Merry Camhi, George Burgess, Enric Cortés, Greg Cailliet, Nick Dulvy, Sonja Fordham, Dave Ebert and Colin Simpfendorfer, to name just a few) who started sounding the alarm, making managers and policy-makers aware of the rapidly growing problem for some elasmobranch populations and the primary causes of the declines.

Despite the challenges of persuading a historically 'elasmophobic' public to care about these trends, the media has played a major role in disseminating bits and pieces of scientific information to the public. Slowly, better knowledge has helped change attitudes towards sharks and – to a much smaller extent – their flat cousins, the rays. In addition, since the public seems to have an innate fascination for 'doom and gloom' stories, its growing interest in all things shark-related has further fuelled mass media interest in the plight of shark populations. The rise in public and media interest is closely related to the increased focus from a wide array of elasmobranch conservation organisations, many of which religiously sound alarm bells, but often without any need or use for the supporting science.

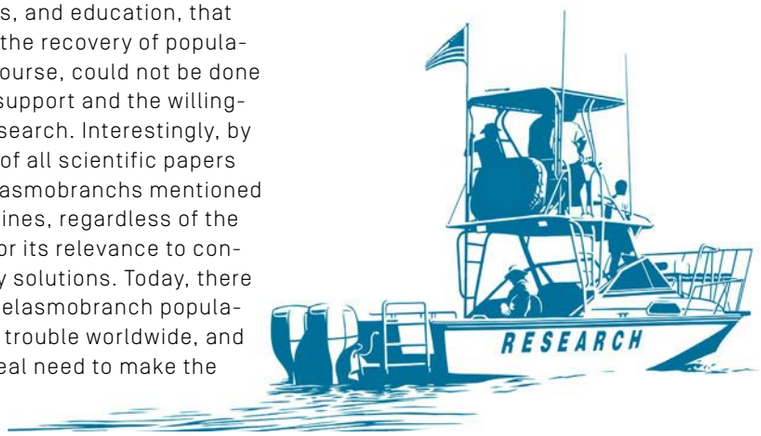
Not unlike other environmental problems of the past, it was primarily the scientific community that brought to light issues of elasmobranch depletion, focusing research in ways that would provide managers and legislators with the invaluable information they needed for strategies, and education, that would promote the recovery of populations. This, of course, could not be done without public support and the willingness to fund research. Interestingly, by 2010 up to 30% of all scientific papers published on elasmobranchs mentioned population declines, regardless of the research topic or its relevance to concrete regulatory solutions. Today, there are still a lot of elasmobranch populations in serious trouble worldwide, and there is still a real need to make the public and policy-makers more aware of the problems. But at what point does this become more of an operational business model than a science-based conservation effort?

Has conservation worked?

Although it has been great to see elasmobranchs get more and more positive attention over the past few decades and to watch people worldwide voice concern for elasmobranch populations, unfortunately the prevailing message from many conservation groups is that only the more charismatic species are in trouble and worthy of protection. Often the solution they put forward is a ban on fishing.

According to Sonja Fordham of Shark Advocates International, dozens of regional, national and international regulatory actions have been put in place over the past 20 years for the specific purpose of better protecting elasmobranch populations – and they don't include the dozens of major ecosystem-level protection measures enacted. Yet there has been surprisingly little mention of or attention paid to the success of these past regulations that have been dedicated to aiding the recovery of populations in trouble, or those deemed most vulnerable. Is that because all the previous conservation efforts have failed? Or perhaps because not enough time has passed to tell whether they're working? Or is it because some have worked and no one really cares to hear about them because their success doesn't lead to profitable conservation?

We all know that because of the special life-history characteristics of elasmobranchs, it's quite easy to fish them down quickly, but it can take decades or even a century for a reduced population to recover. It's hard to imagine that all that legislation, regulation and public education has had no effect on the recovery of populations.



Recovery right under our noses

Falling into the 'sharks-are-in-trouble' mindset is easy to understand, but it is surprising to see how it can affect your thinking as a scientist and how it might affect your interpretation of data. As an elasmobranch scientist for 25 years, I had come to expect to see signs of human-induced environmental decay, pollution and overfishing and the resulting negative impacts on populations, especially along the highly populated coastline of Los Angeles, California.

In 2002, my students and I began a collaborative project with Monterey Bay Aquarium in which we studied juvenile white sharks in southern California as part of the aquarium's white shark conservation research programme. We had heard that gill-net fishers in southern California would occasionally catch young-of-the-year and juvenile white sharks in their nets. We arranged a collaboration with willing fishers to bring incidentally caught juvenile white sharks back to the dock so we could assess their condition and measure, tag and release them offshore. Our primary goal was to determine whether sharks could survive being caught in a gill net. Secondly, we wanted to figure out where they went after being released.

At the same time, my students conducted an exhaustive survey of scientific and fishery records going back to the 1930s to determine how white sharks interacted with recreational and commercial fisheries in southern California. Fisheries data of this nature inevitably have problems and biases, yet despite these a surprising trend began to emerge. It suggested that a growing number of juvenile white sharks were being incidentally caught each year, even though there had been a significant reduction in overall gill-net effort due to increased regulation and reduced fleet size. A trend showing an increasing catch per unit effort typically suggests a population increase. However, I was still in the 'sharks-are-in-trouble' mindset and my initial reaction to the data was disbelief. Moreover, other researchers who were studying part of the adult population of white sharks off central California were arguing that the population was dangerously low, which stimulated several conservation organisations to submit petitions to the state and federal governments to list white sharks under their respective Endangered Species Acts.

How could the most enigmatic shark species be increasing in number off the coast of California with all its problems – habitat loss, pollution, overfishing and 28 million people? It just didn't seem possible. That was until I began to assume the trend was real and consider how the population could increase.

White sharks have been protected from fishing in California since 1994 (fishers cannot land or sell them) and throughout the US Pacific since 2005. Our catch-and-release data showed that 94% of the sharks found alive in gill nets could survive if carefully released. This was great news, and likely helps to explain the increase in incidental catch rates. But is protection from just fishing enough to enable a population to recover?

Surviving fishery encounters is one thing, but if there aren't sufficient food resources, most white sharks would starve or leave the area. There is growing evidence that populations of marine mammals are making remarkable recoveries off California and the eastern Pacific due to better protection, and of course adult white sharks feed heavily on pinnipeds and cetaceans. So the recovery of the marine mammal populations should certainly benefit the white sharks. Healthy marine mammal populations require a stable food source, in addition to protection from fisheries. Most of our pinnipeds feed on the same prey items as juvenile white sharks (squid and fin fishes), so it's likely that improved fisheries management has allowed these prey populations to remain at high enough levels to sustain these growing populations of marine mammals and juvenile white sharks. In addition, coastal predators and their food are all dependent on water quality, which has improved significantly along the California coastline since the 1970s.

As I worked my way through the ecosystem data comparing trends over the past 40 years, I began to see that it had been possible for the white shark population to increase as the figures suggested, but such improvement has required much more than just fisheries protection for this particular species. In addition, my preconceived notions that all sharks are in trouble blinded me from actually seeing signs of recovery and it made me wonder why others aren't seeing these signs as well.

Let's not lose sight of success

I was shocked at how this research changed my attitude and perspective on science, but pleased that it gave me renewed hope for the future. I think it's easy to forget how alarming, yet well-founded science can prompt hard-fought legislation, which can result in restoring coastal oceans and protecting populations for the future. Many do not remember, or simply weren't around to experience, the days prior to the Clean Air Act (1970), Clean Water Act (1971), Marine Mammal Protection Act (1973), Endangered Species Act (1973) and Magnuson-Stevens Act (1996), and what the ocean was like then. I can assure you that, at least in California, things are a lot better now than they were in the 1970s – and, surprisingly, with three times more people living along the coastline. To me, that is truly a testament to the fact that people care and are willing to sacrifice and pay for a cleaner, healthier ocean.

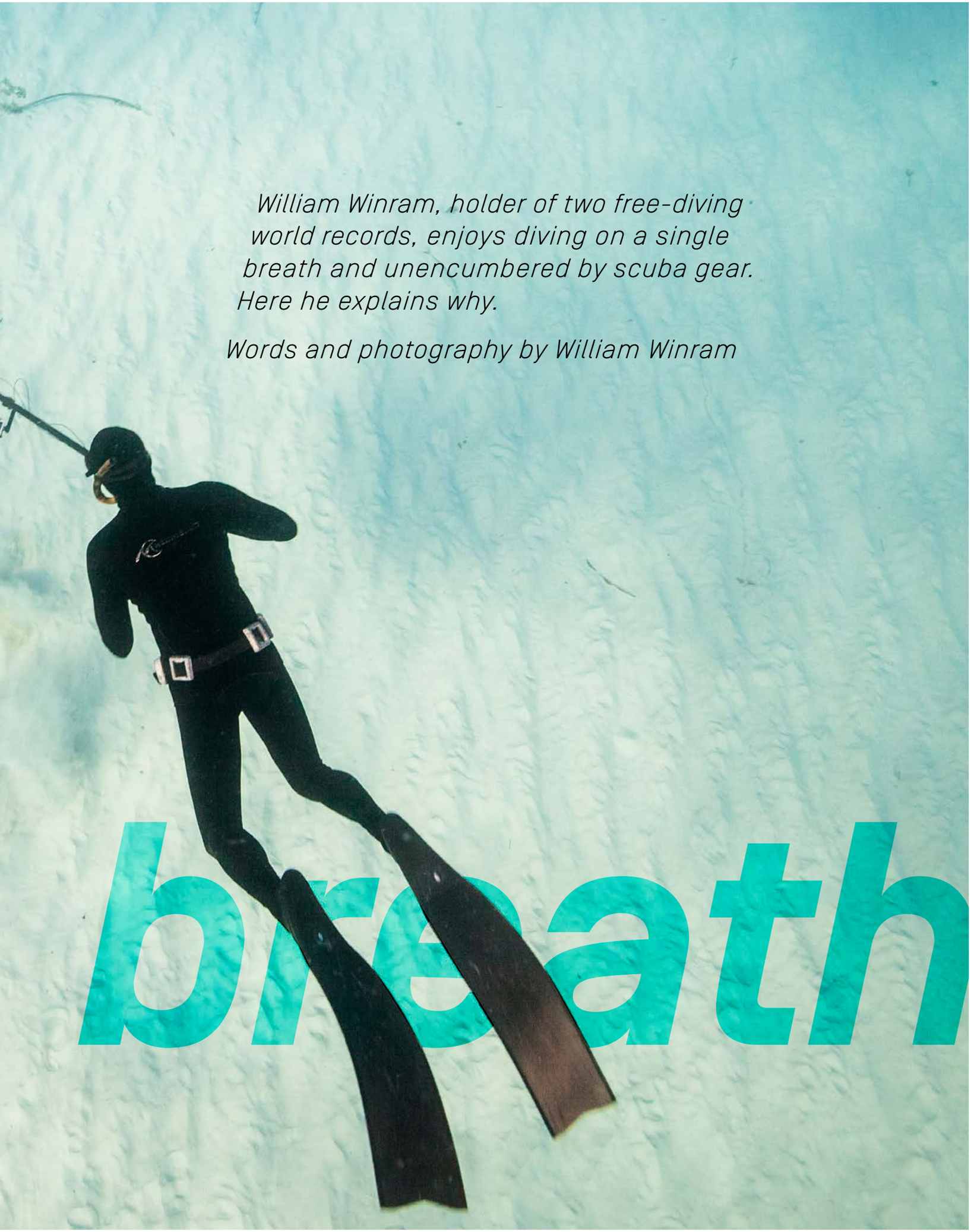
While sounding the alarm is necessary and will always be needed to promote change and conservation, I worry about its effect on how we do science. I see an unfortunate trend where the best way to make our science important and relevant is to focus on 'the-sky-is-falling' issues. Of the past 20 elasmobranch-related grant proposals and manuscripts I've reviewed, more than 80% have resorted to 'the sky-is-falling' statements to justify the importance their research, regardless of whether they offered a concrete remedy. In addition, there are already signs of 'the-sky-is-falling' science having the undesired effect of generating hopelessness among the public and, more disturbingly, among legislators. Crying wolf without good cause is weakening managers' ability to implement adequate strategies. If we can't demonstrate improvement after all that regulation, then how long will it be before some people try to reverse the regulation for nothing more than economic gain?

Good science should be what dictates policy, irrespective of the implications and conservation mantra, and we should be very wary of the 'the sky-is-falling' science business model. Right now we need more scientists looking for signs of recovery because that is what we should expect if all our previous efforts have been working. And if we don't see recovery, then we need to think seriously about developing new strategies.

'I was still in the "sharks-are-in-trouble" mindset and my initial reaction to the data was disbelief'

Using breath-hold diving, also known as free-diving, divers can move quietly and efficiently through the water. These qualities make the technique particularly suitable for tagging sharks, especially sensitive ones like this great hammerhead.

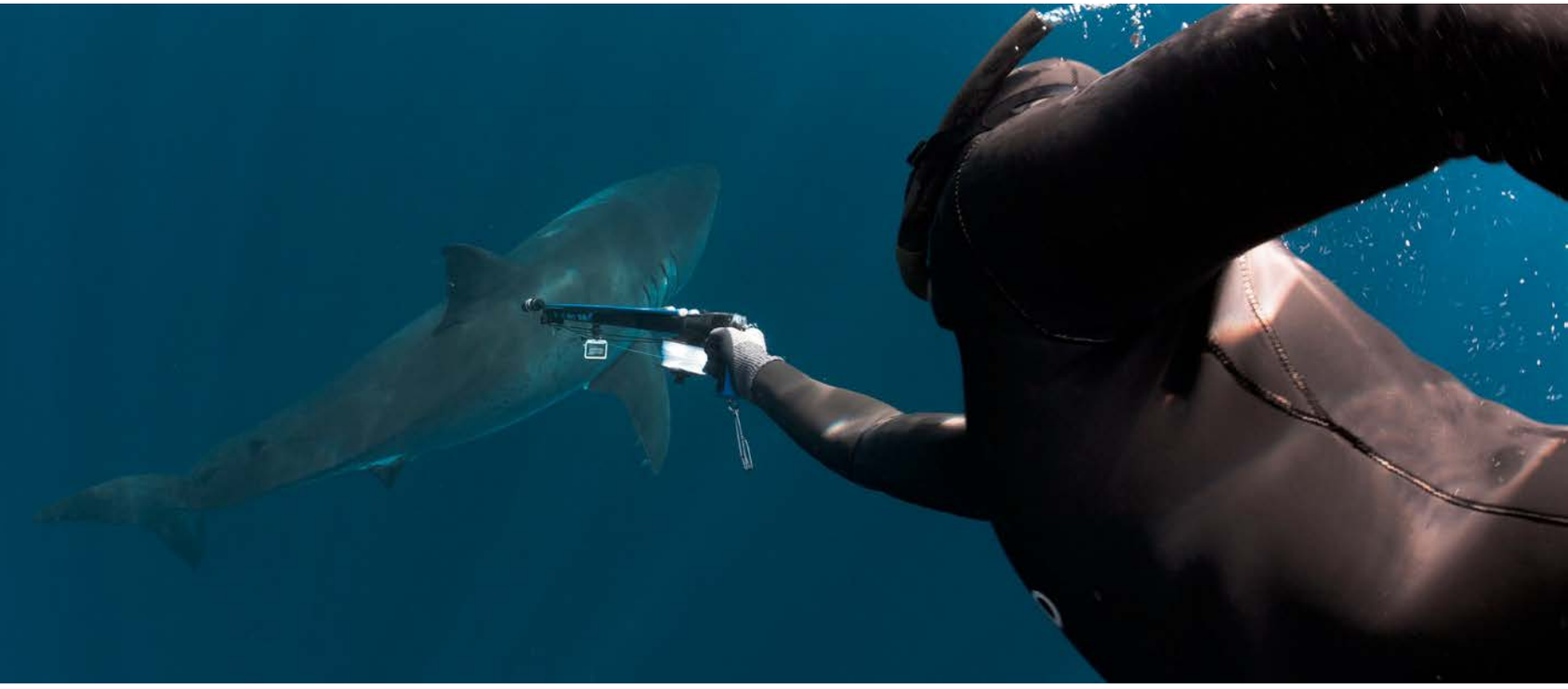
On one



breath

William Winram, holder of two free-diving world records, enjoys diving on a single breath and unencumbered by scuba gear. Here he explains why.

Words and photography by William Winram



↑ William Winram silently closes in on a great white shark with a spear gun used for tagging. In addition to silence and efficiency, another advantage of free-diving is that it doesn't put the lives of the sharks at risk.

→ Free-diving allows divers to approach sharks more peacefully and less intrusively. This great white shark at Guadalupe Island, Mexico, seems unconcerned by the diver swimming next to it.

Free-diving or breath-hold diving has been around for hundreds, perhaps even thousands, of years. It is our most ancient means to enter the sea to hunt and gather what we need. Personally, I started diving on a single breath of air more than 40 years ago. I began by holding onto my father's neck when he swam underwater in the swimming pool. This progressed to my first introduction to diving in the sea while on vacation at age seven in Hawaii. From then on my father, a scuba instructor and search-and-rescue diver, began to teach my brother and me how to free-dive and, eventually, to scuba-dive.

His rationale for starting with free-diving was that it developed a level of skill and understanding of the aquatic environment that would be of great benefit to divers when they donned a tank and regulator at a later stage. He also argued that although free-diving was simpler in terms of the equipment required, it was more complicated in the physical effort and technique needed to be proficient. The investment made in learning to free-dive well would make for much easier diving on scuba later.

My father said too that free-diving instils in you a greater respect for the underwater world and that respect would foster a desire to look after the sea and preserve it for the future. It turns out he was right. I have taught countless scuba-divers to free-dive and although not all of them continued after the course, they all said how invaluable it was to learn the basic skills and breathing techniques because it made them more efficient at breathing and thus improved their experience on scuba. At the same time, it gave them a greater appreciation for the sea.

I am of the opinion that all forms of diving have their place, whether they be used for sport and recreation or for conservation. Rebreather diving, mixed-gas diving, diving on air and free-diving all have their strengths and weaknesses, risks and rewards. What I would like to share here is my perspective as someone who is certified for advanced open-water scuba-diving, but who primarily uses free-diving as an active tool either to explore and discover our underwater world or to aid scientific research – or both.

When teaching free-diving, I often speak of a 'sense of belonging'. There is an innate sense that we belong in the sea when we are diving below its surface on a single breath of air. Some people describe it as a feeling of connection to our ancestry or other marine mammals, but whether or not this is so, that sense of belonging is indisputable: we do, in fact, belong in the sea. After all, we have the same physiological response to it that other marine mammals have.

Like dolphins, whales, seals and other marine mammals, we have what is known as a 'mammalian diving reflex'. This reflex activates when you put your face in the water. It slows the heart rate, shunts or moves the blood from the arms and legs to the body core and causes the spleen to release old red blood cells back into circulation. Oxygenated blood is prioritised for the heart and brain as they are crucial to our survival; the other organs are temporarily put on hold as the body attempts to safely prolong your time under the water.

The strength of the dive reflex differs from person to person, depending on how often they dive and for how many years they have done so. The fact that we all have it is, for me, evidence that we are meant to enter the sea on a single breath of air.

As you practise free-diving mindfully, you will improve your ability to move in the water and to navigate the aquatic world quietly and proficiently – and that will give you the opportunity to discover new experiences and encounters you would not otherwise have. In addition, my experience over the years has shown that often when I am free-diving, marine animals approach me because I am on a breath-hold. Their curiosity at the strange spectacle of a human in the water overcomes their fear and they will approach me as if to get a closer look.

When you have achieved this level of quiet proficiency in free-diving, your ability to approach certain species will go beyond what is possible when you are scuba-diving. Many marine creatures view the release of bubbles (which is unavoidable in scuba-diving) as a form of aggression. A closed-circuit rebreather will solve the problem of the bubbles, but you then lose mobility and speed in the water, both of which are necessary for certain applications of free-diving.

Practically speaking, at a certain level of competency you lower your footprint in the sea. You are able to move as silently and efficiently as a human can in the underwater world. This allows you to approach marine creatures that are shy and elusive, such as the scalloped hammerhead shark *Sphyrna lewini*.

I choose free-diving because I like the simplicity of it. All I need is a mask, snorkel and fins, along with a weighted belt and a wetsuit. I also choose free-diving because there are a myriad of useful applications for it that can fulfil a need when it comes to scientific research and conservation. For instance, in remote atolls and regions where the infrastructure to refill tanks is not available or where the expedition does not have a boat with the requisite compressor or other equipment, the simplicity of free-diving enables the scientific team to conduct its research despite the lack of scuba tanks. Over the years I have met many scientists who free-dive in such situations, initially because they had no other option but then because they grew to appreciate its advantages.

Another example of a good application of free-diving skills is the tagging of sharks, and there are several aspects to the technique that lend themselves to this work. As a free-diver you move freely within the water column, descending to depth and, because you need to breathe, returning to the surface over and over again. While either descending or ascending you can easily change your trajectory in order to cross paths with an animal you wish to tag; you can adjust your depth freely within the limits of your breath-hold and depending on the shark's movements. On a breath-hold, you are also able to move much more quickly in the water – and much more quietly. By comparison, on scuba you can move neither quickly nor quietly in a lateral direction because of the bulky equipment, and moving up and down fast and at depth will greatly increase your risk of a decompression accident.

When we free-dive to tag, there is a certain depth at which, due to the compression, we no longer float and we sink instead. This enables us to drop silently, maintaining a hydrodynamic form as we descend, and by making small movements of a hand or a fin to change the direction of descent we are able to sneak up on an unsuspecting candidate for a tag. This technique is particularly useful when dealing with extremely shy sharks like the scalloped hammerhead.

We employed this method when tagging scalloped hammerheads at the island of Malpelo in the Eastern Pacific in 2008 and again in the Revillagigedo Archipelago off Mexico in 2013. In the latter location, I was helping Dr Mauricio Hoyos, who had been unable to tag the species there for the past five years. As he explained, 'It seems the bubbles and noise of scuba scares them off and does not allow me to get close enough to place a tag.' Although the diving conditions proved difficult, with an extremely heavy current and the sharks staying below 20 metres, I still managed to place 10 tags in six days.

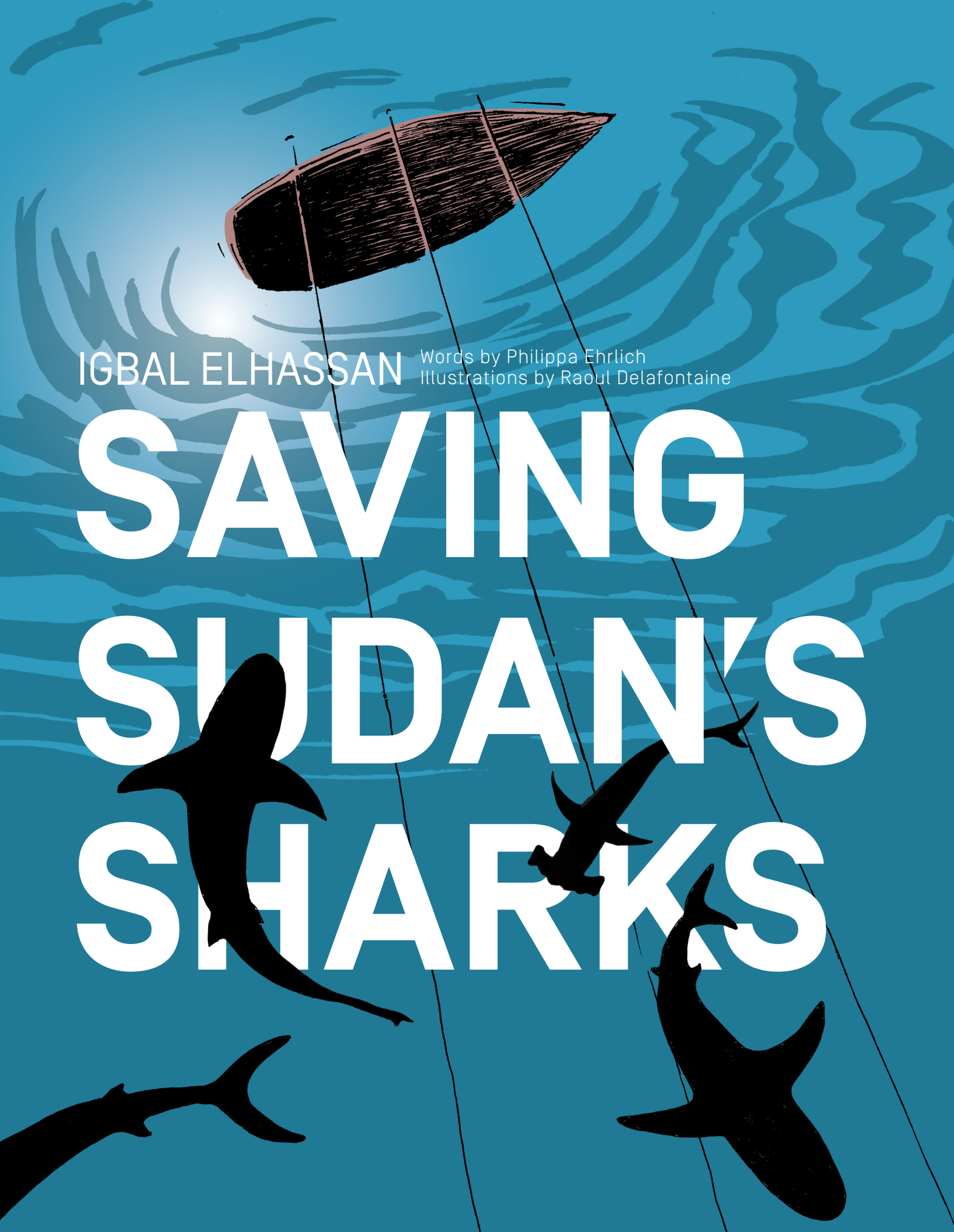
Another advantage of free-diving is that the shark's life is not put at risk. Hammerheads are very fragile species and it has been scientifically demonstrated that they seldom survive the stress of being caught on a hook and line, and long-lines in particular result in very high mortality rates.

Typically, during tagging and biopsy work we try to work in a group of three: one tagging, one photographing or filming, and the third ensuring our safety by keeping a look out for other animals and boats. This is particularly necessary when working with a species like the great white shark *Carcharodon carcharias,* but it's ideal for all other species too. Taking photographs while we work enables us to bring back images of the tagging process and of the animals, each of which bears unique markings or patterns on their bodies (such as fin shape or skin pigmentation) that help us to identify it again later.

Using a modified spear gun while on a breath-hold is the least intrusive method of tagging. As a free-diver, I can move silently towards the shark, aim for the area next to its dorsal fin and fire the spear shaft, which penetrates the skin to a depth of a few centimetres. As the shaft releases when the animal swims off, the dart and transmitter are left behind. The skin heals in 48 to 72 hours and we usually see the animals returning within a few minutes to a few hours.

With the current decline in shark populations and in the overall health of our oceans, it is imperative that we find ways to study these animals that minimise or erase the risk that they will be killed in the process. For this reason, tagging while free-diving is an important addition to the scientific repertoire.

For more information, please visit: TheWatermen.org



IGBAL ELHASSAN

Words by Philippa Ehrlich
Illustrations by Raoul Delafontaine

SAVING SUDAN'S SHARKS

The Sudanese coastline has a rare treasure – one of the few remaining communities of healthy shark populations. Igbal Elhassan is on a mission to keep it that way.

When Igbal Elhassan chose to study sharks for her Master's degree, it was not because she loved them. In her home country, as in most of the world, they had a bad reputation. Fortunately for the sharks that range along Sudan's 750-kilometre coastline, the late Abu Gederi, a professor at the University of Khartoum, pushed her to study them and, 11 years later, she is Sudan's only specialist shark scientist. Single-handedly Igbal has painted the first picture we have of the country's diverse and unusually healthy shark populations. At the same time, exposure to the plight of these formidable creatures has transformed her fear of them into deep compassion and ignited a steely determination in her.

'You know, there are other women doing marine biology and oceanic studies of the Red Sea, but I don't think there is another one who goes out on boats,' laughs Igbal as she describes her first sampling trip aboard a commercial long-liner during her Master's research in 2001. This was the first time that she had ever seen a real-life shark. 'I couldn't believe it. They caught these huge tiger sharks and oceanic whitetips. I wasn't afraid. I was just astonished by their size. I also felt truly sad to see them brought aboard alive and then killed for their liver and fins. Those were horrible moments for me.'

Igbal completed her Master's degree in 2002. The first study on sharks in the waters of Sudan and neighbouring countries, it investigated the socio-economic

aspects of the local fishery as well as basic biological traits of sharks in the region. She identified 23 shark species, including significant populations of oceanic whitetip, grey reef, hammerhead and spot-tail sharks, as well as three species of batoids (rays, skates and sawfishes), including green sawfishes. She also determined the geographical distribution of these species, as well as their mating and pupping seasons, and located nursery areas for the main species that are targeted by fisheries.

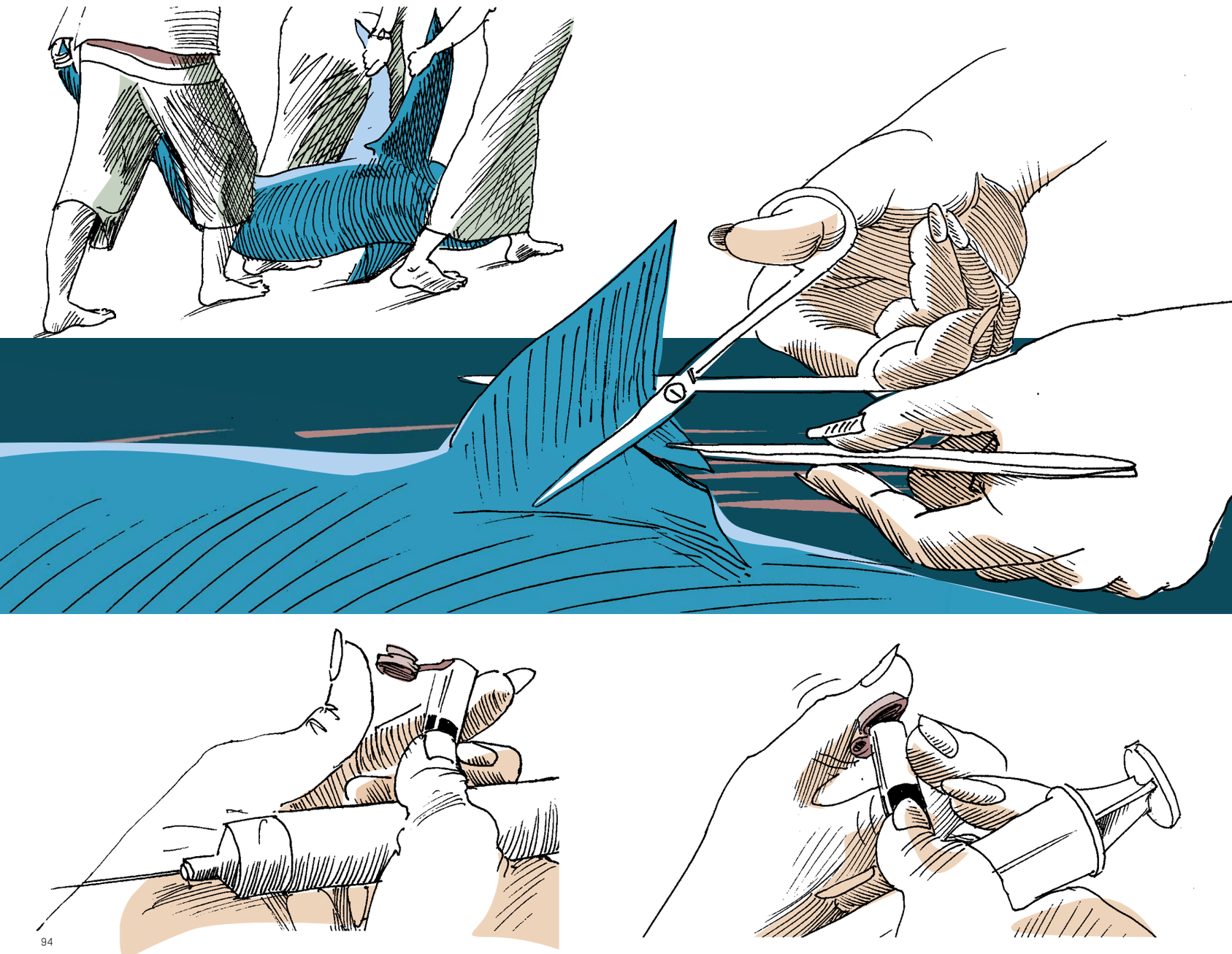
To complete the study, Igbal had to be at landing sites along the Sudanese coast very early in the morning to collect samples. 'It's not an easy job, but when you love what you are doing, it doesn't feel like hard work,' she smiles. 'And I like the contact with the fishermen. They are very respectful towards me. They are always very friendly. They always want to help me. The market feels like my home and I have many stories from there.'

Historically, sharks were not a traditional target and there were very few experienced shark fishermen in Sudan. Igbal believes that local people have an intrinsic understanding of the significance of sharks in the ecosystem. 'This is a tribe. Most of the fishermen are indigenous to the Red Sea region and generally they are aware of what is going on in it. They say in the past there were many sharks and many fish,' she explains.

In the mid-1990s the increase in demand for shark-fin soup drove up the price of fins and commercial fishing for sharks began in Sudan. Yet even today, there are only a few fishermen who target sharks. Some sharks are caught illegally by boats that do not have permission to fish in Sudan's waters and there is the usual problem of them being taken incidentally as by-catch. Sudanese people do not choose to eat sharks and do not buy shark meat directly at the market. Shark is cheaper than bony fish, however, and so some people buy the cooked meat in cafeterias because it is the least expensive item on the menu, not knowing that it is shark.

Sudan has recently signed the Memorandum of Understanding on the Conservation of Migratory Sharks in order to protect certain species in its waters, but it will take time before the country has the infrastructure and resources to implement the agreement. Igbal suggests that enforcement may not be the best approach. 'I believe that if you ban the fishing and bring in the police today, the fishermen will be back catching sharks tomorrow,' she says. 'By talking with people and winning their respect, you can show them that overfishing will affect not only the sharks, but also the other fishes that are important for their livelihoods.'

In the past few years Igbal has taken her expertise further afield to Yemen,



where she collected genetic samples for her PhD research. 'In Yemen they ask me a lot of questions. They have good knowledge and a lot of experience in identifying sharks by their local names,' she comments. Unlike in Sudan, shark fishing is part of Yemeni culture, especially in the south where shark meat is eaten traditionally. As the researcher explains, 'It is difficult to stop shark fishing in Yemen because people depend on sharks in specific regions. They are an important part of the economic life.'

Having begun her genetic work in 2011, Igbal spent three years collecting samples. Although she has samples from numerous species, her thesis will focus on spinner, grey reef, scalloped hammerhead and blacktip sharks. She hopes that her research will help us to understand the structure of shark populations in the Red Sea.

Despite great support and cooperation from the officials and communities that Igbal works with, it is not easy to conduct this kind of research in Sudan. The general economic crisis, combined with years of civil war, has left the country's academic infrastructure in a terrible state, as she describes: 'There are many institutes in Sudan and some of them have a marine department, but the problem is that we have few facilities for research. Some institutes are just buildings with equipment that is long out-of-date. There are staff but there is no funding. In the past there was collaboration between Sudan and countries like Norway and the United Kingdom. They worked with us and gave us technical assistance, but now, because of politics and economics, this has stopped.'

Igbal's courage and quiet determination have not gone unnoticed. In 2012, during a Shark Conservation in Arabia Workshop, she mentioned to Sarah Fowler, scientific adviser to the Save Our Seas Foundation, how difficult it was to pay for public transport to her study sites and was encouraged to apply for funding. The SOSF subsequently introduced Igbal to Dr Mahmood Shivji, who invited her to spend six months at the Save Our Seas Foundation Shark Research Center in Florida. There she will have access to the equipment and technical assistance that she needs to complete her genetic work.

In spite of the challenges, there is great hope for Sudan's sharks. Three of Igbal's students have completed their graduation projects on the animals and one of them hopes to also do her Master's degree on these apex predators. With the Cousteau Society recently pointing to the Sudanese coast as one of the world's last remaining hotspots for healthy shark populations, it seems that she and Igbal will continue to have plenty to study.

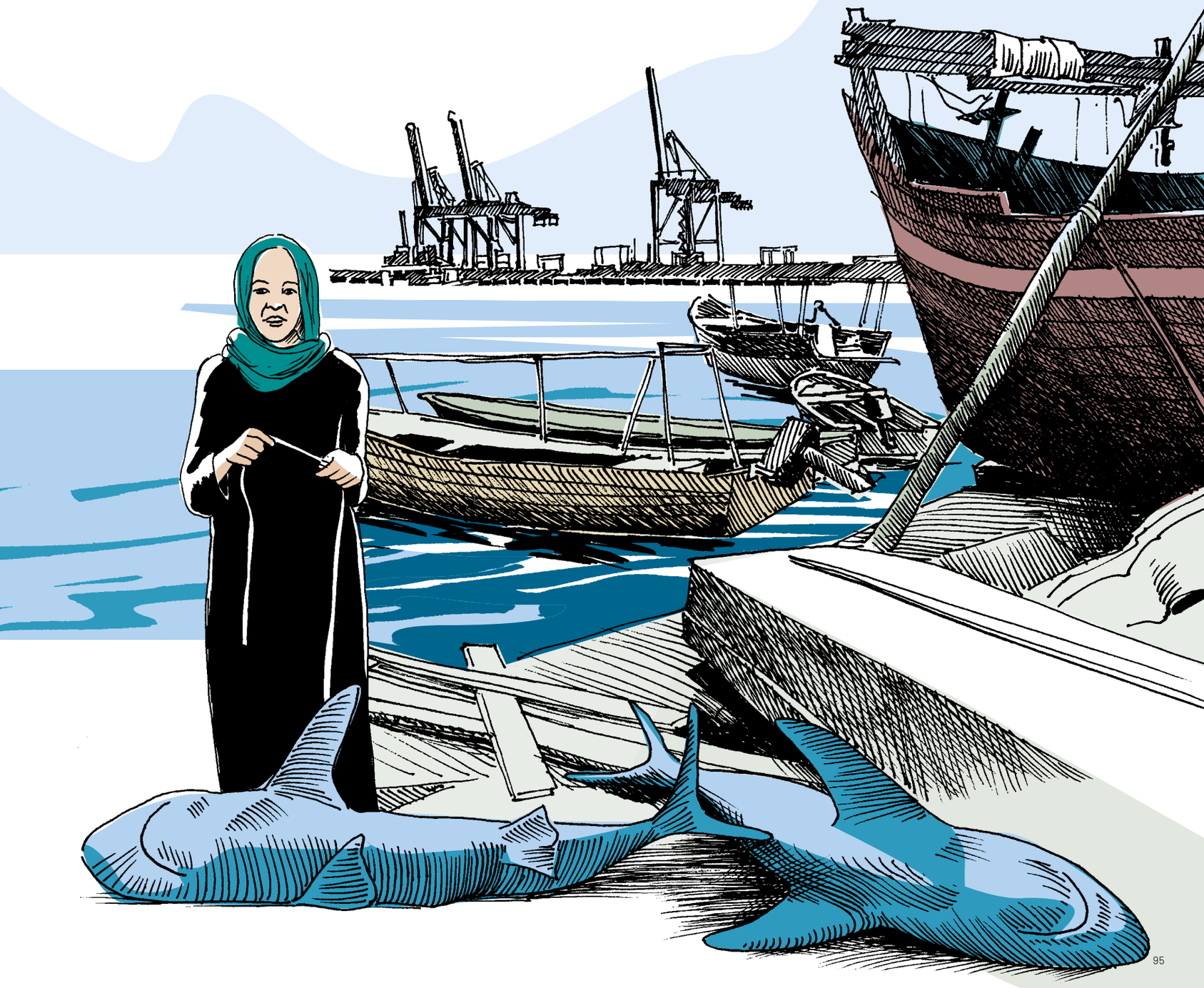


Photo by Samuel Gruber

Jeremy Stafford-Deitsch outlines the history of the Bimini Biological Field Station, the brainchild of Dr Samuel Gruber that has been operating in the Bahamas for 25 years.

Words by Jeremy Stafford-Deitsch

SHARK LAB AT BIMINI

The Bimini Biological Field Station, also known as the Shark Lab, in the early days, with the lab's trustworthy truck in the foreground. The station celebrates its 25th anniversary this year.

Photo by Matthew Potenski

Samuel 'Doc' Gruber, the founder of the Shark Lab, gets up close with a snapper.

Dr Samuel 'Doc' Gruber had two massive battles with cancer. In late 1989 he finally put the disease behind him and, through sheer hard work, regained his strength. He was in his early 50s and pondered the state of his career: the endless days spent in the University of Miami's marine school laboratory; the bureaucratic battles required to equip it so he could learn more and more about the vision of sharks but less and less about the sharks themselves; the never-ending hassles to get funding for his ambitious ship-borne research expeditions; the back-stabbing and petty jealousies of university life. It was time for a change in direction.

Doc had already spent 10 years visiting the Bahamas on research vessels to study the lemon sharks there. The species was disappearing from the waters of the Florida Keys, another of his study areas, and by 1982–83 it had been fished out. It was at Bimini that he struck gold. The great mangrove-fringed lagoon of North Bimini had a healthy supply of lemon sharks – juveniles of all sizes – and, conveniently, the islands are a mere 85 kilometres (53 miles) from the coast of the United States. Moreover, there was something very special about the North Sound that Doc grasped immediately and knew would be enormously significant in the future course of his research: the juvenile sharks had nowhere else to go. If they left the safety of the inshore waters they would in all likelihood be eaten by larger versions of themselves. This meant that they could be studied year after year as they developed, until they were finally big enough to leave the safety of the tangled red mangrove roots, the shallow sea-grass beds and the ever-winding channels.

But, at least in the early days, there was a downside to working in Bimini's remote and beautiful backwaters. In the 1980s and '90s they were used by smugglers who were awaiting delivery of drugs and would then rush them in high-speed boats across the Gulf Stream to the United States. The territories of the drug smugglers and the shark researchers (whom the smugglers suspected were drug enforcement officers in disguise) overlapped, resulting in occasionally alarming confrontations. The plethora of crashed aircraft around Bimini back then attested to how cheap the smugglers held human life when set against the fortunes to be made.

Doc was undeterred. He went to see his dean, an interim dean at the Rosenstiel School of Marine and Atmospheric Science (RSMAS), and put his proposal to him. 'I've beaten cancer. I have another shot at life,' he explained. 'What I want to do is open a marine lab on Bimini, a place of pioneering research. I'll teach there. I'll take care of everything. All I need you to do is give the OK.'

'How do I know you aren't going to open up a house of ill repute?' was the reply. A stunned Doc answered that as he was now a tenured professor at the marine school, he could fulfil his university duties there during the week and set up his lab in Bimini over the weekend – and no-one could stop him. But he put the effort on hold.

Soon afterwards, when a new dean, Professor Bruce Rosendahl, was appointed, Doc took the proposal to him and his reaction was entirely positive, but for the proviso that the marine school could not provide him with funds.

Doc mortgaged his home and borrowed US$30,000 from his elder brother Herbert. The plan was to raise funds by teaching biology courses at the lab when it was up and running. There was already a building on North Bimini that had previously been used as a research station – the Lerner Marine Laboratory – and had closed in 1975. Doc briefly considered it but the rent and upkeep would have been prohibitively expensive – perhaps US$1,000,000 a year – and students and academia would not have mixed with the bars and drug culture of North Bimini at that time. He wanted something lean, the barest minimum of what was required, so that every last cent could go into the research.

The next potential building Doc considered almost turned out to be a disaster: a con artist (who had absconded from justice in the United States and was soon to be escorted back by the CIA) was posing as a real estate agent on Bimini and offered to sell Doc a property he did not in fact own. Luckily, the ruse was discovered just in time.

There was another candidate building Doc knew of in a quiet part of South Bimini: a modest timber structure that was nothing more than a double-wide trailer. It had been used by drug-smuggling Colombians before they were kicked off the island and had thereafter been equipped as a barracks for the Bahamian police, though they never used it. It was now owned by an attorney and friend of Doc's called Pat O'Neal, who offered to lease it to Doc on nothing more than a handshake. From 1990 to the day before Doc bought the lab in 2013, no paperwork was signed.

At the start everyone thought the project mad and doomed to failure: nothing succeeds on these tatty, sleepy islands – dive shops struggle and fold, hotels limp on mostly empty. Doc's determination only increased. Six months of back-breaking work were required to turn the building into the Bimini Biological Field Station, most of the equipment being brought across the Gulf Stream by boat.

From 1990, with the Shark Lab set up, research became field work; the claustrophobic solitude of the laboratory years was behind Doc. The lab survived in the early days because of the courses Doc and his graduate students and colleagues – John Morrissey, Dean Grubbs, Art Myrberg, as well as others invited as guest lecturers – taught there to Dade County students. Doc taught a course entitled Tropical Marine Communities that ran for 22 years. At first his administrators at RSMAS had doubted that he could do justice to the subject and would not let their graduates attend, but the huge popularity and glowing reviews for the course forced them to reverse their decision.

As the years rolled by the Shark Lab researchers did major studies on lemon shark homing, navigation, food and feeding. As a scientist, Doc could not be satisfied with vague terms and glorified guesswork: he wanted to quantify (convert to numbers) what it actually takes for a new-born lemon shark to grow for the first two years, and therefore to understand the relationship between the lemon sharks and the ecosystem in which they develop. This requires a detailed understanding of the North Sound from its autotrophs (primary producers that make biomass from inorganic material, in this case the mangroves and sea grasses) through the various trophic levels (of invertebrates and vertebrates) up to the apex predators, which are the developing sharks. A vast number of studies was needed and painstakingly performed.

Furthermore, the sharks had to be tagged and tracked to learn what they were doing, when and why. Do they use the mangroves for shelter? What is their rate of mortality? A dozen more questions immediately arose. Satellite telemetry was introduced in 2000 so that the entire North Sound could be observed using Landsat images. This meant the researchers did not have to spend so much time outdoors. From here, agent-based modelling was launched: the functioning of the ecosystem was explored at its various levels via computer simulations.

From 1990 the Shark Lab scientists were taking samples from the lemon sharks for genetic investigation because Doc suspected genetics would be the future. Sure enough, the parentage and family trees of the Bimini lemon sharks were thus established (see 'In for the long haul', Issue #2, page 114).

Years before, when Doc had been a post-doctoral researcher studying under the Nobel Laureate Professor Konrad Lorenz at the Max Planck Institute in Seewiesen, Germany, animals were considered to be nothing more than machines. They did not perceive, they merely detected. Nowadays things have changed and a central subject of the field station's research is behaviour, including such topics as personality, learning, social behaviour and cognition.

There is another ambitious shift in the Shark Lab's orientation: to include studies of all the major shark fauna around the islands. Tiger sharks are now most often caught on long-lines (the lemon sharks being too crafty to be regularly re-caught) and the question arises whether there is a tiger shark nursery somewhere on the banks surrounding Bimini. (Just how clever the lemon sharks are is hinted at by the fact that those fitted with transmitters all left the North Sound when a hurricane approached, returning after it had passed by.) Perhaps most exciting of all is the new work on the magnificent great hammerheads that arrive off South Bimini in the winter months. They are being tagged and tracked, and satellite telemetry is planned.

As a University of Miami professor, Doc was required to do committee work and this responsibility was covered by the fact that he was a councillor (for 16 years) of the Bahamas National Trust. He resigned from the trust in protest at the damage done to the inshore ecology of Bimini by the construction of the Bimini Bay Resort. And however myopic and disgraceful that destruction – approved and facilitated by the politicians of a nation that is a contracting party to the international protection of wetlands termed the RAMSAR Convention – it has resulted in the Shark Lab's researchers having the unhappy opportunity to do before-and-after studies of the Bimini sharks and their nurseries to quantify the impact of the devastation.

If the above sketch gives an idea of the range and variety of the research coming out of the Bimini Biological Field Station, it is only half the story. Doc in fact had three founding principles when he established the Shark Lab. The research – to increase what is known about cartilaginous fishes – always comes first, as anyone who does not pull their weight rapidly discovers. The second core principle is to train and educate the next generation of biologists in the hard-won research techniques perfected at the lab so that they can go on to launch their own careers. Thus the field station's principal investigators are doctoral candidates whose research proposals have been approved by Doc and the lab's director and senior scientist Dr Tristan Guttridge. Uniquely, if the doctoral candidates cannot raise funds for their work, the lab is able to support them. As well as being housed and fed for the three years their doctorates are expected to take, all successful candidates naturally have access to the lab's equipment, volunteers and staff.

Thirdly, and crucially, the scientific advances made by the researchers does not remain within the academic cloister. It must be disseminated into the outer world – be it through films, newspaper and magazine articles or interviews – to educate the general public about the fascinating reality of these endangered animals and to provide scientifically robust evidence for conservation initiatives.

In Doc's words: 'We have a stream of young and enthusiastic people. The staff know exactly what they are doing and what can be done. We have boats, challenges, midges, mosquitoes, sunburn and storms. A lot of the marine labs are pretty much fluff: they're there to teach courses. If they have a research function, it's secondary. But what we're doing isn't fluff. Our research is primary. Everything else supports that. We've published some 85 peer-reviewed papers. And we have four or five big dogs running around.'

It is a considerable logistical exercise to run the lab. Typically, there will be 10 fee-paying volunteers (paying about US$750 a month) plus eight staff. The intake is eclectic. The largest number of volunteers/students comes from the United Kingdom, followed by US citizens, with northern Europeans third. The UK volunteers predominate partly because of the educational system: they have gap years to fill (before going to university) and subsequently have dissertations and senior theses to do on

1. The first logo of the Shark Lab | Matthew Potenski
2. Some of the various tags used at the lab (clockwise from left: an ultrasonic tag, Casey tag and PIT tag) | Tim Calver
3. A recent picture of Samuel 'Doc' Gruber, founder of the Shark Lab | Matthew Potenski

4. Doc shows some visitors a juvenile lemon shark | Matthew Potenski
5. Catching juvenile lemon sharks with a net from an airboat | Doug Perrine
6. Shark Lab's dry laboratory and lecture room during a university course around 1998 - no tablets, computers or projector | Samuel Gruber

7. Classroom in the field | Samuel Gruber

8. Lemon sharks being held for the Shark Lab's annual PIT tagging session | Matthew Potenski

9. Tristan Guttridge, the Shark Lab's current director, and Doc tag a tiger shark | Matthew Potenski


BIMINI BIOLOGICAL FIELD STATION
SHARKLAB VHF:88A
1


BBFS
Univ of Miami
2


BIMINI BIOLOGICAL FIELD STATION
3


4


5


6


7


8


9


SHARK
LAB
1


BIMINI BIOLOGICAL FIELD STATION
UNIVERSITY OF MIAMI-RSMAS
2


4


7


6

1. One of the early signs at the entrance to the Shark Lab | Matthew Potenski
2. Signage on the Shark Lab's trustworthy truck | Matthew Potenski
3. Doc and his wife, Marie| Kate Grudecki

4. Doc with a nurse shark, testing the flow of water through its nostrils | Doug Perrine
5. An adult lemon shark attached to a boat ready for tagging by Doc | Tim Calver

6. Doc and his family on Shell Beach in 1995 (from left to right: Meegan, Doc, Marie and Aya) | Samuel Gruber
7. Doc demonstrates tonic immobility | Matthew Potenski
8. Doc's favourite 'selfie' with a shark | Matthew Potenski

their courses. The fact that they speak English is no disadvantage either. But it is the CVs the British volunteers send in that set them apart. Filled with previous volunteer work and expedition-level experience as well as being replete with evidence of both academic ability and practical skill, they put the CVs of many other applicants to shame, as an Anglophile Doc admits. The lab has never had to advertise: word of mouth (often from academic colleagues or previous Shark Lab staff and volunteers) means there are always several times more applicants than can be accepted.

Another dimension of the lab's work is its outreach. It takes Bahamian students with fellowships as well as students from Bahamas Marine EcoCentre, an NGO. Bimini children are regular visitors and the lab staff give lectures to the public as well as doing beach clean-ups. Previously, before the 9/11 attacks slammed the door shut on funds derived from Florida tourism, the Bimini Biological Field Station used to take children from deprived backgrounds for several days. As Doc explains: 'Here comes a black kid from the ghetto who doesn't know the Bahamas, has no idea that it's a black nation. And everyone is black. And then the kid goes into a little laboratory full of white people where the kid is treated like a prince or princess. And we're fawning all over them because they're our little angels. That's a life-changing experience.'

Until 2012 Doc and his wife Marie ran the Shark Lab as a private company; now it is a 501 (c)(3) non-profit organisation, Bimini Biological Field Station Foundation. This gives it much better access to grant money. The property has been bought; the Shark Lab is incorporated in the Bahamas.

What does the future hold for the lab? Every piece of research opens the door on further questions and every year the technology advances, allowing more questions to be answered – so Doc admits he does not know. But if there is one thing the fearless Dr Samuel Gruber fears it is hurricanes. In 1992 he had to evacuate the Shark Lab as Hurricane Andrew approached, having rapidly transformed into a Category 5 hurricane (the highest category). He crammed everyone into his home in South Miami. A devastated Doc was then informed by cell phone by someone on Bimini that the Shark Lab had been knocked off its foundations and was floating in the bay. Two years of back-breaking effort and financial investment had been destroyed. Doc gloomily bought supplies, drove up to Fort Lauderdale airport and flew over to Bimini. Sure enough, he could see a house in the water from the aircraft – but then he realised it was not the Shark Lab. In fact, when he reached the lab, an ecstatic Doc quickly established that the storm damage was minor. The field station was up and running again in a matter of days.

So Doc's burning ambition is somehow to find the funds to rebuild the Bimini Biological Field Station and make it hurricane-proof, and to raise it above the reach of storm and tidal surge so that the research, the Shark Lab's unique research, long continues.

In conversation with Dipani Sutaria

Philippa Ehrlich joined Dipani Sutaria for some of her market surveys in Mumbai, India, and spoke to her about her new research interest in India's shark fishery.

Studies suggest that India has the world's second biggest shark fishery, but very little is known about elasmobranchs along the country's extensive coastline. Dipani Sutaria has spent decades working on India's marine mammals but now she, along with a team of young scientists, is embarking on a new journey into the realm of shark research.

How did a dolphin biologist make the shift to studying sharks?

I still work on dolphins, but this project interested me because when CITES came out with its latest recommendations in 2013, we had a meeting to figure out what to do next. That was the first time I encountered the politics surrounding sharks and shark fisheries in India. I found out that we know very little about shark fisheries and shark biology to start with and that is what motivated me to write a research proposal.

What major questions is your project aiming to address?

We are currently looking at sharks off western India, mainly along the coasts of Maharashtra and Gujarat. We want to find out about species diversity and any seasonal change in diversity, as well as about the sex of individuals in this area, their size and when they reach maturity. If we can, we would like to get an idea of which species are more abundant than others. We also want to figure out the supply chain – at least within India, if not all the way to the international level. Lastly, we want to know what fishermen think about conserving sharks and the policies relating to that, and we'd like to get an idea of where they are fishing, how much they fish and how often they catch sharks.

Is it true that India has the second largest shark fishery in the world?

It may have been true in the past and perhaps it is still true relatively speaking. If sharks are still being caught everywhere – opportunistically, that is – then we could rank quite high. At the moment I am not sure. This claim is based on the FAO [Food and Agriculture Organization] figures of 2006. Shelley Clarke and her colleagues reported that India came just after Indonesia in the shark-fin trade. The numbers are based on imports into Hong Kong and Singapore, not on our exports, so there is a mismatch between their import and our export figures. But if you go down to Kochi and Chennai and those areas, you can still see large numbers of sharks being brought in.

Why do we know so little about sharks in India?

Marine biologists make up a very small group in India. We do not have any conferences focused only on marine systems. A lot of research has been done on terrestrial systems – maybe because it's easier logistically and financially – but the cohort of marine biologists who work from a wildlife and conservation perspective is very small. There are a lot of fisheries colleges in India, but most of them are for applied biology relating to aquaculture. Parents expect their kids to do something that's lucrative in the long term, like medicine or engineering, so doing a Bachelor of Science is the last option. It is changing though. Students are more experimental now, and wildlife biology has a lot of charisma attached to it, so parents are starting to enjoy that their kids are involved with this.

As one of such a small group of shark researchers, do you feel isolated?

We are living in the digital world. I don't feel isolated. We have a good network of people who are happy to help. This was my first shark project and I didn't know anything about identification, so I asked Michael Scholl if he could recommend somebody to come and train us. He suggested Rima Jabado. The Save Our Seas Foundation was very open to the idea of sending her across to India. It played a

Dipani Sutaria, a project leader with the Save Our Seas Foundation, contemplates a small shark she picked up at a fish market in Mumbai, India.

Photo by Philippa Ehrlich

Photo by Philippa Ehrlich

Photos by David Tickler

Dipani believes that the exchange of information between scientists and fishers is the key to conserving India's sharks.

huge role. Everybody was so excited. She gave a presentation to the entire batch of first- and second-year students. She plans to come back once more, maybe towards the end of the project, to look at the data and interviews that we have collected.

Are there any MPAs in India?

Even though we have marine protected areas and sanctuaries, artisanal fisheries are allowed in them. There is nowhere that there are absolutely no fisheries at all. That makes our work difficult as we have no control sites for comparison and no baselines. You can go across grades of fishing intensity but there are no zero-fishing areas anywhere.

Do fishermen target sharks directly in India?

They don't target sharks in Maharashtra or Gujarat. They do have long-line fishing, but that is more for tuna than for sharks. In the mid-1990s shark densities in coastal Gujarat and Maharashtra were probably really high and so fishers brought in more sharks, and bigger ones, but opportunistically. Hence, there was a big shark industry. Fishers caught them more than other fish, so at that time the industry grew and there were truckloads of sharks being taken from our field site in Porbandar to other markets and export centres.

Is finning an issue?

Indian fishers do not fin live sharks. They land the full shark and everything is used because culturally such wastage is not allowed. The liver is used for oil, the meat is consumed and smaller sharks and fins are dried and sent to places where dry fish is eaten. I could never imagine a fisherman throwing away an entire body and just keeping the fin.

Do fishermen know that shark stocks are in decline?

They can see that there is a great de-crease in fisheries. They do know that many more sharks used to be caught. When we ask them about that, the first thing they talk about is international fishing vessels. They say that foreign fishers come with their big boats and stronger engines and more storage space, and so on. Eventually though, during a long conversation, they will admit that there is too much fishing. They also agree that small-mesh nets need to be banned so that juveniles and fish fry are not caught. They know all this, but they don't know what to do about it because this is their only occupation.

What do you think is key to conserving India's sharks?

I am planning to interview a woman in Porbander who was involved in the shark fisheries 20 years ago. She knows that all the sharks have gone. She has very little of value to sell now and her income has really gone down. I'm interested in getting involved in shark conservation from that angle. I believe that the key is in giving and getting information. For now at least, I don't see myself working with rules and regulations. We need to work with the fishermen themselves. If one of them were to say, 'That's where we see all the baby sharks and maybe we should take care of that area', then that would be good.

Working with dead sharks is not the easiest or most glamorous work. What keeps you motivated?

I enjoy research. I like interacting with people and I like working with students very much. I love listening to their questions and trying to work out how to answer those questions. I think that's what drives me: finding out more and figuring out the different sides of the story, getting the whole picture.

Changing acidity changing behaviour

Words by Sue-Ann Watson

Physiological changes in marine animals are known to be caused by ocean acidification but, explains Sue-Ann Watson, it's only recently that scientists have become aware of behavioural changes too.

Covering more than 70% of the earth's surface, the oceans contain 99% of the living space on our planet. But this vast body of water is being altered by our actions on land and in the air. Carbon dioxide (CO_2) emissions from the combustion of fossil fuels, industrial processes and large-scale changes in land use are contributing to global change in the terrestrial and marine biospheres. Currently we're adding an extra 36 billion tonnes of CO_2 to the atmosphere every year.

The oceans are in balance with the atmosphere and act like a giant sponge, absorbing CO_2 from the air. Since the beginning of the Industrial Revolution, they have absorbed approximately one-third of all human CO_2 emissions. Although this helps to remove CO_2 from the atmosphere and so reduce greenhouse gas effects such as warming, CO_2 in the oceans creates other problems. Once in sea water, CO_2 dissolves like gas in a fizzy soft drink. We all know that fizzy soft drinks are acidic and can corrode our teeth. This same chemical process is happening in our oceans. When we record the pH (a measure of acidity) in our oceans now, we can see that they have become more acidic by 0.1 units. This may not sound like much, but pH is measured on a logarithmic scale, so a difference of 0.1 units actually means this extra CO_2 has already made the oceans 30% more acidic than they were 250 years ago. This process is called ocean acidification.

Right now, ocean chemistry is changing 100 times faster than at any period in the past 650,000 years. Projected changes in ocean pH are greater and far more rapid than any experienced in the past 24 million years and possibly the past 300 million years. If we continue our business-as-usual CO_2 emissions, in just 85 years – at the end of the century – the oceans will be 100–150% more acidic than they were before the Industrial Revolution.

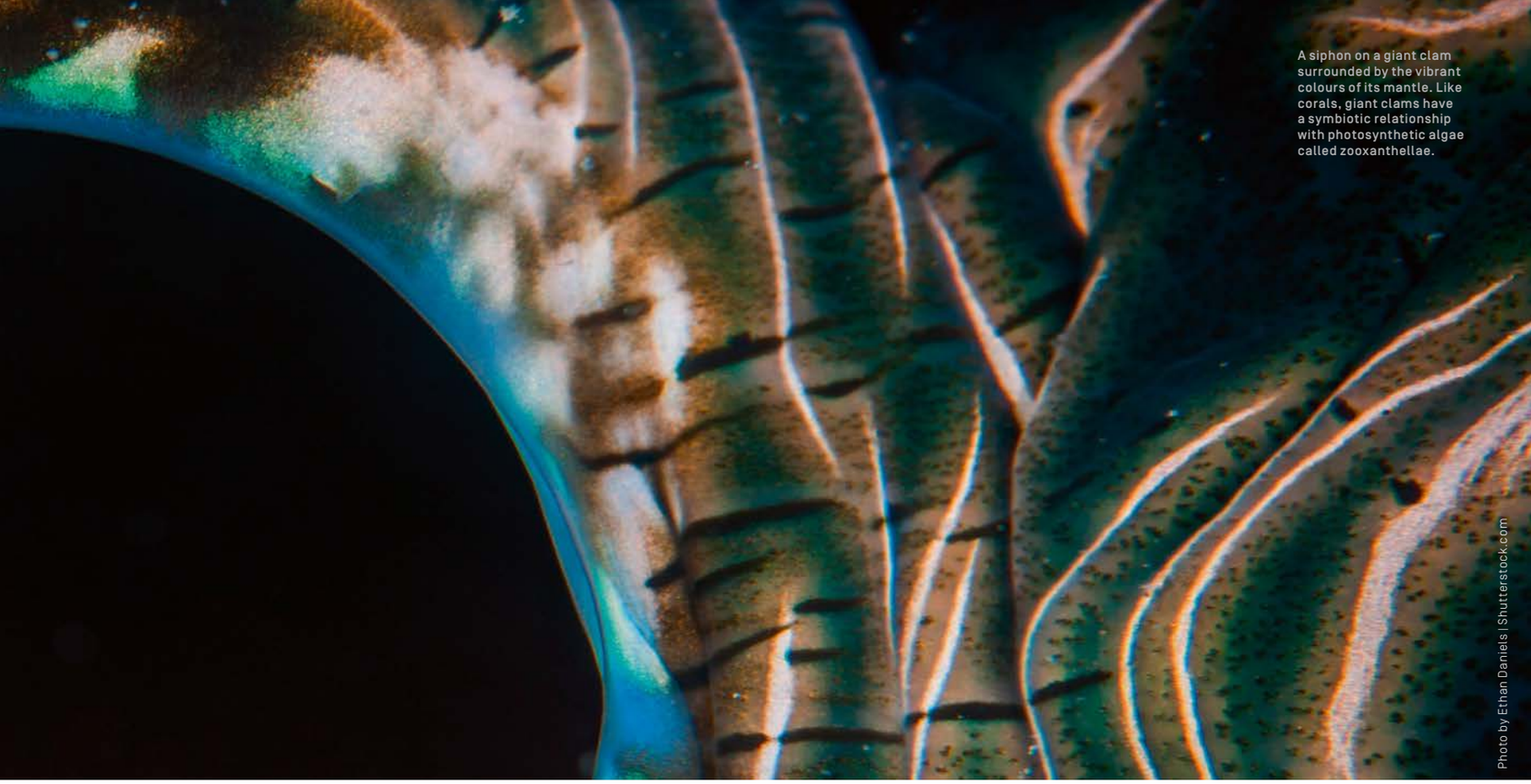
Marine ecosystems are threatened by this increasing CO_2 enrichment of the oceans. In the same way that an acid like vinegar can dissolve the limestone scale in your kettle, the rising acidity in the ocean can make it difficult for shell-growing marine animals, like oysters, mussels, clams, krill and sea urchins, to grow and maintain their limestone shells. We've learnt that the survival rates of oysters and giant clams decrease as CO_2 levels increase. Many other researchers have found negative effects in shell-growing species, and in recent years oyster farms on the west coast of the USA have experienced failures in juvenile oyster recruitment as a result of increasing sea-water acidity.

Now a new and unexpected problem is being revealed. We recently discovered that increasing oceanic CO_2 levels are changing the way marine animals think and behave. Scientists from James Cook University in Queensland, Australia, first made the surprising find while working on coral reef fishes. They observed that, as CO_2 levels rise, the fishes lose their sensory abilities, such as smell, vision and hearing, and are even attracted to the smell of predators. In addition, fish learning and competition between species is disrupted.

Bony fishes, such as coral reef fish species, are quite different to elasmobranchs, like sharks and rays. We had learnt that the behaviour of these bony fishes was altered by rising CO_2 levels, but we didn't know about potential changes in the behaviour of sharks or other elasmobranchs. Sharks can be quite good at regulating their internal tissues and may possess physiological adaptations that help them to cope with rising CO_2 levels. For example, we discovered that epaulette sharks modify their blood chemistry to stop their body fluids from becoming too acidic. Other scientists have found a similar pattern in small-spotted catsharks. So far, these studies have been conducted on small, bottom-dwelling shark species that tend to experience natural CO_2 fluctuations in their environment. Sharks that live in more stable open-ocean, pelagic environments may be less tolerant to rising CO_2 levels.

Last year scientists started examining shark behaviour too and found that it can also be affected by ocean acidification. Smooth dogfish sharks avoid food odours and show reduced attack behaviour, while swimming patterns in small-spotted catsharks change when CO_2 levels are high. We next need to determine the effects of rising CO_2 levels on other elasmobranchs.

Although we've understood for a while that ocean acidification causes shell-growing problems, its potential effects on invertebrate behaviour have been unknown. Invertebrates are critical for the functioning of all marine ecosystems and dominate the lower trophic levels that support marine food webs. Although we



A siphon on a giant clam surrounded by the vibrant colours of its mantle. Like corals, giant clams have a symbiotic relationship with photosynthetic algae called zooxanthellae.

Photo by Ethan Daniels | Shutterstock.com

knew very high CO_2 levels could change crab behaviour, these levels were many times higher than the changes that could occur in the oceans. I wanted to investigate the potential effects of end-of-century CO_2 levels to determine whether ocean acidification could be a problem for invertebrate behaviour.

Generally when we think of snails, it is slow, slimy land snails that come to mind. The oceans, however, often have a surprise for us. Tropical conch snails have evolved a modified foot and shell trapdoor so that they can jump away from their predator, the venomous, slow-moving cone shell. This behaviour is readily observed, so I used jumping snails as a test species. I found that at elevated CO_2 levels, half the snails stopped jumping away from the predator. Those that did jump took twice as long before deciding to do so, and when they did jump, it was along a path closer to the cone shell. Their physical ability to jump was not affected, indicating that it was their decision-making that was impaired.

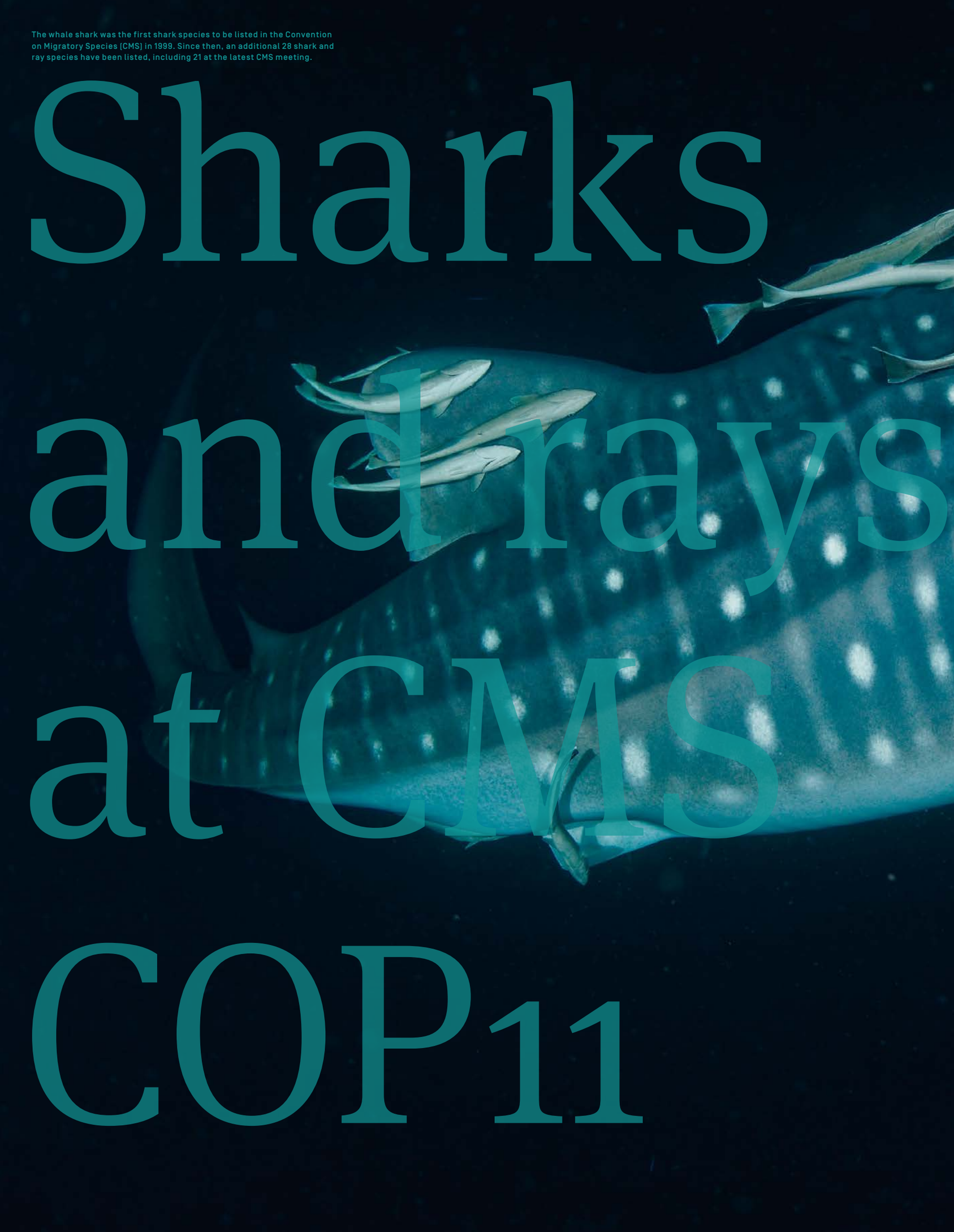
Last year, we also found that the activity and defensive behaviour of squids were altered by ocean acidification. Other new research from Chile has revealed that when CO_2 levels are elevated a commercially important temperate snail changes its self-righting and predator-avoidance behaviour. These studies on molluscs are the first to show that ocean acidification affects the behaviour of marine animals other than fishes. Impacts on shell-growth and now behaviour present a double problem for shell-growing animals such as shellfish.

We've found that rising ocean acidity hampers brain and nerve function in sea creatures by interfering with a neurotransmitter receptor called the GABAA receptor. These critical neuroreceptors are found throughout the animal kingdom, from simple creatures like hydra to more complex animals like mammals. Ocean acidification causes chemical changes in sea water that mean water-breathing animals need to make compensating adjustments in their bodies. As CO_2 increases, fish excrete chloride ions and accumulate bicarbonate ions to help prevent their bodies from becoming too acidic. It is these changes that we think lead to abnormal behaviour, as the altered ion balance excites rather than inhibits the GABAA receptor.

It is important to consider the potential for animals to adapt to change. Interestingly, we've shown that over generations fishes can adjust their growth and metabolism to higher temperatures and CO_2 levels. If parents experience elevated CO_2 and temperature conditions, then their offspring function as normal in these conditions. This adjustment is called acclimation. However, when we test fish behaviour, even if the parents experience an elevated CO_2 environment, no benefits are passed on to the offspring. This indicates that adjusting, or acclimating, across generations cannot fix behavioural impairments. What this means is that we will need to see genetic adaption, which is random chance mutations in genes, if the behavioural changes associated with ocean acidification are to be overcome.

Altered behaviours of bony fishes, invertebrate groups such as snails, squid and crabs, and sharks could have potentially far-reaching implications for marine ecosystems. These animals are essential for ecosystem function and provide significant goods and services to human societies. Changes in key ecological behaviours, such as predator-avoidance strategies and feeding responses, could result in changes to species interactions that may have widespread consequences for marine food webs. Predator versus prey battles in ocean food chains may become different to what we see today.

The oceans face a variety of human challenges that include overfishing, the destruction of habitats, dredging and increased sedimentation and turbidity, the accumulation of plastic waste, nutrient run-off from land and warming temperatures – all these in addition to ocean acidification. We do not yet understand the complete individual and cumulative consequences of these challenges for ocean life. Even if fishes can acclimate to ocean acidification, we don't know the full extent of its impact on their well-being and that of the ocean at large, and the combined effects of human-related threats remain unknown. As we change the planet and the way it functions, we are heading into uncharted territory. What we do know is that the oceans provide us with food, clean air and climate moderation. Finding solutions soon, before CO_2 levels rise much higher, will be of substantial and long-term environmental, social and economic benefit to mankind.



The whale shark was the first shark species to be listed in the Convention on Migratory Species (CMS) in 1999. Since then, an additional 28 shark and ray species have been listed, including 21 at the latest CMS meeting.

Sharks and rays at CMS COP11

Photo by Michael Scholl

CMS COP11, held in Quito, Ecuador, towards the end of 2014, listed a record number of migratory sharks and rays for global protection. But, asks Andrea Pauly, what comes next?

Words by Andrea Pauly

After six days of intense negotiations, the 11th meeting of the Conference of the Parties to the Convention on the Conservation of Migratory Species of Wild Animals (CMS COP11) marked a new era in international elasmobranch conservation.

'The conference in Quito has generated an unprecedented level of attention for migratory sharks and rays,' commented Bradnee Chambers, the Convention's executive secretary. 'Never before in the 35-year history of CMS has the international community agreed to list as many species of elasmobranchs in the Appendices of the Convention. This highlights the growing commitment of the 120 member states to conserve these species.'

A record number of 21 proposals to list shark and ray species was approved (see table on page 115), as was Resolution 11.20 on the Conservation of Migratory Shark and Rays, which addresses the most pressing threats to these fishes and provides guidance for Parties on the priority actions that need to be taken in the coming years. In some circles, COP11 has been labelled the Shark COP, raising expectations for the future performance of the Convention to improve the conservation status of these species.

Shark conservation under CMS

As a treaty under the aegis of the United Nations Environment Programme, CMS offers a global platform for the conservation and sustainable use of migratory animals and their habitats. It also lays the legal foundation for internationally coordinated conservation measures throughout their range. As the only global Convention specialising in the conservation of migratory species, CMS complements a number of other wildlife-related Conventions.

CMS has a long history of shark conservation, starting with the listing of the whale shark in 1999. This was before any Regional Fisheries Management Organisations (RFMOs) or the Convention on the International Trade in Endangered Species (CITES) had agreed to manage any elasmobranch species. Between 2002 and 2011 five more shark species were listed under CMS, including the first commercially exploited species in Appendix II: the shortfin mako and porbeagle sharks. In 2005, at COP8, CMS Parties called upon range States to develop a global instrument for the protection of migratory sharks. Hence, some see the Convention as breaking new ground for conservation initiatives, providing a suitable forum to bring species onto the international agenda.

In response to the 2005 call for a global instrument, and after three rounds of negotiations, the CMS Memorandum of Understanding for migratory sharks (the Sharks MOU) was agreed in 2010. The Sharks MOU represents the first global agreement dedicated to the conservation of migratory sharks and rays. When it was adopted, the negotiating Parties agreed that it should be legally non-binding and should aim to achieve and maintain a favourable conservation status for migratory sharks. This should be based on the best available scientific information and take into account the socio-economic value of these species.

As of February 2015, 38 countries have signed this agreement, thereby committing themselves to implementing the associated global Conservation Plan for Sharks. The main objectives of the Plan (see box on page 114) focus on five core areas that relate to research and data collection, fisheries management, habitat protection, raising awareness and international cooperation.

COP11

The COP11 decision to list no fewer than 21 additional shark and ray species represents a remarkable moment in the history of CMS. Proposed by Kenya, Egypt, the European Union, Fiji, Costa Rica and Ecuador, the additions comprised six shark species (three thresher sharks, silky shark, great hammerhead and scalloped hammerhead) and 15 rays (the sawfishes, devil rays and reef manta ray). All 120 Parties agreed that these species require international protection, and in some cases even strict protection.

As of February 2015, when the COP11 listings came into force, the Convention counts 29 species of sharks and rays in its two Appendices (see table on page 114). Sixteen ray species (manta rays, devil rays and sawfishes) and two shark species (white and basking sharks) are listed in Appendix I and Appendix II, while an additional 11 shark species are contained only in Appendix II.

The species listed in Appendix I – the highest protection category of the Convention – are those that are threatened with extinction (see box on page 114). Appendix I foresees strict protection measures, including a ban on catching the listed species (as defined in Article 5 of the CMS). Parties that are range States for these species are legally bound to incorporate the strict protection measures into their national laws and to ensure that the Convention's provisions are fully enforced.

Migratory species that need, or would significantly benefit from, international cooperation are listed in Appendix II of the CMS. An Appendix II listing commits countries to coordinating transboundary conservation measures throughout the species' range by developing a specialised agreement (the Sharks MOU).

Resolution 11.20 on the Conservation of Migratory Sharks and Rays, which was also approved at the COP11 meeting, makes provision for sustainable fishing and trade, the enforcement of the ban on finning, compliance with regulations under RFMOs and CITES relating to sharks and rays, and the development and implementation of national plans of action for sharks based on the International Plan of Action of the Food and Agriculture Organization of the United Nations (FAO). The resolution does not intend to duplicate the work of the Sharks MOU, although it contains certain key elements of the MOU and the Conservation Plan for Migratory Sharks. Rather, it was developed to complement and support the objectives of the MOU by utilising the strength of the Convention's broad membership.

Next steps and challenges

The next important step after COP11 will be the Second Meeting of Signatories of the CMS Sharks MOU (MOS2), which is planned for early 2016. MOS2 will provide a forum for discussing whether species recently listed on CMS should be added to the MOU species list; currently only seven shark species are covered by the MOU. An important factor to be taken into account by the signatories is the capacity of this young agreement to conserve a long list of protected species for which individually defined measures must be undertaken.

A second crucial decision will be to agree on priorities as suggested by the MOU Advisory Committee and to organise implementation at the international level through cooperation with other range states and in conjunction with existing treaties, such as the FAO, CITES and RFMOs. Signatories have agreed that the activities of existing international organisations, in particular FAO, RFMOs and Regional Seas Conventions, should be complemented rather than duplicated. The mandate of RFMOs to promote the conservation and management of fish stocks is well recognised by the MOU signatories.

This need to feed the objectives of the Sharks MOU into the agendas of other international and regional organisations dealing with the conservation and management of migratory elasmobranchs is, in fact, both the greatest potential and the greatest challenge of the MOU. This is particularly true when it comes to one of the MOU's main objectives: to make fisheries more sustainable. Here good cooperation with RFMOs is an absolute must. Ensuring that both directed and non-directed fisheries for sharks and rays are sustainable requires proper monitoring schemes so that data can be collected and information can be shared at the species level. The Convention's broad membership is expected to bring expertise to global conservation efforts in areas such as research, compliance, enforcement and capacity building.

More developed is the relationship between CITES and CMS, whose Parties have agreed to a Joint Programme of Work. Parties to both Conventions have agreed to optimise the effectiveness of their actions concerning sharks and rays. They have requested their Secretariats to strengthen synergies with fisheries and other relevant bodies and to cooperate on building capacity so that the work of both Conventions can be carried out successfully.

Finally, NGOs and academic institutions are seen as important partners for the Sharks MOU. The CMS Secretariat has benefited from excellent cooperation with NGOs in the past when it comes to implementation. As mandated by its Parties, the CMS Secretariat has already built up a wide network of partners who actively support its efforts to build capacity, raise awareness and conduct research. The MOU offers the opportunity for relevant organisations to become official cooperating partners. At MOS2, signatories are expected to decide on the terms of reference for such partnerships and the role that partners to the MOU may play.

The decisions of COP11 have created strong political momentum for the conservation of sharks and rays around the world. The time is right to strengthen political will to implement the provisions of the CMS and to encourage more countries to sign the CMS Sharks MOU. Time will tell how feasible it is to bridge effectively the needs of fisheries and conservation.

For more information:
The Convention on the Conservation of Migratory Species of Wild Animals: www.cms.int
Memorandum of Understanding on the Conservation of Migratory Sharks: www.sharksmou.org

SOSF and CMS

Words by Sarah Fowler

It is no coincidence that many of the species listed in the Appendices of CMS have also been the subject of numerous SOSF research projects. The 'big three' species (the whale, white and basking sharks) that were the first sharks to be listed under CMS have an almost equally long history of SOSF-funded research. More recently, the SOSF has paid particular attention to research and conservation initiatives that focus on the poorly known but highly endangered sawfishes, Pristidae, and the mantas and devil rays, and has issued calls for research and conservation projects dedicated to these species. Not only new data, but also increased scientific and public awareness of the risks faced by these rays emerged from these SOSF initiatives, and together they contributed significantly to the development of the successful listing proposals in 2014. We look forward to continuing our support for the implementation of the listings through the efforts of SOSF researchers.

Listed: sharks and rays in the CMS

Sharks and rays in CMS Appendices and the CMS Sharks MOU, and the year of listing

Species	CMS Appendix I	CMS Appendix II	Shark MOU Annexe 1
Whale shark *Rhincodon typus*		1999	2010
White shark *Carcharodon carcharias*	2002	2002	2010
Basking shark *Cetorhinus maximus*	2005	2005	2010
Porbeagle *Lamna nasus*		2008	2010
Spiny dogfish *Squalus acanthias* (northern hemisphere population)		2008	2010
Shortfin mako shark *Isurus oxyrinchus*		2008	2010
Longfin mako shark *Isurus paucus*		2008	2010
Giant/Oceanic manta ray *Manta birostris*	2011	2011	Considered for listing at MOS2

CMS Species Appendices

Appendix I
Migratory species threatened with extinction are listed in Appendix I, the highest protection category of the Convention. Countries that are party to the Convention strive towards strictly protecting these animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that could endanger them.

Appendix II
Appendix II includes migratory species that need or would significantly benefit from international cooperation. It commits countries to coordinating transboundary conservation measures throughout the species' range by developing a specialised agreement. To this end, the CMS encourages range States to conclude global or regional agreements.
In this respect, CMS acts as a framework Convention. The agreements in accordance with the provisions of Appendix II may range from legally binding treaties to less formal instruments, such as memoranda of understanding – the CMS Sharks MOU is an example – and these can be adapted to the requirements of particular regions. The capacity to develop models that are tailored to conservation needs across the migratory species' range is unique to CMS.

Objectives of the CMS Conservation Plan
The objectives of the CMS Sharks MOU Conservation Plan are listed in its Annexe III:

- To improve the understanding of migratory shark populations through research, monitoring and information exchange.
- To ensure that directed and non-directed fisheries for sharks are sustainable.
- To ensure the protection of critical habitats and migratory corridors and critical life stages of sharks as far as is practicable.
- To increase public awareness of threats to sharks and their habitats and encourage public participation in conservation activities.
- To enhance national, regional and international cooperation. In pursuing activities described under this objective, signatories should endeavour to cooperate through RFMOs, the FAO, Regional Seas Conventions and multi-lateral environmental agreements related to biodiversity.

Signatories to the CMS Sharks MOU
As of November 2014, the CMS Sharks MOU had 38 signatories: 37 national governments and the European Union.

Species included at COP11

Species	CMS Appendix I	CMS Appendix II	Shark MOU Annexe 1
Reef manta ray *Manta alfredi*	2014	2014	Considered for listing at MOS2
Great hammerhead shark *Sphyrna mokarran*		2014	
Scalloped hammerhead shark *Sphyrna lewini*		2014	
Thresher sharks (*Alopias* spp.)		2014	
• *Alopias vulpinus* • *Alopias alopias* • *Alopias supercilliosus*			
Silky shark *Carcharhinus falciformis*	2014	2014	
Sawfishes (Pristidae)	2014	2014	
• *Anoxypristis cuspidata* • *Pristis clavata* • *Pristis pectinata* • *Pristis zijsron* • *Pristis pristis*			
Devil/mobula rays (*Mobula* spp.)	2014	2014	
• *Mobula mobular* • *Mobula japanica* • *Mobula thurstoni* • *Mobula tarapacana* • *Mobula eregoodootenkee* • *Mobula kuhlii* • *Mobula hypostoma* • *Mobula rochebrunei* • *Mobula munkiana*			

Photo by Rainer von Brandis

Mantas are among the sharks' flatter and less famous cousins – the rays. During the past few years, the Save Our Seas Foundation has dedicated extra support to manta and mobula ray projects, largely through the Manta Trust, one of our partner organisations.

inside stories

There is no shortage of work to be done in the areas of ocean research, conservation and education. In addition to the projects we fund around the world, the Save Our Seas Foundation (SOSF) is proud to directly manage four centres and hold long-term relationships with four NGO partners, all of which are leading vital work to protect our marine environment and wildlife.

Of the SOSF centres, two concentrate on education – the Island School Seychelles and the Shark Education Centre – and two are dedicated to research – the D'Arros Research Centre and the Shark Research Center. Located in the Seychelles, South Africa and the USA, the centres extend the on-the-ground reach of the foundation to these countries and beyond.

The partnerships we hold with independent NGOs, the Bimini Biological Field Station (also known as the Shark Lab), CetaceaLab, the Manta Trust and Shark Spotters are mutually supportive and closer in terms of funding and communication than our regular projects. Each partner has its own area of expertise and is conducting long-term research and conservation work that goes beyond the normal project cycle length. This is one of the reasons we partner with them; the other is the passionate people who lead and drive this work – and have inspired us.

The following pages are dedicated to stories from these centres and partners, and from the great people working there who are leading the charge for marine conservation.

The essen

Shark Research Center

For Mahmood Shivji and his team at the SOSF Shark Research Center, exploring the genomes of sharks has turned up many exciting surprises – discoveries that could lead to medical advances for humankind.

Words by Mahmood Shivji

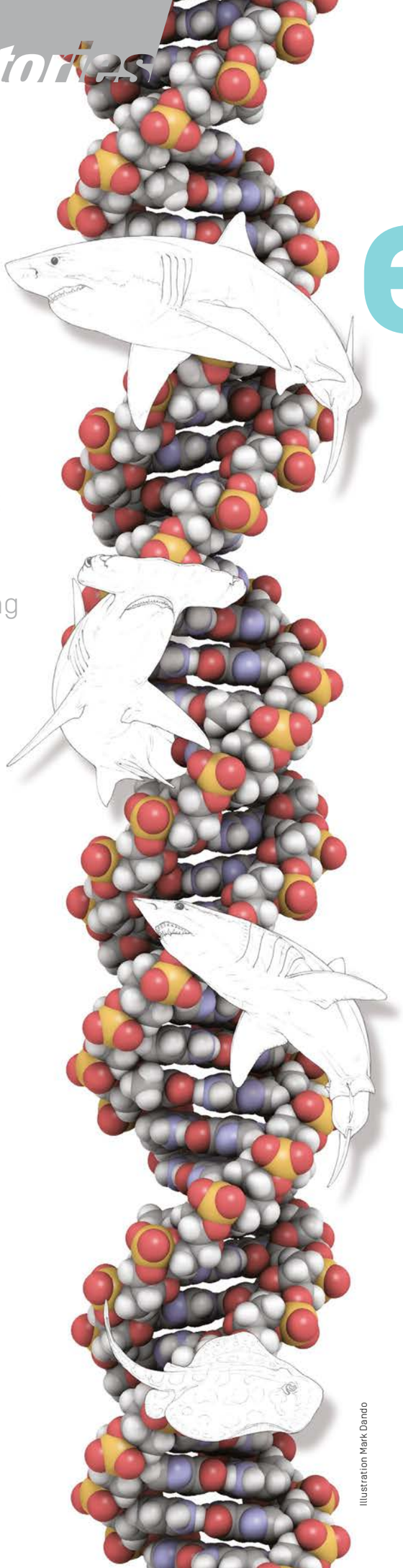


Illustration Mark Dando

Sharks, rays and other elasmobranchs are some of the most remarkable animals on the planet. They are well known for their high-performance sensory systems that make many of them into daunting predators. But these animals also have robust immune systems, as well as highly efficient wound-healing capabilities that are as yet unexplained. For the past year now, the Save Our Seas Foundation Shark Research Center (SOSF Shark Research Center) in Florida has been studying shark DNA at a large scale in search of the genes responsible for such novel traits. Already we are finding hints of unique properties that reveal surprises about these animals' evolutionary histories and may one day even point the way to new medical advances.

A key question the SOSF Shark Research Center focuses on is: what makes a shark – a shark? In other words, how are sharks different from other vertebrates that don't share their unusual traits? We're investigating these evolutionary marvels at the most fundamental level possible – by studying their entire genetic blueprints, or genomes. This includes identifying all their genes.

A genome is the collection of all the DNA, including all the genes, in an organism's chromosomes. All the information that determines what makes an organism function, including how it behaves physiologically and physically, is hidden in the genome and the genes within it. In other words, a genome is a treasure trove of biological information that underpins the very essence of organisms and species. And by comparing a genome from one species to those of other species, we gain insights into that species' evolutionary origin and subsequent developmental pathways.

In so-called animal research 'model species', such as mice, zebra fish, fruit flies and nematodes, studies of genomes and gene expression are surging ahead

nce of sharks

at full speed and have already led to deep insights into how animals work at their most fundamental level. The small size of these animals and the ease of breeding them and keeping them in the lab have made them the main focus for basic and biomedical research. Today their entire DNA sequences and all their genes have been determined, opening up numerous research options. This includes comparisons that aid in the understanding of human genes, many of which have counterparts in these model species. The ultimate goal is, of course, to use these insights to find better ways to detect and treat the many genetically based diseases that plague humankind.

Genome-scale investigation of sharks and rays is work that is in its infancy, if not still at its birth. At the SOSF Shark Research Center, we've taken on this research challenge.

We are making progress towards uncovering intriguing genetic functioning in these animals that is also hinting at future medical applications. Several biochemical investigations of sharks have shown that they have unique features in their ancient immune systems. For example, sharks have a specialised class of antibodies – an immune system's attack cells – that are much smaller than human antibodies. Some researchers are already considering these novel molecules for use as therapeutic agents to deliver cancer-killing drugs to tumours in humans because their small size will enable them to penetrate tumour tissues more easily.

Studies of shark teeth are also yielding potentially useful applications for human health. Shark teeth have a unique chemical composition and structure that provide strong mechanical properties and are being used as a model for designing synthetic dental restoration materials for humans that are more durable than materials currently used. The microstructure of shark skin inhibits the growth of bacteria and has inspired the formulation of materials that can be used in hospitals to reduce the high incidence of bacterial contamination.

There are even potential energy-saving applications to be derived from the unique evolutionary features of sharks. The ability of some sharks (such as shortfin makos) to swim really fast has led to biomimicry research on their skin to formulate paints for ship hulls that will increase the efficiency of movement through water and reduce the growth of surface-fouling organisms (algae and barnacles).

All these useful shark features have genetic foundations. However, we know almost nothing about the genes involved in making sharks such unique creatures. We're still working to figure out what other intriguing biological properties sharks and rays have and whether they offer more biomedical and other useful applications. Studies by the SOSF Shark Research Center, the Guy Harvey Research Institute and collaborators from Cornell University are offering tantalising findings.

Our examination of all the genes expressed in the heart of the white shark has shown that some aspects of its biochemistry are more similar to mammals than the zebra fish model species. That's a very unexpected finding considering that sharks are, after all, fish. Clearly, there is a lot more novelty to shark functioning than meets the eye.

There are even more surprises. New findings from our examination of genes expressed in the white, shortfin mako and great hammerhead sharks and the yellow stingray have revealed more genes related to wound healing than are found in bony fishes. This discovery, the first ever of wound-healing genes in elasmobranchs, could provide the key to their rapid wound healing and be a step towards application in humans. Another very interesting finding from our comparative work is that sharks and rays have more genes involved in the activation of the immune system than bony fishes have. This genetic feature may also be linked to the ability of sharks and rays to heal so efficiently from wounds. These early findings need to be investigated further, of course, but even our first look at shark genomes is yielding tremendously exciting results.

It seems very likely that digging deeply into the genetics of sharks and rays is going to continue revealing important new features and this has us moving full speed ahead on other aspects of elasmobranch genomes. As part of this, the SOSF Shark Research Center and Cornell University collaborators are determining the DNA sequence of the entire genome of the white shark. The analyses are showing that the white shark genome is massive – about twice the size of the human genome – and the key question is, why? Are there that many more genes in white sharks than humans, and if so what are these genes? Another possibility is that white sharks may have duplicated parts of their genomes in their evolutionary progression. Comparing the genes and associated genetic background of sharks to other vertebrates will help us answer these questions – and that overarching question of what makes a shark a shark.

As fascinating and potentially important as such work may be to biological understanding and human health, there's also a significant conservation application. In the simplest terms, we're showing a strong connection between the welfare of humans and the welfare of sharks. The evidence strongly suggests that sharks' evolutionary antiquity and unique properties are going to offer humans major benefits. That means, if we lose the sharks to overfishing and the poor stewardship of our oceans, we could lose that potential for major innovations in human medicine and technology. That, in itself, should offer strong motivation for conserving these wondrous animals.

Although it happened almost three years ago, I still remember taking part in the initial discussion about creating a mobulid identification guide that would be both comprehensive and global. 'How hard could it be?' I thought. After all, there are only 11 species in total: two mantas and nine mobulas. Well, it turns out that it could be – and is – quite a complicated task, given the ambiguities surrounding some of the species. This, coupled with the complexity of conducting research in war-stricken or extremely remote regions of the world, made it all the more challenging. But I am getting ahead of myself. First let me explain why we set up this project in the first place.

It is no secret that manta and mobula populations are in decline around the world, largely because of the increasing demand for their dried gill plates, which are used in Chinese medicine. Like other elasmobranchs, mobulid rays are characterised by their conservative life-history traits, which make them highly susceptible to any fishing pressure and extremely slow to recover from depletion. But we need to be able to give fisheries management authorities a large amount of scientific data to demonstrate these traits so that they can manage the stocks appropriately. And this is where we encountered one critical problem. It became apparent that one of the constraining factors to collecting the data required was the difficulty in distinguishing between the 11 mobulid species. The result was that little – and in some circumstances even inaccurate – data were gathered. Either way, we realised that it was time for somebody to take the lead and create a global mobulid guide, one that would augment the data currently available and help researchers and enforcement agencies to identify specimens effortlessly.

Obtaining the data necessary to create an ID guide proved to be no easy task. With help from Guy Stevens and Giuseppe Notarbartolo Di Sciara, my co-authors at The Manta Trust, we began by analysing all existing literature about mobulids, going back as far as the late 1800s to better understand which species were lacking the necessary information. We would then focus our time and resources in regions with the highest chances of encountering these species of interest. Of course, it turned out that we had to focus on all the species to some extent or other!

Fortunately, thanks to part funding from the Save Our Seas Foundation, my primary field research is in Sri Lanka, enabling me to gather data about five of the 11 mobulid species in significant detail. It felt good to realise that the countless early mornings spent at the chaotic, smelly and noisy fish markets were finally paying off – not just by providing information critical to the protection of mobulid rays at conventions such as CITES, but also by enhancing data in the ID guide. But this was not enough – there were still another six species out there! We decided to reach out to all the mobulid projects established around the world, some of which are part of the extensive Manta Trust network. News of our requests for information spread via e-mails, presentations at international conferences, Facebook, Twitter and countless Skype calls. Colleagues from all around the globe contacted us, helping to provide incredibly valuable data. But still there were some information gaps – and that is when my travels began.

My first trip was to India, the land of unbelievably vibrant and diverse fish markets. With help from a local colleague, Mohanraj Theivasigamani, we established a project funded by the Save Our Seas Foundation to continually survey two key markets near Tuticorin, a small city on the Coromandel Coast that is still famed for its pearl fishery, although it ended decades ago. What followed was a two-year project that generated a significant amount of data. Although this new information complemented what we had learnt in Sri Lanka, it unfortunately did not shed light on any new species for the ID guide.

For a scientist, travelling the world is sometimes a requirement and often taken for granted. Yet there are some scientists living in communities that do not have this luxury. By far one of the most challenging projects we supervise is based in the Gaza Strip, Palestine. This began after we came across some videos in early 2013 that described a 'mass stranding' of *Mobula mobular,* an endangered species found only in the Mediterranean. Upon closer inspection of the videos, it was apparent that fishermen were extracting the rays' gill plates and this made us highly sceptical that it had indeed been purely a 'stranding'.

Through an elaborate network of contacts, we finally got in touch with Dr Mohammed Abudaya, who is based at Al-Azhar University in Gaza. After a brief investigation he was able to confirm that it was no mass stranding but a seasonal fishery targeting the rays. A few months later, with exclusive support from the Save Our Seas Foundation, we established a project to survey this war-torn region in 2014 and 2015. Usually I prefer to train researchers on the ground in person, but the political situation meant that I was unable to. As a result, we conducted the very first remote mobulid ID training workshop. We are now working to analyse these two years' worth of extremely exciting data for the ID guide.

One species that proves to be particularly elusive is *Mobula rochebrunei*, which is apparently found only along the west coast of Africa. The one preserved specimen in existence resides in the Paris Natural History Museum, far past its prime. Sadly, Ebola broke out while we were en route to West Africa and we had to make a last-minute diversion to Morocco and Western Sahara, which yielded no additional information for this species. Making use of our extensive Manta Trust network, we finally got in contact with an extremely enthusiastic researcher in Guinea, Framoudou Doumbouya, who, using Save Our Seas Foundation funds, was instantly able to set about investigating the local markets in search of this species. We are now eagerly awaiting data that we hope will indicate or confirm the presence of this species in the region.

As I write this, I am heading down to Florida to visit the Mote Marine Laboratory, where a research group led by Kim Hull and Robert Hueter and funded by the Save Our Seas Foundation is studying eagle rays. During field research, members of the group have noticed recent aggregations of *Mobula hypostoma,* a species found only along the western front of the Atlantic. Thanks to their invitation to accompany them on a few field expeditions, I am looking forward to spending some days with these animals, as I have yet to see one in real life.

All this travelling is just the easy part of creating an ID guide. Using all the data accumulated from my travels and provided by colleagues at The Manta Trust, partner projects all around the world and any random contact I was able to make, we are now working to develop a database of information for use in the ID guide.

The next few months will be spent poring over the thousands of images taken to determine each and every morphological variation that can help us to differentiate between the extremely similar species. It's a tough task, but there is consolation in knowing that the result will help to advance the protection of these species and ensure that legislation is adhered to. And more than that, all the projects created in the wake of this guide through The Manta Trust will help to obtain incredibly vital baseline information that is fundamental to a better understanding of these species.

Manta and mobula rays are not well understood. At least one of the reasons for this is the difficulty of distinguishing between species. By travelling around the world and studying both live and dead specimens, Daniel aims to create a guide that will enable scientists to tell which mobulid is which.

Photo by Steve De Neef

The Manta Trust

Mobulid ID – a real challenge

When you're collecting data about a species, the first thing to do is identify it – and that's difficult when it comes to mobulids. Daniel Fernando and colleagues are compiling an ID guide, in itself no easy task.

Words by Daniel Fernando

The difference between kelp and rope

Photo by Thomas P. Peschak

CetaceaLab

Janie Wray was surprised to see a young whale apparently enjoying a kelp massage – and then it clicked. Is this why whales so easily become entangled in rope fishing gear?

Words by Janie Wray

Cetacea Lab is a whale research facility nestled among the giant red cedars of Gil Island on the remote northern coast of British Columbia, Canada. Surrounding Gil Island are two deep channels known as Whale and Squally. Both names describe this habitat perfectly: the first reflects the boom in the humpback population while the second tells of winter gales that keep boat traffic to a minimum. We built this station more than a decade ago and at the time had no idea that our arrival would coincide with the return of the great humpback whale after years of hunting that ended in the late 1960s.

During our first surveys in 2004 and 2005 we documented 42 individual humpback whales. This number doubled in just four years and by the end of 2014 it had climbed to 335. The nutrient-rich habitat of this stretch of coast is becoming an increasingly important feeding ground for mothers, calves, juveniles and old adults that have seen change come and go. From early spring until mid-summer the most common foraging behaviour observed here is bubble-net feeding. The same whales meet year after year and together they perform an underwater spiral dance of cooperative and bubble-producing movements that force schools of herring from the depths of the ocean to the surface. In a feeding frenzy, giant gaping mouths consume tonnes of fish and krill each day. This dance is repeated over and over in a marathon that lasts from dusk till dawn for weeks on end. As spring becomes summer, the

urgency to replenish fat cells after months without food diminishes and we begin to witness more social and robust activities between humpback whales.

Although we continue to share the good news of the return of the great humpback whale to the north coast of British Columbia, it comes at a price. The incidence of these gentle giants accidentally becoming entangled in fishing nets and crab and prawn gear is rising at an alarming rate and along this coast there is no real action plan in place to deal with the problem. More than half the entanglements occur around a humpback's tail; second and third most frequent are those around the mouth and pectoral fins. When a humpback whale becomes entangled in fishing gear, serious infection can occur from flesh wounds caused by ropes rubbing tightly against its body. These ropes can bind the whale's long pectorals to its sides and then, unable to move or dive to feed, the giant faces a long and torturous death by starvation. Sometimes the gear is wrapped around its head, with the same result.

In Alaska and along the east coast of Canada and the USA it has been documented that more than 70% of the humpback population bear scars from entanglement, indicating that the whales have had close encounters with ropes or nets at some point in their lives. This also suggests that the way to deal with this increasing problem is to prevent the entanglement from taking place. Along the coast of British Columbia the two most common sources of cetacean entanglements are gill nets and crab or prawn pots. Many humpbacks become caught up in the vertical ropes that connect the pots on the ocean floor to buoys on the surface. The pots are also attached to each other by means of horizontal ropes. These lines are hazardous for humpbacks, which can ensnare themselves while feeding in the depths with their mouths open. But this, I believe, is not the only danger.

It was during an early morning survey that I caught a glimmer of insight from the playfulness of a juvenile humpback we call Ivory. It was just a few hours after sunrise – not that you would have known, as the fog was so thick it was impossible to see more than a few metres into the distance. Personally, I love these days on the water. Travel is extremely slow; I stop and listen for blows, then move forward again at just three to five knots. If I hear a blow, I turn everything off, pour a cup of coffee from my thermos and, with patience in my heart, sit and wait for the day to present itself. The fog usually burns off by 1 pm, creating a magical encounter between me and the majestic Great Bear Rainforest. With every moment the surroundings become clearer, revealing the connection between land and sea in a different light.

On this day I was sitting close to a large kelp bed wrapped around a tiny little rock island when I heard a blow. I could see movement in the kelp bed as it rose and fell. Then something very white, bumpy and long began to emerge. Long amber ribbons of kelp hung from what I now recognised as the pectoral fin of a humpback whale. Curiosity now had me and I moved closer, not really sure what was happening. Was the whale in trouble? It took a few minutes, but I soon realised that this young whale was actually playing in the kelp! Rolling and rolling, wrapping the long stems around its body, then moving to a new patch. I imagine that the rub of these cool, solid structures along the whale's body must have felt like a giant back massage – the kelp spa for whales!

Then the light bulb came on and I made the connection. Is this what attracts humpback whales to the vertical lines that link rows of crab pots to the surface? Are they going in for a kelp roll or back scratch, not knowing the difference between the harmless benefits of kelp and the deadly power of man-made ropes, inches thick and impossible to break through? In that moment my heart broke; how could the innocence of such playful behaviour have the potential to end so tragically? This is just one small piece of a giant puzzle, but it's another important clue to finding a way to protect these majestic animals.

Along the east coast of the USA the development of fishing gear and practices that are less likely to entangle a whale is becoming mandatory. For instance, the numbers of vertical lines in areas of high humpback abundance are to be reduced, and there are now restrictions on where and how gear is set and the number of traps or pots per line. One great example is the sinking of lines between prawn traps, so that instead of floating they lie on the ocean floor and cannot get in the way of a feeding whale. This presents problems, though, for fishermen in areas where the sea floor is rocky because over time the ropes may break from rubbing on the rocks. Another requirement is that the line attached to a buoy or flotation device must have a weak link so that an entangled whale is able to break free. In Australia many entanglements occur because floating buoy ropes are extremely long; when lobster fishers move traps from deep offshore waters to shallower inshore waters they neglect to shorten the retrieval buoy line. Shortening excessive rope immediately decreases the chance of entanglement. Changes such as these can also save fishermen the costs associated with the loss or destruction of their gear.

Unfortunately none of these regulations or practices are in place along the coast of British Columbia and the conversation to implement such changes needs to begin now. A few years ago a humpback swam right past the lab with a gill net wrapped around its head and dragging a 15-metre cork line behind it. It took 24 hours and an entire community working together to save this whale, but in the end we succeeded. The support that we received from local people on that day gives me great hope. There is no doubt that, as the population of humpback whales continues to increase, we need to work together with those who make a living from the marine resources of the British Columbian coast and take collective responsibility for the safety of whales. No creature on this planet deserves to suffer a long and tragic death when there is the potential to avoid it.

Janie Wray and the CetaceaLab have witnessed the comeback of the humpback whale along the coast of Canada's Great Bear Rainforest. From 42 individuals in 2004, whale numbers have swelled to 335 in the lab's latest survey.

Saving Solar

It was at first light that I saw Solar, a resident humpback whale, passing by the lab. He was obviously under stress and it was immediately clear why: a gill net, with lead lines attached, had become wrapped around his head and one line was already cutting into his blow-hole. Trailing behind him were at least 15 metres of cork line. With all this fishing gear wrapped around his head and body, Solar was unable to dive or even open his mouth to feed. He could not survive for long.

Through a series of phone calls and urgent messages we arranged for Paul Cottrell of Fisheries and Oceans Canada to fly up the next morning to help us in this dire situation. We called the Guardian Watchmen of the First Nation Village of Hartley Bay and within minutes they were on the water to help us track the whale.

It was a long and emotional day, and well into the night we had to face the fact that we had lost sight of Solar. Still, there was no way we were going to give up. Once it was daylight again, it took three boats and four more hours before we managed to relocate the distressed young whale. Now the real struggle was about to unfold. How do you safely remove a net from the head of a humpback whale?

Paul and his crew had to clip their boat onto the trailing cork line in order to attach the whale to the vessel. What we witnessed next was inspirational: the calmness and level of professionalism in a group of men working so closely together. Each time the whale came up to breathe, the slack in the rope was an opportunity to winch in the lines and bring the huge animal a bit closer to the boat. Minutes became hours. With each cut into the gill net, the men inched nearer to Solar. But the closer Solar was to the boat, the more frantic he became, creating a dangerous situation for everyone involved. Whenever he surfaced, a tonal blow, or cry of distress, would echo across the water. It was the most heart-wrenching sound I have ever heard.

Then everything happened so fast. The men were close enough to cut the last of the ropes. We heard the sound of the ripping net – then complete silence. Standing on the decks of our boats, we watched as Solar swam free, his body finally able to move with the true grace of a humpback whale. He will be scarred from this experience, but at least he now has a chance to live a full life.

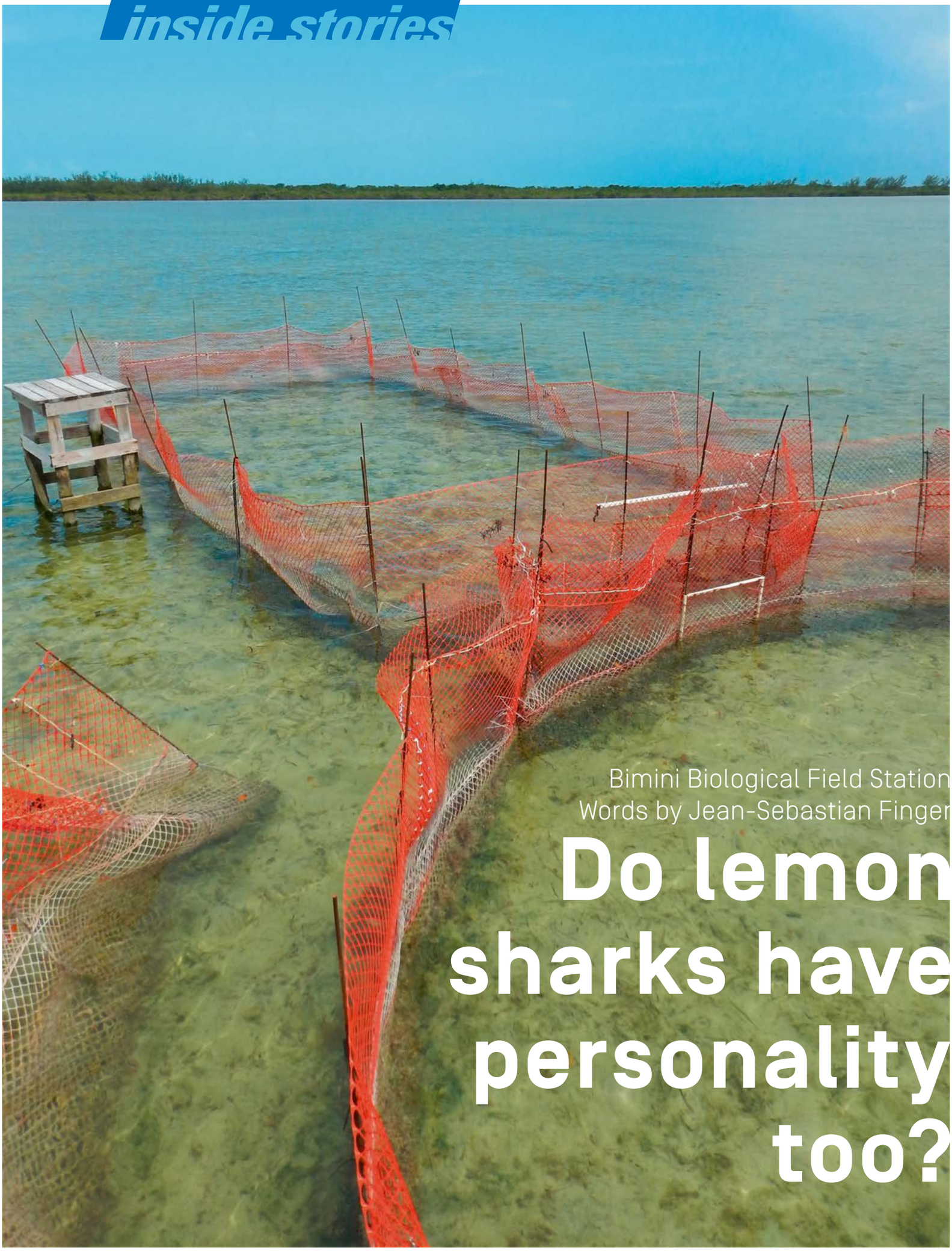


Photo by Michael Scholl

Bimini Biological Field Station

Words by Jean-Sebastian Finger

Do lemon sharks have personality too?

Personality in animals is actually similar to personality in humans. Essentially we look for differences in behaviour between individuals of the same species, in this case the lemon shark. In a non-technical, human context, anyone is capable of basically assessing such differences. For example, you might describe one person as more social than another or someone else as calmer, and so on. We compare people instinctively and are thus able to classify their personalities in a non-systematic way.

A comparative psychologist or animal behaviourist, however, needs more to be able to specify animal personality. It is not enough that individual subjects simply show differences in behaviour; they must do so consistently. For instance, you meet two people at a party: one may be social and the other less so. If you meet them again you would expect them to show the same differences: the social person would remain social and the less social person would still be less social. In a similar way this is what we are looking for in sharks. If the shark displays the same behaviour over time, it demonstrates that it has personality.

Studying personality in humans is comparatively straightforward. You can ask them to fill in a questionnaire, for instance. However, it is fairly difficult for a shark to complete a questionnaire! So to demonstrate and classify the personality of individual sharks, some sort of behavioural test needs to be designed. Observations have to be based on natural behaviour of significance to the juvenile lemon sharks. The trick is knowing what is important to the shark, and happily – due to decades of study at the Bimini Biological Field Station, or Shark Lab – we know a lot about the behaviour of juvenile lemon sharks. And this has been very useful in my own first investigation of personality in lemon sharks.

As I was learning more about these young sharks, two behaviours in particular caught my interest. Firstly, lemon sharks are highly social animals and their social behaviour is more complex than we thought, as Shark Lab director Dr Tristan Guttridge demonstrated nearly a decade ago. Therefore I wanted to verify whether some lemon sharks are consistently more, or less, social than others.

The second behaviour that caught my attention comes from one of the numerous studies done by Doc Gruber, the founder of Shark Lab, and graduate student John Morrissey, way back in the 1980s. That particular study investigated site attachment in young lemon sharks and showed that they have very limited home ranges and keep to their mangrove nurseries for about three years. What was particularly interesting about Gruber and Morrissey's findings, however, was that on occasion some little sharks ventured out of their home into dangerous waters. The researchers called these movements 'excursions'. These jaunts made me wonder whether the sharks were experiencing a kind of wanderlust or desire to explore an unknown environment. 'What if some of these little guys were more of an explorer than others?' I mused. And if they were, I wondered whether consistently different exploratory behaviour could be demonstrated over long time periods in these young, social lemon sharks.

Answers to such questions may be quite important for these sharks because their survival depends on everyday decisions. For instance, going out into deeper water, away from the safety of the mangrove nursery, would be quite risky for a little shark. At the same time, however, it might provide more food resources. Similarly, being highly social might be safer, but a social shark may be required to share food or even lose out on food due to competition. Therefore, these young lemon sharks need to find a balance between their resource needs and their safety. I considered that finding personality would indicate that not every individual has the same strategy to cope with the risk–benefit trade-offs, and thus gives the species greater flexibility in surviving the vagaries of a changeable environment.

To assess these ideas we first had to find a method to test personality in juvenile lemon sharks with respect to both exploratory and social behaviours. After watching groups of captive lemon sharks we decided to build different-shaped shark pens in the shallow North Sound nursery. The first one was circular and big enough (10-metre diameter) to support six individual lemon sharks that could swim on their own, away from the others if they wanted to. Next to this pen was a rectangular pen designed to be large enough (12 x 6 metres) that a small lemon shark could explore it. After tweaking the set-up over months of experimentation, we were finally able to start testing our sharks.

It went like this: in the first 'social' pen, six sharks of similar size were able to swim together either with or away from their pen partners. By recording them on videos for 20-minute sessions, we were able to obtain a score for each of the six sharks that represented whether it was social (swam with the others) or anti-social (stayed aloof and away from the others). After that, the same sharks were ushered into the 'exploration' pen, a place they had never seen before. In this pen we could follow their movement patterns, such as how much exploration that each individual showed, again with video analysis. All the sharks were then released into their natural habitat and were recaptured regularly, after six months to a year, and retested.

Photo by Michael Scholl

↑ Jean-Sebastian Finger's research work will shed new light on personality in sharks. Knowing whether sharks have personality and how it affects their growth and survival will help to ensure their successful management.

← A pen that holds lemon shark study subjects at the Bimini Biological Field Station. Enclosures like this can be used to isolate groups of sharks and keep others together in different environments. Scientists can then observe how they behave in different settings.

Until we perform a rigorous statistical analysis, our results are still preliminary, but we are quite confident that the study will clearly demonstrate strong personality traits among individual lemon sharks, even after several trials months to years apart. We suspect that some sharks are far more social than others, and some are explorers while others stick around home. My general conclusion from this first step is that the behaviour of sharks, like that of humans, cannot be generalised into an average because of individual personalities.

However, my three-year doctoral research is only a first step towards understanding personality in sharks. For instance, we are investigating whether these personalities can be observed directly in the wild and whether differences affect growth rate, survival and the probability of capture by humans. These are important questions to answer if, for example, population and conservation management programmes are to be improved. As time passes we will be able to gather enough observations to resolve such questions. In this regard, as I complete my doctoral research this study will be taken up by a new doctoral student, Felice Dhellemmes, who for the next three years will extend and confirm my findings.

Finally, research that would have been difficult or nearly impossible with large animals such as sharks has benefited greatly from the massive experience in field work and knowledge the Shark Lab has gleaned about lemon sharks over the past quarter century. I gratefully acknowledge the help of all the hard-working staff and volunteers, as well as the generous support from several groups that made this project possible.

Island School Seychelles

MARINE EXPLORERS IN THE SEYCHELLES

Words by Abi March

The people of the Seychelles have a close and ancient relationship with the ocean as a source of food, yet few of them dip below its surface to explore what it has to offer beyond a livelihood. Our Marine Explorers Programme would like to change that. It's all about enabling young Seychellois to experience the magnificent marine life found in their country. Some of them want to learn more about topics that already interest them and to spend more time snorkelling in the sea they already love. Others are experiencing a whole new world, discovering a curiosity about what lies beneath the waves, donning snorkel gear for the first time and finding out about the ocean for themselves.

It started in June 2014, when we at the SOSF Island School Seychelles spread the word that we were looking for enthusiastic individuals to join the Marine Explorers Programme. Designed to run over two weeks, the programme introduces students to different coastal habitats in the Seychelles and looks at their importance, the animals that live in them and the threats that they face. This is achieved by a combination of indoor lessons and exploring the outdoor environment, including with a snorkel every day. We launched the application process and visited nine secondary schools on Mahé, Praslin and La Digue, speaking to more than 1,000 students. We received more than a hundred applications, which were judged by representatives from the Save Our Seas Foundation, the Ministry of Education, the Ministry of Environment and Energy, and Global Vision International (GVI Seychelles).

Take 24 young students and show them the amazing life in the ocean around them, says Abi March, and before you know it you have 24 marine ambassadors.

The selection process was completed and 24 enthusiastic explorers took part in the first week of the programme during the August–September school holiday, completing their second week in the December holiday. Our headquarters was the GVI Seychelles base at Cap Ternay on Mahé, a great location that provided both indoor space and access to a variety of ecosystems to explore. With Baie Ternay National Marine Park right on the doorstep and Port Launay National Marine Park nearby, we couldn't have asked for a better 'classroom'.

Snorkelling was the highlight for all the students. More than half of them had never snorkelled before, but their enthusiasm outweighed any apprehension and they all took to it like fish to water. Come rain or shine, the announcement that the next activity would be snorkelling was met with a flurry of excitement and within minutes the students were ready, their masks and snorkels already on.

Taking 24 students on this ocean adventure was both rewarding and enlightening. In the sea grass, every sea cucumber discovered was excitedly announced. By the time they got to the coral reefs the youngsters were in their element, recognising many different families of fish they had just learnt about in the classroom. Fourteen-year-old Guyan said it all when, having identified the family of every fish I pointed out, he explained, 'Usually I don't have a good memory, but I remember stuff I'm really interested in.'

The students continually asked us what the different animals were and as the programme progressed their descriptions

Photo by Michael Scholl

Photo by Abi March

improved from 'I saw a red fish, what was it?' to a particular favourite from 13-year-old Alvania: 'I saw a fish, I think it was a butterflyfish and it had the face of a raccoon.' An excellent description of a raccoon butterflyfish!

As well as the fish, we discovered moray eels hiding in crevices, stingrays resting camouflaged on the sandy bottom, turtles foraging on the reef. Every habitat we explored produced new and exciting creatures, from tiny hermit crabs on the sandy beaches and mudskippers on the rocky shores to stingrays in the mangroves and turtles on the coral reefs. Why were all of these different habitats and animals so important? We began to learn how each animal has a role to play in maintaining a healthy ecosystem and that different habitats provide different things for the animals and plants that live in them: a home, a hiding place, somewhere to find food, a safe place to give birth.

We started discovering more about sharks and how important and awesome they are. To begin with, most of the students had a negative opinion of sharks, thinking of them as scary and dangerous. They all said they had seen a shark before, but when they were asked where, the answers *'Jaws'* and *'Sharknado'* revealed that few had ever encountered a real shark in the water. We explored the reasons why sharks have a bad reputation and the students were surprised to learn that it was not justified.

It wasn't just the students who were keen. Primary school teacher Fred Hypolite joined us on the programme and proved to be an enthusiastic learner who loves the environment. He hadn't had much interaction with the marine side of it until now and he took every opportunity to ask questions and take notes, then the following term shared with his younger students all he had learnt. Irma Dubois, a previous SOSF Island School Seychelles student, also assisted during the December programme. It was great to see Irma share her enthusiasm for the marine environment with the students and we're delighted that both she and Fred are continuing to work with us at SOSF Island School Seychelles.

The Marine Explorers Programme ignited in its participants a passion for the marine world and since it ended they have regularly attended weekend snorkel sessions and activities at the Natural History Museum. We're looking forward to 2015 and seeing these students develop further as marine ambassadors, as well as meeting the next group of students who will take the plunge into this year's Marine Explorers Programme.

We thank the Environmental Education Unit at the Ministry of Education for their support of this programme and providing daily transport to Cap Ternay. We also thank GVI Seychelles and Seychelles National Parks Authority for their hospitality at Cap Ternay and their support during our snorkelling expeditions.

↑ The 2014 Marine Explorers wander along a beach towards their next activity and adventure.

← Although there were a variety of indoor and outdoor activities for them to enjoy, snorkelling was the unanimous favourite among the Marine Explorers. These young children had the opportunity to explore different marine ecosystems of the Seychelles at first hand.

If you're a stingray – or a stingray researcher – St Joseph Atoll in the Seychelles is a good place to be. Chantel Elston tells of inroads being made into the vast unknown of stingray biology.

Words by Chantel Elston

I'd like you to stop for a moment and think of everything you know about stingrays. For most people, the answer is probably not much. In fact, I bet the first thing you'll think of has something to do with the late Steve Irwin. But you needn't worry; the truth is, the scientific community doesn't know much about these animals either.

What we do know is that there are more than 70 species of whiptail stingrays belonging to a family called Dasyatidae. These animals have wide-ranging distributions and generally occur in shallow tropical waters. Evolutionarily they are closely related to sharks and share many similar features, such as having only cartilage in their skeletons. Unfortunately, though, the unanswered questions, including basics such as the size at maturity for many species, far outweigh the answered ones. Human curiosity is naturally attracted to what it finds most interesting and the larger and more charismatic animals, such as sharks, have been in the forefront of elasmobranch research. Consequently research on stingrays has lagged behind.

The Save Our Seas Foundation D'Arros Research Centre (SOSF–DRC) might be a pinprick in the Indian Ocean, but despite its tiny size and remote location, it's in just the right spot to start closing this knowledge gap on stingrays. It is situated only one kilometre from St Joseph Atoll, a place that could easily be nicknamed 'Stingray City'. Shallow sand flats surrounding a deeper lagoon teem with three stingray species, from juveniles through to adults.

The first question that SOSF–DRC scientific director Rainer von Brandis asked about these stingrays was, 'What do they eat?' Not surprisingly, he couldn't find an accurate answer. Although numerous references in guide books and scientific literature state that the three species – cowtail ray *Pastinachus sephen,* mangrove whiptail *Himantura granulata* and porcupine ray *Urogymnus asperrimus* – eat benthic organisms and fish, only one detailed dietary study has been published, and that was on the porcupine ray in Australia. Rainer's simple enquiry gave rise to a research project in 2014 that aims not only to delve into the three species' diets, but to find answers to many other questions too.

Two successful field trips were conducted in 2014, during which we used the relatively novel non-lethal technique of gastric lavage (or stomach flushing) to collect stomach contents from 55 porcupine rays. In addition, we surgically implanted acoustic transmitters into 17 mangrove whiptails and 13 porcupine rays. At predetermined intervals, these transmitters send out pings that are recorded by a network of receivers in the lagoon. This will enable us to monitor the movements of these stingrays for the next couple of years, even when the researchers are away from the island.

Preliminary results have been very enlightening and Rainer finally has part of the answer to his question. After sifting through what was essentially stingray vomit, we found that porcupine rays eat mostly annelid worms (which are very common in our sediment samples). Every now and then a prawn or shrimp is found among the worms and we hypothesise that when a porcupine ray finds one of these crustaceans it's like hitting the jackpot. On future field trips stomach contents from the two other stingray species will be collected and blood and muscle samples will be taken for stable isotope analyses. These analyses will provide insight into the long-term variation in the stingrays' diets.

The surgically implanted acoustic trackers also provided a wealth of information. After the stingrays were tagged in March, the data from the receivers were downloaded in November and more than 200,000 pings were recorded. Even a quick glance at this data provided some surprises. We found that the smallest tagged juvenile (a mere 30-centimetre disc-width) ventured into the dangerous deep of the lagoon where large, predatory sicklefin lemon sharks lurk. This was contrary to our hypothesis that small juveniles always remain on the shallow sand flats where it is relatively safe. Also, larger individuals were found to leave the atoll; in fact one was recorded about 15 kilometres away. These preliminary results lead to even more questions, such as why do the stingrays leave the atoll? Is it because there is not enough food for the larger individuals? Do they leave the atoll to mate? We hope to find some answers over the next two years.

'But what does it matter?' one might ask. Why is it important to know what stingrays eat or where they spend their time? Well, something to store in your stingray fact collection is that they are crucial to the ecosystems in which they occur. They fall in the middle of the food web and are important in the transfer of energy from lower trophic levels, such as shrimp, to higher trophic levels, such as sharks. They also play a major role in modifying the soft sediments over which they occur, shifting and aerating the sediments as they feed.

Unfortunately, many stingray populations are in decline due to their susceptibility to overfishing. Like sharks, stingrays grow slowly, breed late and give birth to few young. This means they can't replace their numbers quickly enough to compensate for the numbers being removed both by targeted fisheries and through bycatch. In fact, the porcupine ray is listed as Vulnerable by the IUCN, and St Joseph Atoll is one of the few places in the world – if not the only location – where it occurs in such high abundance. We're really lucky to be working on this species at St Joseph; Andrew Chin, who is also funded by the SOSF to research porcupine rays, has a much harder job finding these rays on Australia's Great Barrier Reef as they are rare and difficult to locate there.

A Global Shark Red List assessment that was published last year highlighted the plight of stingrays; they are the fifth most threatened of all the shark, ray, skate and chimaera families, with 30% of species considered threatened and 39% of species lacking enough data to make an assessment. Thus any knowledge gathered about these animals is a gain. What we learn from this project will be beneficial not only when trying to manage the St Joseph population of stingrays, but when trying to understand and conserve these species throughout their tropical range.

St Joseph Atoll in the Seychelles is teeming with stingrays, and Chantel Elston is there to study them, especially what they eat. Her initial results suggest that their diet consists largely of marine annelid worms – related to earthworms – from the lagoon's sandy bottom.

Photo by Rainer von Brandis

D'Arros Research Centre

Unravelling stingray secrets

Listening in

Words by Rainer von Brandis

Acoustic telemetry has become an increasingly popular tool for the long-term remote monitoring of the movements of fish, sharks, rays and turtles. An array of acoustic receivers deployed on the ocean floor 'listens' for animals fitted with uniquely coded transmitters. These transmitters are thumb-sized tags that are either attached externally or surgically implanted into the body cavity. Whenever a tagged animal swims within range of a receiver, its unique tag number and the date and time are stored on the receiver for future download.

In partnership with Danah Divers, an organisation committed to diving for marine conservation, the SOSF–DRC has deployed 90 receivers over the entire extent of the Amirantes Bank (about 3,500 square kilometres), making it the largest and most widespread array in the Seychelles. Thus far Danah Divers and SOSF–DRC have tagged 23 manta rays, 25 juvenile hawksbill turtles, 30 stingrays and more than 100 sharks.

The data from the receivers are downloaded twice a year and often the number of tag detections amounts to several hundreds of thousands. As well as answering specific questions about the movements and general ecology of the tagged species, the data enable us to find out how these species move in relation to each other. For instance, do stingrays and turtles avoid areas frequented by sharks? Importantly though, the main purpose of the acoustic telemetry project is to support the establishment and future management of the anticipated D'Arros Island and St Joseph Atoll Marine Protected Area. Specifically, the data will guide us in delineating the boundaries of the protected area and highlight specific areas that need special protection.

Photo by Paul Millar

Shark Education Centre | Words by Paul Millar

Marine Explorers

Learning to love th

Getting kids involved in learning about the sea is as much fun for educator Paul Millar as it is for the youngsters themselves.

↑ The Marine Explorers at the Shark Education Centre, South Africa, are immersed in marine activities once a week, including surfing, snorkelling and learning about ocean life.

→ In addition to the Marine Explorers, the Shark Education Centre hosts school groups and takes children to explore nearby rock pools.

Well before the doorbell rings we hear it: the distorted 'doof-doof' of a mini-bus taxi's speakers being stretched beyond their limit. Then comes the noise of kids starting their weekend, popping with a boisterous, school-induced cabin fever that sounds like it needs treatment. Little heads bounce up and down, just visible above the Shark Education Centre's wall.

'Is everything all right out there?' I hear a concerned colleague ask distantly from elsewhere in the building.

'Yup, it's just the Marine Explorers arriving,' I try to explain.

The doorbell rings. Repeatedly. No need to check who's there. I buzz them in and am instantly swamped by enthusiastic greetings of 'Hello, Uncle Paul!' and 'Can we get into our wetsuits now?' In South Africa the 'Uncle' thing is a term of respect used by kids when addressing any adult, related or not, and it can imply an element of familiarity, which in this case I am comfortable with. But the enthusiasm in the Marine Explorers' greetings stems from their anticipation of getting into the water, and that's mostly what it's about.

The Marine Explorers Club meets on Friday afternoons and most of the sessions are spent surfing, snorkelling or learning about marine life at one of a few locations in False Bay, near the Save Our Seas Shark Education Centre. The role of healthy outdoor activities as a mitigator of personal and social issues is well-documented, and fortunately urban South Africa has seen a much-needed growth in initiatives of this kind. The Marine Explorers programme involves its participants in exactly such activities, but it goes one step further – it has a strong conservation focus. US educator David Sobel addresses individual and societal needs, together with the good intentions of conservationists, in his article 'Beyond ecophobia', pointing out that 'If we want children to flourish, to become truly empowered, then let us allow them to love the earth before we ask them to save it.'

Sobel's choice of the word 'allow' makes sense – love cannot be taught. It can, at most, be facilitated by providing experiences, in this case a surf, a dive or an exploration of the rocky shores. An experience may lead us to become aware, interested, possibly excited, even in love. So when a child staggers out of the water, bedraggled but smiling, and flops happily onto the same sand that a few weeks earlier seemed dirty and annoying, we have a far better chance of success when we ask him to save the earth and its oceans. Like when, through daily habit, he drops his food wrapping on the beach and the kelp gulls greedily investigate, the educator's explanation as to why we shouldn't litter finds resonance. And, as the weeks go by, it is interesting to witness the role of peers in this kind of learning, as the kids monitor each other and quite quickly become champions of the cause themselves. And we all know kids listen to kids far better than they do to adults!

Each Marine Explorers group usually has seven weeks of surfing, followed by the same period of snorkelling. With today's friendly soft-boards and the perfect beginner waves at Muizenberg beach, surfing comes about as close to instant gratification as a water sport can. It's interesting to see how the kids start to take notice of the different conditions each time they surf – the tides, the wind direction, the swell size and even the beach profile – and they start to become dialled into these aspects of the natural world. And with this awareness comes

Photo by Mac Stone

e sea

curiosity. At first they stampede over the mussel shells into the water to catch a wave, but with time they start to look more closely, discuss what they see with one another and pepper us educators with insightful questions about the sea.

There is obviously no shortage of eager kids wanting to be involved, but we need to find the right groups to work with. South Africa has one of the most unequal societies in the world and it is important that the programme reaches kids who otherwise might not receive this sort of exposure and experience. This means working with children who come from the so-called 'townships' or informal settlements.

Apart from the practicalities of transport, proximity to the sea is important so that the participants can continue with their new-found passion independently or with limited support as they get older. And we really want them, as emerging ambassadors for marine health, to continue their involvement with the sea. The programme therefore currently works with youngsters in Grades 5 and 6 at two different schools, both within walking distance of the shores of False Bay.

Although our participants attend schools nearby, it's not just a matter of strolling down to the beach every Friday. Cape Town's moody weather, curvaceous coastline and wild winds, together with a swell that can change from flat to monster in a few hours, means that each week can see us heading to a different venue. But this also gives the participants the opportunity to see parts of the beautiful southern Cape Peninsula that, although so close by, are new to them.

After the thrill of surfing, we spend another seven weeks learning to snorkel. The water confidence built up during surfing pays dividends as the kids learn to breathe through a snorkel and become accustomed to having their heads underwater for prolonged periods of time. As they progress, the focus shifts from trying to use the diving gear effectively to seeing what is around them. For us educators, this is as inspirational as it is for the kids. Muted yelps of excitement as a fish or shyshark swims under us, deeper swims along the bottom to see the sea stars and other curious invertebrates up close, and wide-eyed amazement as a shoal of mullet surrounds a child make all of us feel alive and in love with the sea.

So once the marine bug has bitten, the kids seem keen to learn more about the sea. They take in a lot as we chat about what we see when we are exploring, but we also include a few more formal learning sessions and ensure that every Marine Explorer attends one of our Marine Awareness camps. These three-day camps help to build the participants' knowledge of marine life and raise awareness of the importance of healthy marine systems by means of various lessons and activities. They also deepen the vital experiential foundation of the programme.

One of the most refreshing parts of putting a programme like this together has been the abundance of goodwill we encounter. Nearly every person or organisation that we have approached has been eager to assist. Students from the University of Cape Town's Underwater Club pitch up every week to help out with the kids in the water. Pisces Diving, a local dive centre, is amazingly supportive. PADI is kind enough to sponsor certification of our young participants. Xpression on the Beach, a local surf shop, has provided surfboards for every session, and Reef Wetsuits has given us great deals to help the Marine Explorers cope with our icy waters.

Of course, we don't know what the future holds for the children fortunate enough to be involved in the Marine Explorers Club, but for now it's fair to say that the participants are having a lot of health-giving fun and learning a lot. And it's not just their knowledge that's growing; it's that place in their hearts that feels love for the sea – and that, surely, is a good place to start.

'It was wonderful, we could breathe underwater. In my life I have never done this before.'

Andrew Mzantsi, 12 years

BEHIND THE SCENES

Mac Stone and Joris van Alphen, the two winners of the inaugural Save Our Seas Foundation Photography Grant, were assigned the task of documenting the richness of South Africa's False Bay as part of their prize. Each describes his experience.

South Africa became part of my geographic vocabulary when I was nine years old. My best friend's dad, a supporter of Nelson Mandela, was smuggled out of the country in the bathroom of a cruise ship to escape persecution during apartheid. Many years later he moved to the US, raised a family and told stories about South Africa over curry dinners. What I remember most clearly was the fondness with which he still referred to his former home. He extolled a country that was full of extremes – beachside mansions and close-quartered townships, bustling cities and vast wildernesses, arid escarpments and temperate oceans – a place whose identity seemed indefinitely locked in a tug of war. I wanted nothing more than to visit.

As fate would have it, 20 years later I found myself in a gyrocopter humming over Cape Town. The towering facade of Table Mountain erupted out of a fog bank. It was primeval. But below, brief windows in the veil of fog revealed glimpses of busy streets and mazes of neighbourhoods, thickets of industry. The daily balancing act, or lack thereof in some cases, is what makes this place so dynamic, its story worth telling – and was the purpose of my being here. I would be documenting contrasting worlds, going back and forth between aquatic wilderness and urban shorelines, riding the intersecting lines of their coexistence.

The initial week of the assignment began with a series of firsts: my first time driving on the opposite side of the road; my first time diving in temperate water; my first time swimming with large sharks. Getting thrown into the deep end would be an apt description. Sure, I grazed a few curbs and soiled my wetsuit along the way, but I came to understand that the success of this assignment hinged on problem solving. When my pilot couldn't fly because of strong winds, I hiked up to high ground. When I couldn't dive because of choppy seas, I invested time in getting to know the trek-netting fishermen and the Shark Spotters.

It's no surprise, but the biggest obstacle during my month in South Africa was the weather. Every assignment photographer tells horror stories of ideal plans becoming laughable wishes. What was difficult to swallow, however, was that my 'bad weather' still looked like sunny San Diego. It was like a cruel joke. I needed crowded beaches, dramatic horizons and clear water. Instead I had ripping winds, textureless blue skies and False Bay's version of pea soup.

On my first day in the bay, I set out to photograph sevengill cowsharks. The water was so turbid I couldn't see more than a few metres. Shadows of a dozen massive sharks loomed in and out of towering, swaying kelp. When I got back to the boat after running out of air I was jacked up on adrenalin. It was incredible photographing in that cold, foreign environment. I leaned over to high-five my assistant who had been to that site a dozen times and she confessed, 'That was the most terrifying dive I've ever been on.' Fortunately for me, there is a priceless privilege to being an outsider looking in. I had no baseline for what was normal and could form my own opinions along the way. I jumped back in 15 minutes later.

Over the course of the assignment I stayed glued to Wind Guru, a forecasting app that became my omniscient overlord. You have to be careful what you wish for, though, because when the winds let up, the real stress started. In favourable conditions, I had 20 things that needed to be photographed. By the second week, time management was critical to capturing images and I had to capitalise on every opportunity knowing that the next dive or flight could be my last.

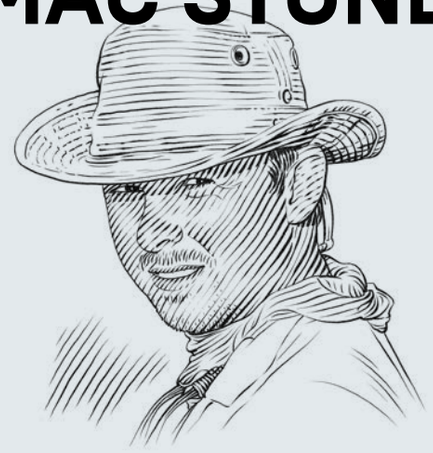
Regardless of weather, I established something of a routine. The typical day consisted of waking up before dawn and trolling the popular beaches for bold swimmers and good light. I would wade into the water and interrupt their peaceful communion to take a few photos. By 9 am I was in the car, wet and sandy, and heading out to Muizenberg or further down the coast to see if the trek-netters were working. By mid-afternoon I was in Fish Hoek swimming with beach-goers until it was time for the Shark Spotters to bring in the exclusion net. Then, at last light, I'd see who was left to try and get a few last frames before nightfall. Rinse and repeat.

More often than not, there were no sharks in the seine nets, no exclusion net to remove and I would come home empty-handed. It killed me to have a day go by without taking a publishable photo. What counted, though, was that I constantly showed up. The Shark Spotters all knew my name and the fishermen could recognise me walking down the beach a kilometre away. When photographing a human component, trust is ultimately what makes the discomfort and awkwardness of the camera disappear. So when the trek-netters finally pulled a bronze whaler on shore, they elbowed out the spectators and made sure I had a front-row seat. It was the image I had been waiting weeks to get, showing the stewardship of the seine-net crew as they safely return a writhing shark to sea.

Looking back on it now, I wish I could say that it was silly how much I stressed about this story. Every day was a grind of constantly questioning if I was making the right decisions. I lost many hours of sleep and several meals worrying about how the visual narrative would unfold or if it would be good enough. Not just because it was my reputation on the line, but also because I felt a debt was owed. What the Save Our Seas Foundation is accomplishing in False Bay on behalf of marine conservation is truly remarkable. It has helped transform a feared predator into dozens of jobs, educating its citizens that marine wilderness and urban life can coexist. Perhaps the measure of a society is not in its lack of dichotomies, but in the gracefulness with which it balances them.

Mac Stone

ON ASSIGNMENT MAC STONE



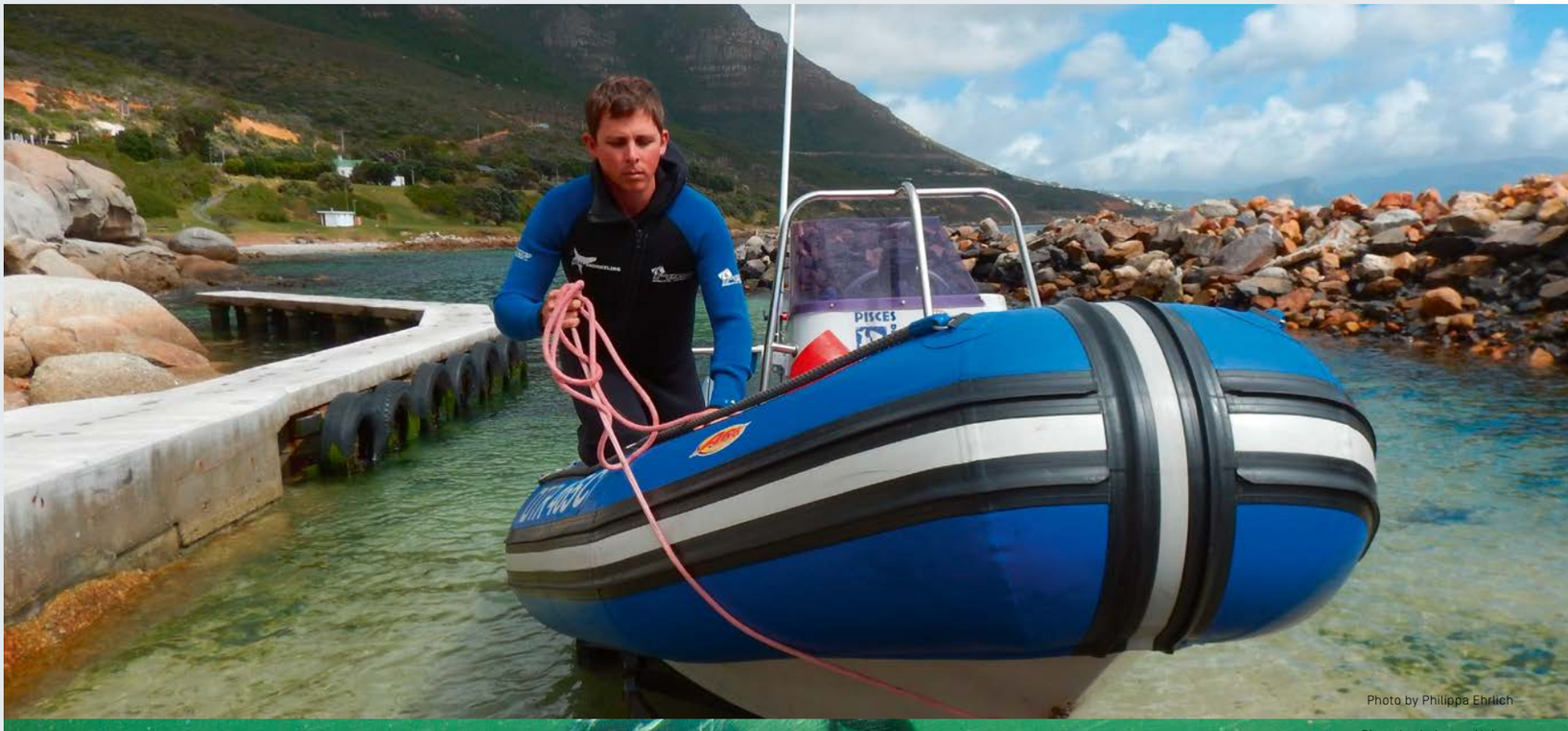


Photo by Philippa Ehrlich

Photo by Joris van Alphen

ON ASSIGNMENT JORIS VAN ALPHEN

'False Bay's rocky reef fish are more endangered than Africa's rhinos' was the one-sentence story brief that landed in my inbox one month before I set foot in South Africa. It was the start of an exciting yet also daunting adventure.

False Bay is an exceptionally beautiful place, with some of the richest coastal waters on the planet set against a dramatic backdrop of equally remarkable mountains. I fell in love with it almost instantly. Words can't describe what it feels like to be out on the water there. I would dive among fairytale-like kelp fronds and colourful reef fish while the occasional seal or shark zoomed by, and then surface to find a pod of humpback whales cruising past just a stone's throw away. Then I'd hoist myself back onto the boat to return to shore and watch gannets fly over as the setting sun broke through the clouds, washing the bay in that golden light that seems unique to Africa.

Any assignment presents its challenges and frustrations, and this one proved to be no exception. To tell the story of False Bay's rocky reef fishes, I wanted to capture three main subjects: the fishes themselves, the people who fish for them, and the scientific research efforts to ensure that fish and fishermen alike have a future. Although it has an abundance of exciting wildlife and inspiring views, False Bay is a deceptively tough place to work in. Treacherous south-easterly winds taunt the place in summer. Blowing straight into its mouth, they turn the otherwise sheltered bay into a washing machine. Often this meant that none of us – photographer, fishermen or scientists – could head out to sea. It soon became clear that the bulk of the photo story would have to come together in precious few days of actual shooting. When the stormy weather held on for more than a week it was all I could do to keep feelings of doubt and fear of failure from getting to me.

Once at sea, there was of course a new set of challenges. Despite warm summer air, the water in False Bay can be as cold as 11 °C (52 °F). It sucks the energy out of your body, especially when you're doing three or four boat dives in a row. As I dropped off the RIB into the blue-green depths, the shock of the cold made my heart pump fast and my mind work slowly. The nauseating motion of the swell was a constant reminder that I was but a poorly adapted visitor in this domain. Compared to the seals, penguins and other animals that move so gracefully through the water, I felt clunky in my heavy dive equipment.

One image that proved challenging to make was the underwater photo of a hooked fish with the hull of a fishing boat in the background. It required a separate boat and the support of a team of three, so that I could move between different fishing boats depending on which one was having luck catching, and also for reasons of safety. Then the struggle began. Everything would bob up and down independently in the chop – not just the boat and the fish, but also the camera and I. Just as the fish and the boat aligned, a wave would drop and obscure my viewfinder. Meanwhile I was swimming against the current. After many hundreds of misses, I finally managed to shoot one frame that worked.

The process was also unnerving for a different reason. The odds of getting bitten by a white shark are extremely slim. However, to float in open water where fishermen have been chumming and amid panicked fish struggling on hooks is the sort of thing one might consider tempting fate. I was thankful to have an assistant with me at all times, scanning the water around us so we could get out quickly in the event of a white shark showing up. The experience gave me an intimate understanding of the meaning of the phrase 'safety in numbers', even if the number in question was only two.

One of my most memorable experiences was spending time with the fishermen of *Kalky's 5*. Initially they were sceptical of the stranger who wanted to come on their boat. I would arrive in the harbour at 2 am to meet the crew, put on oilskins and board the boat. At 3 am we would inch out of the harbour in a cloud of diesel fumes and begin our slow journey. The crew passed the time loudly playing dominoes and took particular joy in shouting insults at each other and of course at me. For once in my life, my obscure mother language came in handy abroad. When it comes to insults, it turns out that Afrikaans and Dutch have hardly diverged at all. It made it much easier for me to connect with the crew and win their trust.

We would reach our destination just before sunrise, some three hours later. The fishermen would cut their bait, unravel their lines and start fishing. It was a shock to me how little they caught on most days. Often they returned after 12 hours at sea with only a handful of small fish each.

Drifting in a small fishing boat off the Cape of Good Hope was not an experience I would necessarily describe as pleasant. The boat rolled enough to make even some of the crew throw up on occasion. Still, each time I went out with the fishermen I felt extremely privileged to be allowed into their world. Perhaps this is the biggest of all gifts that photography can bring. It is a passport to places I would otherwise never visit and people I would never meet. When the day came to say goodbye I wanted to thank them for their time and patience. But Bruno, always the most cheerful of the bunch, interrupted me. 'No,' he said, suddenly stern. 'It's we who should thank you, for showing our work to the world.' I didn't know what to say. I can only hope I have done them justice.

Joris van Alphen

BEHIND THE SCENES

Photo by Philippa Ehrlich

Photo by Mac Stone

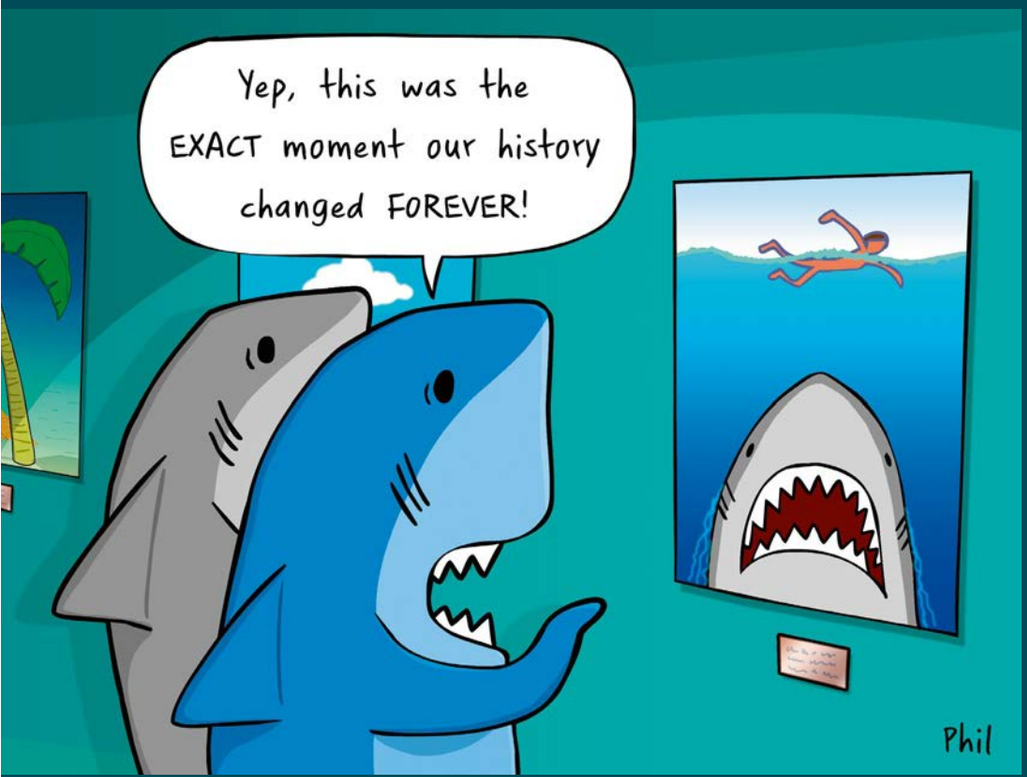
Photo by Mac Stone

Photo by Mac Stone

Photo by Ian McAllister | Pacific Wild

Next issue

On Canada's west coast, north of Vancouver, the Great Bear Rainforest is a swathe of temperate rainforest that runs for 400 kilometres. While the forest itself is home to caribou, grizzly bears, cougars and coastal gray wolves, the marine world off its shores is just as bountiful. Herring, salmon, sea otters, orcas and humpback whales are among the throng of marine life. Join us in issue 4, when we'll get to know the life in this rugged landscape of land and sea.



The *Save Our Seas* magazine is available for free online on both issuu and Zinio. View it on your desktop, tablet or phone anywhere you like!

ABOUT THE FOUNDATION

In the effort to protect our oceans, the Save Our Seas Foundation (SOSF) funds and supports research, conservation and education projects worldwide, focusing primarily on charismatic threatened wildlife and their habitats. From a small not-for-profit organisation funding just five projects, in less than 10 years the Save Our Seas Foundation has grown to become a major player in the fight to save the world's oceans and the wealth of marine life they contain. While the SOSF itself is not a research institute, its generous contributions of financial, practical and scientific support have, to date, facilitated more than 160 marine research and conservation projects around the world.

To find out more about the foundation, visit: **saveourseas.com**

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