THE SAVE OUR SEAS FOUNDATION MAGAZINE

saveourseas

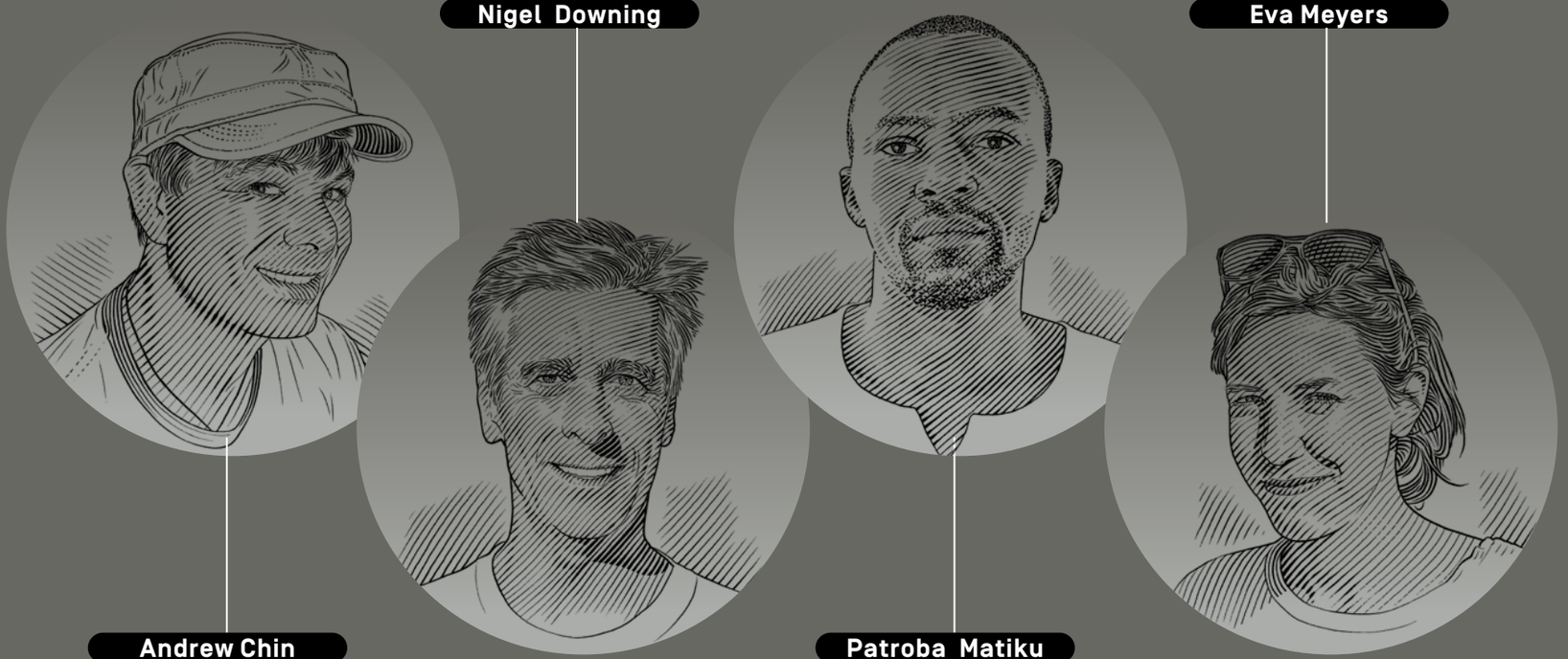
ANGEL SHARKS | DEEP SEA | SAWFISH

As a PhD student, Nigel scoured the rivers of Senegal for sawfishes in numbers that at the time he took for granted. Forty years later, he revisited his old field work haunts to see what has become of these elusive and now vulnerable populations – and to take the opportunity to reconnect with his scientific past and seek out an old friend. Passionate about sharks from an early age and eager to work with them throughout his career as a scientist, Nigel is now revisiting his early love: smalltooth sawfish, an incredibly endangered species that may all but have disappeared from the eastern Atlantic.

From a child with an irrational fear of sharks, Eva has emerged as a passionate and determined shark scientist. Her curiosity and concern for these enigmatic creatures led her to found the Angel Shark Project. She balances her science and field work with engaging the public and citizen scientists. Indeed, members of the diving community now contribute to her increasing findings by registering their own sightings on the ePOSEIDON online database. Over the years, the project's work has unravelled some of the mysteries that surround angel sharks, the most cryptic of sharks.

Nigel Downing

Eva Meyers



Andrew Chin

Growing up miles from the sea amid the skyscrapers of Singapore didn't keep Andrew from an unerring enthusiasm for the ocean. The shark-obsessed child poring over dive magazines and hooked on natural history documentaries grew up to complete a PhD on blacktip reef sharks and found the Oceania Chondrichthyan Society. Andrew is an AIMS@JCU postdoctoral research fellow studying the connectivity and management of hammerhead sharks. He is also working on a project to develop the Australian Shark Information System and Report Card, and in 2017 he launched Shark Search Indo-Pacific to assess sharks and rays across the region. He is a scientific advisor to the Save Our Seas Foundation.

Patroba Matiku

Patroba has been curious about life underwater all his life. As a child growing up fishing with his friends on the shores of Lake Tanganyika, he got to know the various fish species and learned to identify them. This inherent passion set him on a path to explore ecology and to understand fishes and their environment. He gravitated towards marine fishes for his Bachelor and MSc degrees, and launched his career in fisheries research and coastal conservation at the Tanzanian Fisheries Research Institute. Fuelled by the knowledge that so much remains unknown, Patroba researches rays so that we can better protect them.

The ethereal-looking angelshark is a reminder of how much we have left to discover in our oceans. Overlooked by science until now, these sharks might disappear before we've learned enough to properly protect them. Photo by Michael Sealey

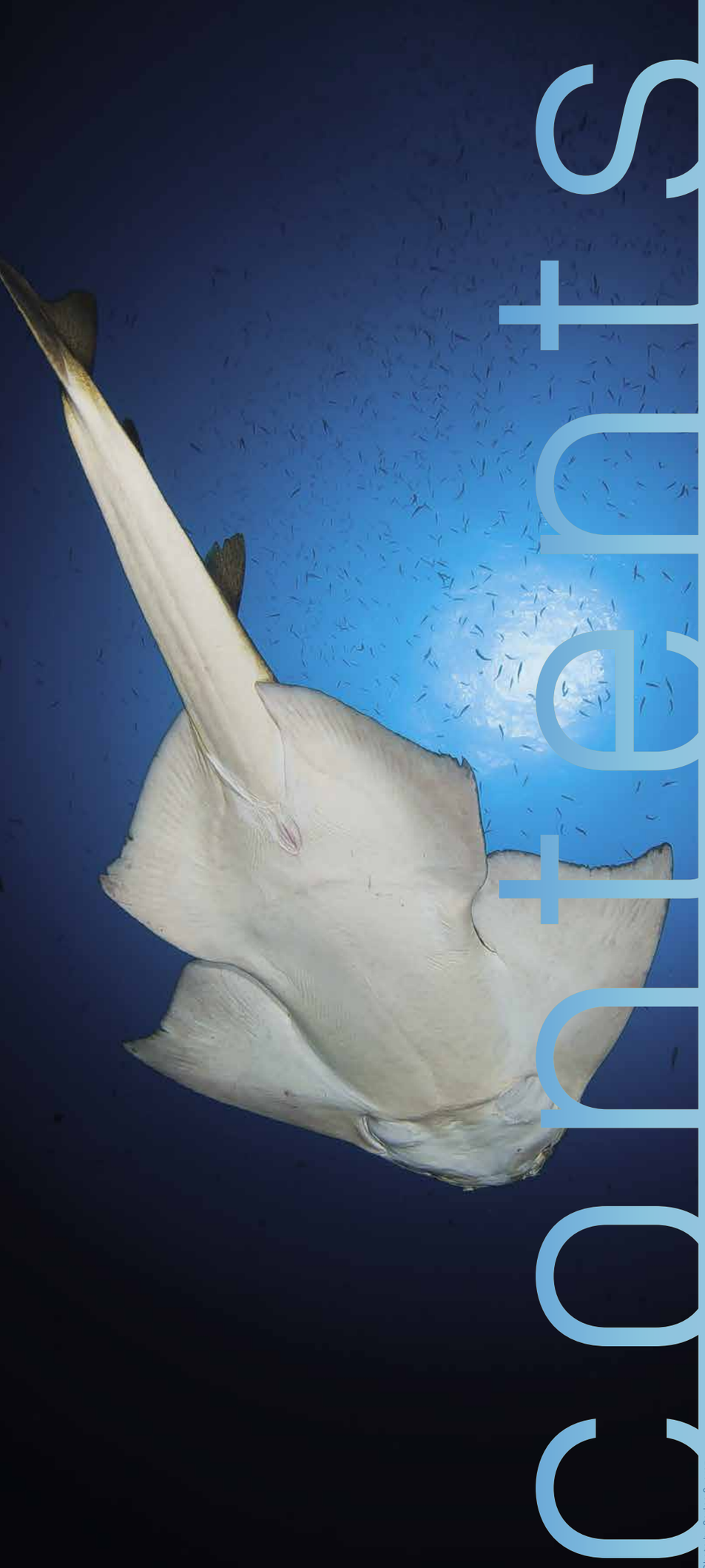


Photo by Carlos Suarez

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

THE FOUNDER
SAVE OUR SEAS
FOUNDATION

Artwork by Gregory Gilbert-Lodge

Photo by Michael Scholl

The question of how one can contribute to conservation often arises in discussions. My answer is to start at home! Everyone today has a responsibility to adapt their own lifestyle and behaviour and to take simple steps towards a healthier and more responsible relationship with the environment so that their ecological footprint is reduced. Becoming informed is far easier today than it was a few decades ago, and once again education starts at home by sharing information with family and one's circle of influence.

Nothing makes me happier than to take my son Elliot snorkelling, especially with sharks. Seeing his smile and lack of nervousness demonstrates to me how our ideas and behaviour are modelled by our family, social and cultural environments. Many island cultures (those of Fiji, Hawaii, Cook, Marshall, Solomon, Papua New Guinea and Japan, among many others) have existed in close contact with the ocean and have venerated and worshipped sharks in their mythology for countless generations. Sadly, our own Western beliefs have been shaped by stories and myths relating to the USS *Indianapolis* and Hollywood movies like *Jaws* and *Sharknado*. Such beliefs often fail to recognise the crucial importance of sharks in the ocean ecosystem or the fact that these predators prefer to eat fish – or, indeed, that it is statistically proven that relatively few people are killed by sharks. Recent studies have shown that far more people around the world have died from taking selfies than from encounters with sharks!

Recently when I was at a movie theatre with my son I became concerned as a trailer for the film *Meg* appeared on the screen. I needn't have worried – he began to laugh and whispered, 'This is ridiculous, there are no sharks like that!' Elliot respects sharks and understands that they are an essential part of a healthy ocean ecosystem. He certainly is not unafraid, but he admires and appreciates them, and I could not ask more of anyone. It is essential to check facts in today's world and to form one's own ideas. As parents, we are duty-bound to ensure that we pass true facts and knowledge on to our children.

Knowledge comes from research, and in this issue our contributors investigate some lesser known but Critically Endangered species – angel sharks in the Canary Islands and sawfishes in Senegal and Papua New Guinea – discuss the very nature of marine science, delve into the ocean depths around the Galápagos and explore how recent advances in elasmobranch genomics could one day benefit medical research – and thus humankind.

Michael C. Scholl
Chief Executive Officer
Save Our Seas Foundation

edito

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Photo by Fred Bavendam
Minden Pictures | National Geographic Creative

2018

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

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

Frequency of bleaching alarms scientists

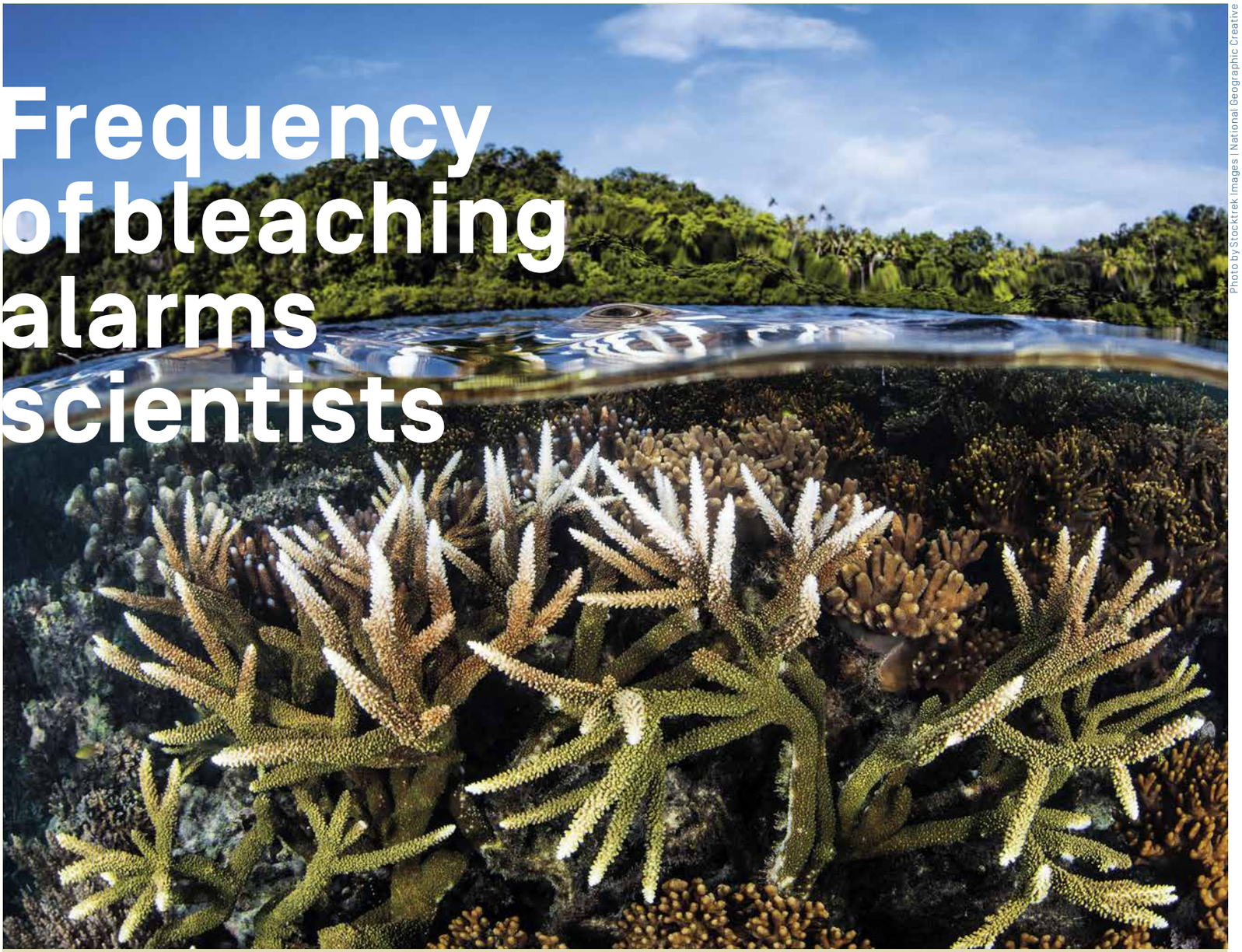


Photo by Stocktrek Images | National Geographic Creative

Scientists have found that coral bleaching events are occurring more frequently, with the intervals between major bleaching episodes now as short as six years. The finding, published by Terry Hughes from the Australian Research Council Centre for Excellence for Coral Reef Studies at James Cook University and a host of co-authors in *Science* in 2018, points to an increased likelihood of annual bleaching in the future.

Coral bleaching is a response by corals to environmental stress, usually an increase in water temperature. The zooxanthellae, or tiny algae that live in the coral tissues and generate food by photosynthesis, are expelled and the remaining coral skeleton appears white. Although not dead, bleached corals are severely compromised. They can recover, but a shortening interval between bleaching events hinders their ability to do so. Climate studies show that the temperature conditions that lead to bleaching are becoming more and more common.

Looking at 100 reef locations in 54 countries around the globe over the period 1980 to 2016, the researchers concluded that, prior to 1980, while coral bleaching events were recorded at local scales (tens of kilometres in extent), regional-scale bleaching (thousands of kilometres in extent) was a rare phenomenon. The reason for the bleaching events was usually the addition or movement of sediment in an area, unusual temperatures or the influx of fresh water. During the 1980s, worldwide bleaching events became apparent as the effects of El Niño became stronger – the result of global warming. In addition, in the past 20 years more bleaching has been recorded outside of El Niño events.

The researchers believe that coral reefs are now subjected to soon-to-be unsustainable levels of bleaching intensity and frequency. These levels, they say, are indicative of the human-dominated Anthropocene era. Given that even the fastest-growing corals take between 10 and 15 years to recover after bleaching, the ever-decreasing interval is cause for alarm.

The paper by Terry Hughes and his colleagues concludes, 'The future condition of reefs, and the ecosystem services they provide to people, will depend critically on the trajectory of global emissions and on our diminishing capacity to build resilience to recurrent high-frequency bleaching through management of local stressors before the next bleaching event occurs.'

Hughes et al. 2018. Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science* 359: 80–83.

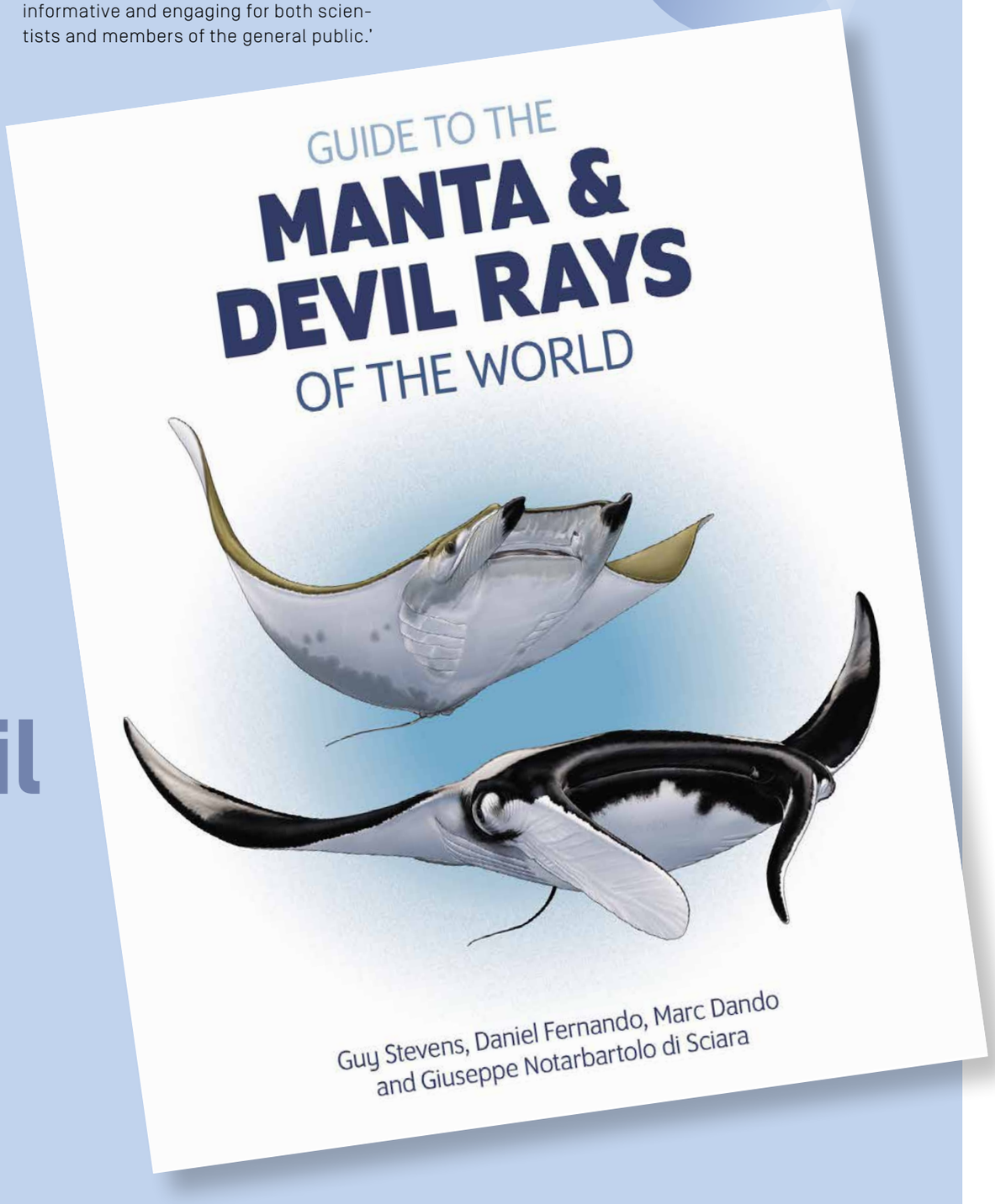
Finally a field guide to manta and devil rays

The first illustrated field guide to the manta and devil rays of the world was published in 2018 by Wild Nature Press. 'Aside from the mantas, mobulids are generally a very poorly studied group of fishes. The main reason that a book like this has not been created until now is simply because not enough was known about this group of rays to write such a guide. Furthermore, the underwater images did not exist to illustrate the species in question,' explains author Guy Stevens, founder and CEO of the Manta Trust.

Together with Daniel Fernando, Marc Dando and Giuseppe Notarbartolo di Sciara, Stevens has now written a 144-page field guide that opens the world of this family of rays to scientists, divers and ocean lovers alike. 'The guide has been in development for a long time, its publication slowed by the recent taxonomic revisions of the family. We hope that it will help to reduce the instances of species misidentification in the published literature, which unfortunately still occur with regularity,' he says.

More than 200 colour photos, drawings and plates illustrate the book. It is a comprehensive resource, covering the identification, characteristics, threats to and distribution of each species, as well as general information on the taxonomy, biology and behaviour of rays in general.

'The idea for the guide first came about in 2009 when I began visiting fish markets in Sri Lanka,' recalls Stevens. 'At these markets there were several species of mobulids that I was unable to identify accurately and when I searched through the literature I found that the existing keys to their identification were outdated and often not very helpful.' He adds, 'I hope that the content of this field guide will be informative and engaging for both scientists and members of the general public.'



Tracking where sharks feed

Photo by Brian J. Skerry | National Geographic Creative

Troubling global declines in shark populations have scientists exploring different ways to manage and protect them. To protect sharks more effectively, we need to gain an adequate understanding of their life histories. What sharks are feeding on – and where they're feeding – can help scientists to decipher how food webs are constructed and how ecosystems are interconnected. Ultimately, understanding where sharks are feeding may identify areas that are important to them and guide policies to better protect them.

New research by Christopher Bird from the University of Southampton and his co-authors, published in 2018 in *Nature Ecology & Evolution*, investigates the feeding habits of sharks around the world. The scientists compared carbon isotopes from the muscle tissue in sharks from three different oceanic habitats: the continental shelf, the open ocean and the deep sea.

As the basis of all food webs, carbon can be traced in different forms called isotopes. The ratios of carbon-13 isotopes in plant tissue will be different according to the type of plant photosynthesis taking place. This means that the ratios of carbon-13 will differ in phytoplankton in oceans around the globe. Scientists can use these chemical tracers to ascertain which types of plants were eaten by animals. Where the isotopes have passed along the food chain and left a signature in sharks, they can also determine where the sharks were feeding. 'If an animal feeds in the same place where it was caught, the carbon isotope signals in the shark and phytoplankton will match,' said Bird in an interview for the University of Southampton's website. 'However, if the shark has moved between feeding and where it was caught, then the signals will be different.'

After measuring isotopes from 114 different shark species around the world, the researchers found that sharks of the continental shelf feed close to home across a range of food webs. Protecting them using marine protected areas (MPAs) could well be a suitable conservation strategy, provided that the MPAs cover the range of habitats used. Conversely, oceanic sharks seem to travel to mid-latitudinal regions to feed in cooler waters where nutrients are rich – but the competing presence of fisheries poses a conservation threat, particularly where oceanic sharks are vulnerable to exploitation.

In the same interview with Southampton University, co-author Clive Trueman asserted, 'The results have important implications for conservation. Globally, sharks are not doing well. Many shark populations have declined in the last few decades, particularly in the wide-ranging oceanic sharks that are targeted by fishing boats and caught accidentally in tuna fisheries as by-catch. Governments are now creating large marine protected areas around the globe, which help to reduce fishing, but most of these protected areas are in tropical waters and may not provide effective protection for oceanic sharks.'

Bird et al. 2018. A global perspective on the trophic geography of sharks. *Nature Ecology & Evolution* 2: 299–305.

OCEAN VIEW

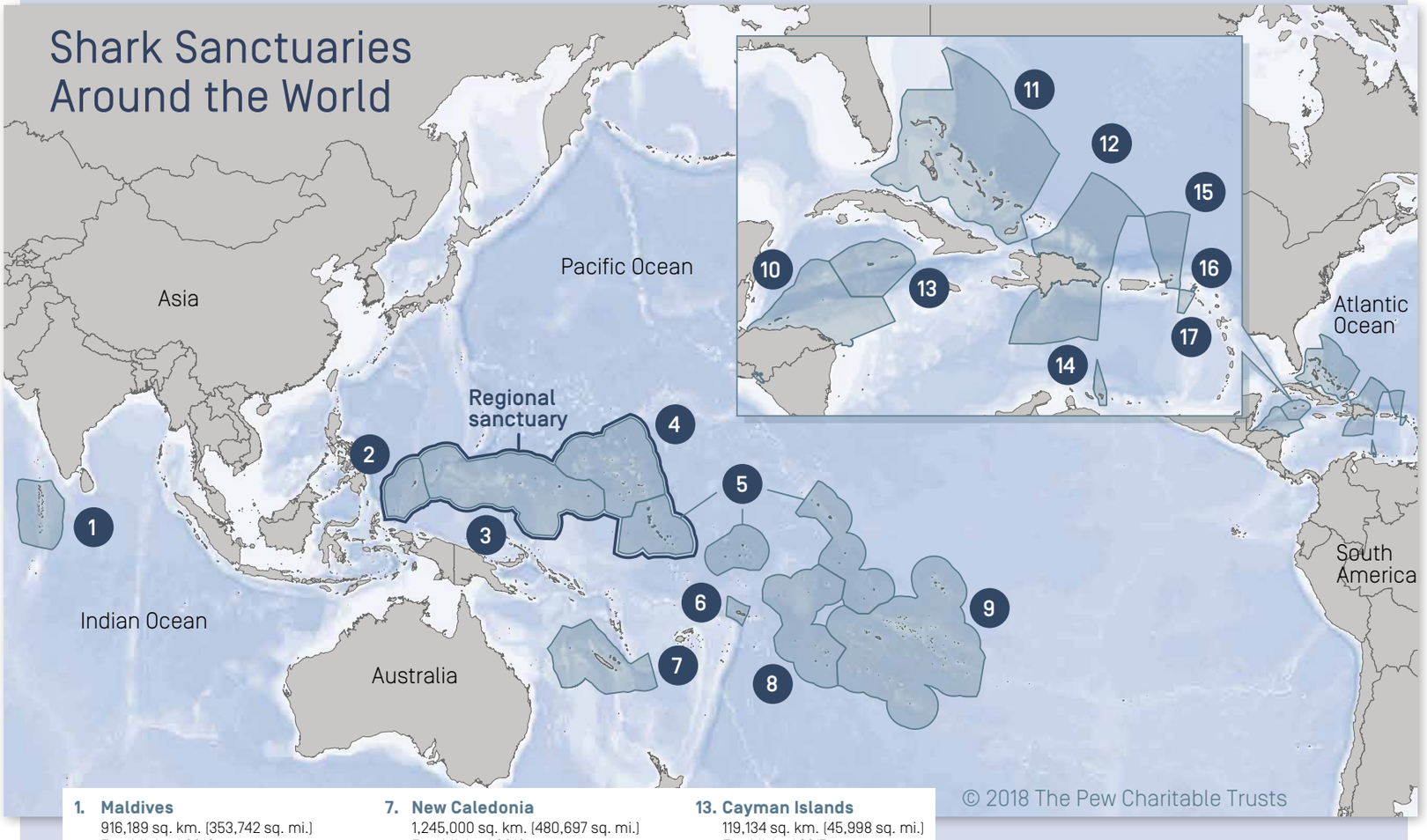
Scientists have completed a first global diver-based survey of shark sanctuaries around the world. The researchers assessed baseline shark populations, patterns of human use, and education and threats. Christine Ward-Paige and Boris Worm from Dalhousie University in Canada assessed 15 shark sanctuaries and compared their observations with data from 23 non-sanctuary countries.

In 2009, Palau became the first nation to ban commercial shark fishing in its waters. In addition, it implemented laws that ban the possession, trade and sale of sharks and their products. Since then, 15 'shark sanctuaries' have been declared by coastal nations across the Atlantic, Indian and Pacific oceans. Together they now cover three per cent of the oceans worldwide.

The paper, published in 2017 in *Global Environmental Change*, shows that while each country showed specific trends, some generalisations could be made. Declines in shark populations appear to be less pronounced: there is less evidence of sharks and their products being sold in local markets; and the threat of fishing was lower inside designated shark sanctuaries. When asked about the outlook for sharks in the region, divers in shark sanctuaries seemed more positive about their conservation, although they did point out the need for other interventions.

However, there are certain challenges that are not adequately addressed by shark sanctuaries: pollution, habitat loss, ghost fishing gear and by-catch are issues that require other means of mitigation. The authors emphasise the need for 'higher-resolution data on shark abundance, incidental catch and markets to direct priority conservation needs and optimise the conservation benefits of existing and future shark sanctuaries'. They conclude that shark sanctuaries are useful in the arsenal of conservation tools, but need the support of other measures to protect sharks adequately.

Are sharks safer in sanctuaries?



1. **Maldives**
   916,189 sq. km. (353,742 sq. mi.)
   Established 2010
2. **Palau**
   604,289 sq. km. (233,317 sq. mi.)
   Established 2009
3. **Federated States of Micronesia**
   2,992,597 sq. km. (1,155,448 sq. m.)
   Established 2015
4. **Marshall Islands**
   1,992,232 sq. km. (769,205 sq. mi.)
   Established 2011
5. **Kiribati**
   3,437,132 sq. km. (1,327,084 sq. mi.)
   Established 2015
6. **Samoa**
   128,000 sq.km. (49,421 sq.mi.)
   Established 2018
7. **New Caledonia**
   1,245,000 sq. km. (480,697 sq. mi.)
   Established 2013
8. **Cook Islands**
   1,960,135 sq. km. (756,812 sq. mi.)
   Established 2012
9. **French Polynesia**
   4,767,242 sq. km. (1,840,642 sq. mi.)
   Established 2012
10. **Honduras**
    240,240 sq. km. (92,757 sq. mi.)
    Established 2011
11. **The Bahamas**
    629,293 sq. km. (242,971 sq. mi.)
    Established 2011
12. **Dominican Republic**
    269,489 sq. km. (104,050 sq. mi.)
    Established 2017
13. **Cayman Islands**
    119,134 sq. km. (45,998 sq. mi.)
    Established 2015
14. **Bonaire**
    9,706 sq. km. (3,747 sq. mi.)
    Established 2015
15. **British Virgin Islands**
    80,117 sq. km. (30,933 sq. mi.)
    Established 2014
16. **St. Maarten**
    499 sq. km. (193 sq. mi.)
    Established 2016
17. **Saba**
    8,033 sq. km. (3,102 sq. mi.)
    Established 2015

OCEAN VIEW

Ward-Paige CA and Worm B. 2017. Global evaluation of shark sanctuaries. *Global Environmental Change* 47: 174–189.

wins hearts and minds

'The greatest nature series of all time' is how science writer Ed Yong hailed the BBC series *Blue Planet II* in his piece for *The Atlantic* in January 2018. Since the series first aired in September 2017 – and more than 14 million viewers tuned in to watch it on BBC One – it has gone on to garner accolades and acclaim. The 'Most Watched' programme of 2017 in the United Kingdom was presented with a special Impact Award at the National Television Awards for raising the profile of the issues facing our oceans. It then went on to pick up two BAFTAs in April 2018.

Cinematographer Dan Beecham, a member of the huge team that made the series, speaks of the phenomenal reception it has received from the public. 'I have to admit to being surprised by the scale of the impact the series has had, both locally and internationally. I think it's had a really strong effect on the opinions and outlook of the general public, as well as of policy makers. I always knew the series was going to feature strong conservation messages, which is a relatively new thing for the big BBC wildlife series. I was impressed by how strong this messaging was, but also how delicately it was handled. As a result, it's been really effective.'

He goes on to explain why he believes that *Blue Planet II* was well placed at this time to make the impact it did. 'I think we [society] were at a stage where marine conservation issues, especially the issue of plastics, already had a growing amount of support, with a massive ground swell behind them. *Blue Planet II* helped push this forward to another level and really bring it to the public's attention. It's great to see how many cafés, bars and shops are going out of their way to do something about this themselves, before they are forced to by legislation. It's really exciting and a giant step forward, I think. We've still got a long way to go, but things are moving the right way.'

Beecham was involved in shooting the scene that shows giant trevally fish hunting fledgling terns. Recalling the experience, he says, 'I worked on the underwater element of this story and the long-lens shots were all done by my good friend Ted Giffords. I remember how overwhelmed I felt when I first saw Ted's shots as we reviewed the footage in the evenings while we were shooting out in the Seychelles. I knew then he'd got some really special stuff. That was a little while ago now and we tend to view the footage so many times that it loses its impact, so it was wonderful to see the shots edited together and finally released to the public after we'd kept the story quiet for so long. It got a great reaction, which was fantastic to watch.'

He admitted, 'I was sceptical about our chances of documenting the behaviour, having spent a lot of time in the water with giant trevallies in the past. When we pulled it off, I was over the moon. My role in documenting this behaviour had its own challenges. It took a while for the trevallies to get used to me and allow me to approach them, so patience and field craft played a big element in my role, but it was nothing like the challenge that Ted faced in getting those long-lens shots. I still don't quite know how he pulled it off – he must be part fish!'

The question of which scene was a favourite to shoot inevitably arises when talking about wildlife film work, but Dan isn't able to single out just one. 'There were so many special moments working on the series that it's tricky to pick one. The moments that stick out in my mind are always those where I managed to get a shot that I know is important in tying a story together – an important shot that links the other shots and helps to complete the story. I get a very particular rush when getting shots like this and it's that rush, that thrill that keeps me in the job. I remember having it when working on the story about sea lions herding tuna in the Galápagos Islands. Some of the drone shots really help to break down the behaviour for the viewer. These shots took a lot of patience to get, so I'm quite happy with them.'

In another conversation piece for *The Atlantic*, writer James Parker points out that, perhaps more than ever before, *Blue Planet II* helps us confront how our global oceans now truly look. Part of that means recognising what our impact has been on their functioning and inhabitants. 'Speaking personally, the original *Blue Planet* series, which aired back in 2001, was very inspiring and informative for me. I'd go so far as to say it gave me direction in life,' begins Beecham when asked what he hopes the series might do for a realm that is both his livelihood and his clear passion. 'If *Blue Planet II* has a similar legacy and inspires a future generation of film-makers, conservationists and scientists to make their life's work protecting the world's oceans, then we can be very happy with what we've achieved.'

Conservation priorities refined

There is a particular conundrum facing conservation. With an ever-growing list of threatened species but a limited pool of resources, effective conservation action relies on the prioritisation of species and places most at risk of extinction. R William Stein and a team of researchers, including Nick Dulvy, have identified 21 countries as targets to prioritise for shark, ray and chimaera conservation.

Their paper, published in 2018 in *Nature Ecology & Evolution*, uses evolutionary distinctiveness – how long ago a species branched off from its nearest neighbour in the evolutionary tree – as a measure to identify the most threatened creatures in our oceans and prioritise them for conservation action. The idea behind evolutionary distinctiveness is that some species have few close living relatives and are evolutionarily unique. These are species that have had more time to evolve differently over the course of evolutionary history. If species with high evolutionary distinctiveness were to go extinct, a proportionally larger amount of evolutionary history would be lost.

The researchers looked at evolutionary distinctiveness in combination with the criteria typically highlighted by the IUCN for a species to be included on its Red List: the species' threat status, geographical range and life history traits. Their study found that mackerel sharks (Lamniformes), which are targeted largely by pelagic long-line fisheries, and guitarfishes, wedgefishes and sawfishes (Rhinopristiformes), which are kept as valuable by-catch, represent both high evolutionary distinctiveness and threat status. They are therefore key groups that need better protection.

The analysis highlighted 21 countries across the south-western Atlantic Ocean, West Africa, the south-western Indian Ocean and the north-western and south-western Pacific Ocean to prioritise for conservation action. Knowing which species are most threatened and represent the highest evolutionary distinctiveness, and where they are found, can narrow the focus for conservation strategies. The authors conclude that improved fisheries management, regulated trade and adequate spatial planning are required to mitigate the effects of overfishing, which is the single largest threat to the evolutionary history that sharks, rays and chimaeras represent.

Stein RW et al. 2018. Global priorities for conserving the evolutionary history of sharks, rays and chimaeras. *Nature Ecology & Evolution* 2: 288–298.

Photo by Reinhard Dirscherl | Biosphoto

Photo by Martin Harvey | Biosphoto

Lying off the coast of central Tanzania, Mafia is the largest island in an archipelago of the same name where fishing has long been the main source of income. The surrounding waters boast a remarkable biodiversity – one that Patroba Matiku would like to see maintained while still allowing local fishers to earn a living.

You grew up fascinated by the fishes in Lake Victoria in your home country, Tanzania. What is your relationship with the ocean like today?

My early fascination developed to take an academic path, and many years of work experience have provided a basis for what I do today. As a scientist in applied marine conservation research, I look at how we manage and maintain marine species and the ecosystem processes they support so that coastal communities that depend on the functioning of those processes can benefit. My particular focus is Mafia Island. I also organise conservation programmes to help implement my findings and make them applicable to the people they will ultimately affect.

How would you describe the relationship between local residents of Mafia Island and the ocean?

The economy of Mafia Island's residents depends heavily on fisheries because other livelihoods are restricted. Agriculture, for instance, is limited by poor soil. The island is also separated from the Tanzanian mainland, which prevents its residents from conducting business-oriented enterprises. These challenges motivate the majority of households in the Mafia archipelago to turn to businesses linked to fisheries. For example, the women of the islands of Jibondo and Bwejuu are fully involved in an octopus fishery and in the processing of ray flesh. The income from these activities only just meets their daily needs. Conserving marine resources is still a great challenge. The local communities normally have no time for the sustainable utilisation of marine resources.

From the Field

A short interview with Patroba Matiku

Some of Mafia Island and its associated islands are protected by the Mafia Island Marine Park. How would you describe this region?

The park covers more than 700 square kilometres (270 square miles) and encompasses six islands, including the inhabitated islands of Chole, Juani, Jibondo and Bwejuu. There is a buffer zone 800 metres (875 yards) wide that encircles the entire park to mitigate the effects of activities like commercial fishing outside its borders. The protected waters of Mafia Island are high in species and genetic diversity: the shallow waters host, among others, more than 400 fish and 400 sponge species, as well as 200 different algae. The Mafia Island ecosystem also acts as the source of many different larvae that are distributed northwards by the North East African Coastal Current, enriching marine life found many kilometres from the archipelago.

How do you go about interviewing the fishermen at landing sites to survey their catch?

Before I started my research, I visited all the fish landing sites on Mafia Island and introduced myself to village chairmen and to fishing leaders. I then arranged to meet the local fishermen who specifically target rays. During our meeting, we agreed on how I would be getting samples from them in the future. Some of the local fishermen actually allowed me to board their fishing vessels for night-fishing so that I could get a sense of exactly what happens on the fishing ground.

Have you learnt anything particularly interesting as your project unfolds?

Yes, while interviewing the local fishermen I have been told very interesting stories about ray fish behaviour during the rainy season and when the sea temperature changes. More research now needs to be done to interpret these stories scientifically. And in terms of concerns about the demand for rays in the targeted fishery, it looks like ray liver oil is now becoming a desirable product. People mix it with paint to give it an unpleasant smell that deters the organisms that stick to the hull of fishing vessels and affect their speed, performance and durability.

guano

THE BIRDS' BOUNTY

Islands like Guañape Norte and its feathered inhabitants have been at the centre of one of Peru's most lucrative enterprises for hundreds of years. Once the site of a booming trade that changed the face of intensive modern agriculture, Peru is emerging once more as the world's largest producer of organic fertiliser. The health of Peru's ocean and the seabirds that call it home underpins the nation's economic success.

PORT-
FOLIO
TOMÁS
MUNITA

The story of Peru, its seabirds and the guano that miners toil to turn into agricultural gold is one where environmental and social issues collide. Part national history, part natural history, this assignment draws on photographer Tomás Munita's experience in portraying how we interact with the natural world.

'Guano', derived from the Andean Quechua language, is the name given to accumulations of bird droppings used as fertiliser. The dry climate of Peru enables guano to build up in mineral-rich layers on the coastal islands where seabirds roost and breed. Spanish colonial records report guano as a resource prized by the Inca to enrich agricultural soils. Demand for guano fertiliser boomed worldwide in the 1800s, but exports declined after Fritz Haber developed the Haber–Bosch process of nitrogen fixation in 1909 and synthetic fertilisers replaced guano.

Tomás Munita is an independent documentary photographer with a special interest in social and environmental issues. He has worked for The Associated Press (AP), focusing on Latin America, and won Leica's Oskar Barnack Award for his AP reporting in Afghanistan in 2006. His work features regularly in *The New York Times* and he has received four World Press Photo Awards. Munita was presented with the ICP Young Photographer Infinity Award by the International Center of Photography in New York in 2005. Freelance since 2006, he is based in his home town of Santiago de Chile.

The Guañape Islands rise, rocky and dry, from the Pacific Ocean off the coast of northern Peru. The two largest islands to the north and south are Isla Guañape Norte and Isla Guañape Sur and, together with the smaller Islotes Cantores and Islotes Los Leones, they are a haven for Peruvian boobies, Guanay cormorants, Inca terns, Peruvian pelicans and Humboldt penguins. The islands were declared protected areas in 2009 by the National Wildlife Refuge System of Peru.

The Peruvian boobies that wheel in the skies over Guañape Norte choose to breed on coastal islands, nesting on steep slopes and cliff edges or on bare ground. The species is the second most abundant seabird in the region, but its numbers plummeted from an estimated three million birds in the mid-1900s to fewer than 200,000 birds after an El Niño event in the 1980s. The Guanay cormorant, dubbed the 'billion-dollar bird', is Peru's most important guano producer.

Today the growth in demand for organic produce has reinvigorated the Peruvian guano industry after its importance waned at the end of the 19th century. Scientific studies show that seabird guano increases soil nutrients, plant tissue nutrients and plant productivity. The incentive to market guano as the ideal organic fertiliser is therefore high; could the riches of the 1800s be revived? It was the overharvesting of thick guano deposits that endangered the vital nesting habitats of seabirds in the 1800s; today the threats to seabirds are climate change and overfishing.

Nutrient-rich waters off Peru's coast host nearly 20% of global industrial fish catches. This is a region of upwelling: year-round surface winds pull microscopic plankton up from the ocean's depths to bloom at the surface and the Humboldt Current brings cold, nutrient-rich water from Antarctica. This means that food is in abundance for fish – the same fish on which seabirds like the Peruvian booby and the Guanay cormorant depend. Overfishing of the Peruvian *anchoveta* threatens populations of the cormorant, which is now classified as Near Threatened on the IUCN's Red List. Seabirds have starved in their millions following declines in anchovy stocks related to El Niño, a phenomenon that scientists worry might be exacerbated by climate change.

The steep cliffs and rugged terrain of Peru's coastal islands may seem inhospitable to human beings, but to seabirds they are an essential haven. These are the same islands over which two wars have been fought to claim possession, so valuable were their guano-coated rocks. Today the Peruvian government realises that the economic sustainability of the guano islands is only viable if the seabirds and the marine ecosystem on which they depend is managed. Walls restrict access to sensitive nesting areas and the region has been declared a marine protected area as part of the Guano Islands and Capes National Reserve System.

The process of guano mining has changed little in hundreds of years, as mechanisation of the labour typically done by hand would potentially frighten away the very birds on which this industry depends. The work is back-breaking: men carry 50-kilogram (110-pound) bags of guano up and down the island's steep paths to load up to 100 tons of their product into the waiting transport boats. Seasonal workers labour on the island for months at a time, earning about 1,200 Peruvian soles (US$360) per month for their efforts.

Guano that has accumulated over years hardens into solid layers under the harsh Peruvian sun. During the so-called Guano Era in Peru, the economy blossomed thanks to exports to Europe. However, when those exports crashed, bringing the era to an end, Peru was left none the richer for its stint as the world's largest producer of fertiliser. Today, seasonal workers of mostly Quechua heritage harvest guano under stricter controls. What sustainability in guano mining looks like in the coming years will have consequences for both seabirds and the miners who earn their livelihood in the industry.


SECRET
LIVES OF

ANGEL-SHARKS

Words by Eva Meyers

Photo by Michael J. Sealey

Angel sharks are the second most threatened family of sharks, rays and skates in the world. The Angel Shark Conservation Network was formed to try to change that.

Photo by Michael J. Sealey

Angel sharks have been known to humans for millennia. Aristotle was fascinated by them and thought, mistakenly, that they supported his early theories of hybridisation. One of the species, the angelshark, has all but disappeared from its European range and is now seen regularly only in the Canary Islands, where Eva Meyers has set her heart on unlocking its secrets before it's too late.

Introducing angel sharks

Angel sharks are flat-bodied and peaceful sharks that live on the sea floor. Their tendency to lie buried under the sand and remain unnoticed, almost invisible, helps them to evade not only potential predators and prey, but also scientists, who have overlooked them for many decades. Not only that, this very special group of sharks has been repeatedly misidentified around the world: in some regions, angel sharks have been landed as rays; in other places, they have been confused with 'monkfish'; and in several countries they are not considered worth reporting at all. Angels inhabit all our oceans and like other elasmobranchs (sharks and rays), they have a key function in the ecosystem. Unfortunately, despite their talent for making themselves invisible, angel sharks have been heavily affected by the intensified effort of demersal fisheries, particularly in Europe.

If we go back in time, three angel shark species – the angelshark, the sawback angelshark and the smoothback angelshark – inhabited the north-eastern Atlantic, the Mediterranean Sea and the Black Sea. Although there are no historical population estimates for these three species, data from research vessels and fishery landings suggest that there have been severe population declines over the past century. It is suspected that the causes for these declines were the intensification of fisheries, habitat loss and the species' slow reproductive rates that make population recovery difficult. The three species have consequently been classified as Critically Endangered on the IUCN Red List of Threatened Species, making them some of the most vulnerble elasmobranch species in Europe.

There is one place in the Atlantic Ocean, across from the windy coast of Morocco, where it seems that various sharks and rays have found an ideal habitat in which to co-exist. Stingrays, butterfly rays, bull rays, devil rays and, in particular, one of these three angel shark species, the angelshark, are all residents of the Canary Islands. This archipelago is the only known location in Europe where divers can regularly share a dive with angelsharks.

A first angelshark

Gran Canaria, March 2014

What was I to expect from a shark that nobody could tell me anything about? What would I see? Would I even see anything? What was I to look for? And what chance did I even have of finding a mysterious shark that disappears into the sand, one that Aristotle described as 'the shark that can change colour and mimic the pattern of the fish it hunts'? Questions whirled around in my head, making me at one moment anxious about how impossible my quest seemed and at the next thrilled at the potential for discovery.

I remember every moment of the day I saw my first angelshark. The water was freezing and my heart threatened to beat out of my chest. It had been a while since I had last dived and I didn´t really know Gran Canaria or anyone there. Quite simply, I didn't know what to expect. But I had come as 'the shark expert', so at least it should appear that I knew exactly what I was doing! There was no point in searching for more information about angelsharks because there was so little available – only descriptions of dead sharks caught in fishing nets or kept in glass cabinets where they had remained for years, waiting for someone to notice them. Let's face it, angel sharks are not considered the most sexy or exciting of the shark species – at least until recently.

On that memorable day I was with Tony Sánchez, who had offered to take me diving in a spot where he had seen many angelsharks before. Tony knew so much more about these sharks than I did. He told me that he found them lying under the sand in water that was only 10 metres (33 feet) deep. And it was still a good time of year to see them, so we might be lucky. Most divers that I'd met so far had told me that angelsharks prefer cold water. It was March and the water in the Canary Islands was between 17 and 19 °C (62 and 66 °F).

At a sheltered bay called Sardina del Norte, we got into the water and swam for about 20 minutes before Tony stopped and pointed at the sand. I looked at him and looked at the sand, then back at him. I could see he was laughing. I looked at the sand again and still I couldn't see anything. Was he making fun of me? He kept pointing at the sand and finally lifted some of it. Out of nowhere, a flat shark with angel-like wings appeared. My first angelshark, a female about 1.2 metres (four feet) long, was looking at us but not moving. She let us approach. Slowly and carefully I

Catching young sharks to measure, weigh and tag allows scientists to track how these animals are using potential nursery areas.

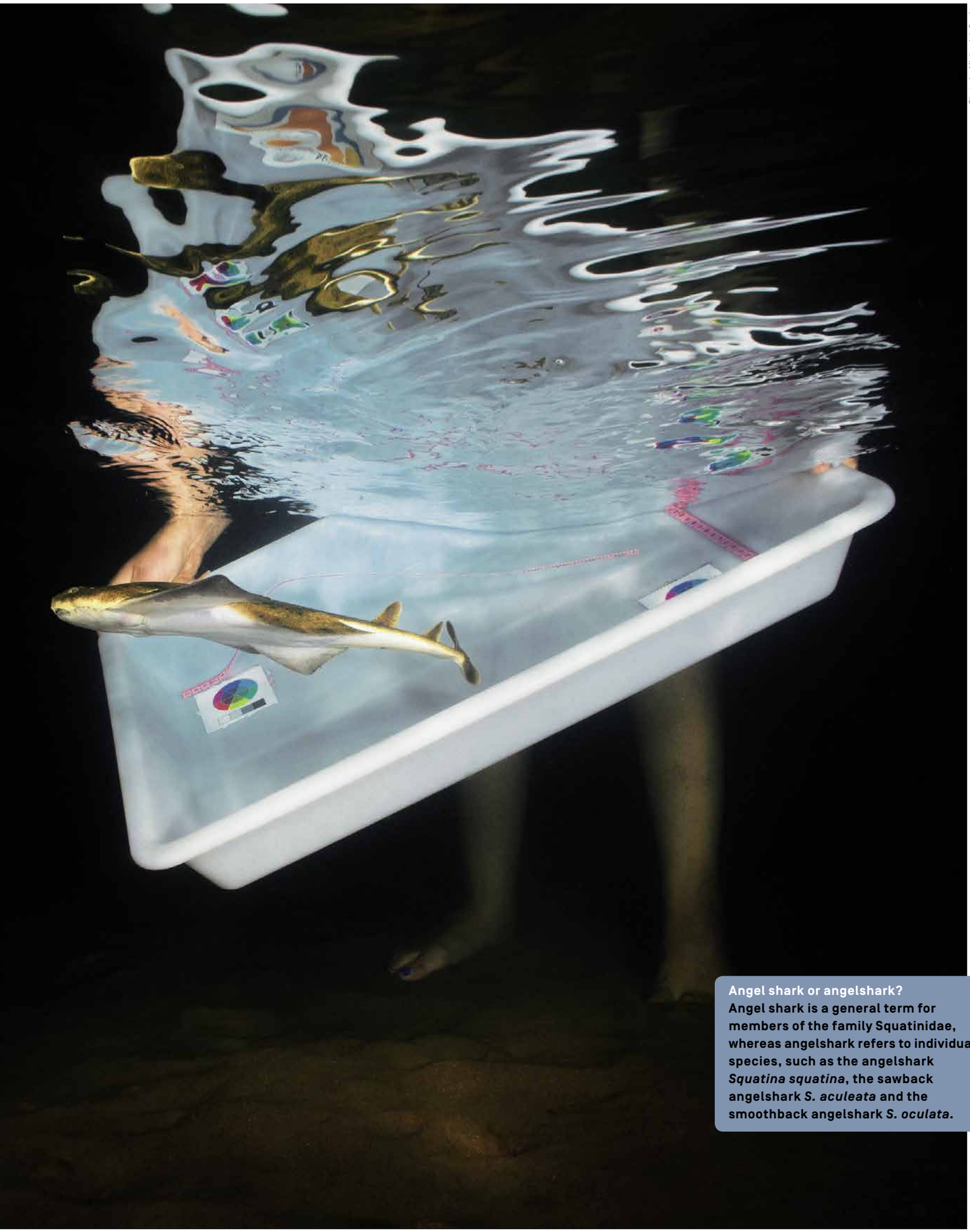


Photo by Michael J. Seatey

Angel shark or angelshark?
Angel shark is a general term for members of the family Squatinidae, whereas angelshark refers to individual species, such as the angelshark *Squatina squatina*, the sawback angelshark *S. aculeata* and the smoothback angelshark *S. oculata*.

Photo by Michael J. Sealey

All three angel shark species are listed by the IUCN as Critically Endangered. Locally extinct in the North Sea and much of the northern Mediterranean, the angelshark *Squatina squatina* is only reliably observed around the Canary Islands.

Photo by Carlos Suarez

Angelsharks prefer the sea floor and are found in shallow water close inshore right out to a depth of 150 metres (500 feet).

moved nearer, afraid to spook her, but she stayed so calm that I felt confident enough to get even closer. Suddenly she 'woke up' and lifted her wings, the sand falling off her like glitter, and then she slowly swam away from us, floating gently through the water. That was when I became mesmerised by these enigmatic sharks and began to understand what makes the angelshark one of the most special creatures in the ocean. Despite all the hurdles that have arisen since then, I can look back at that moment and the many hours I have spent underwater with these sharks and know it has all been worthwhile.

Before I came to the Canary Islands, I started to look into this curious group of 'flatsharks' and in doing so moved away from the traditional scientific sources and dug into social media. At that time, I was finishing my Master's degree in Germany and working as an intern for the Memorandum of Understanding on the Conservation of Migratory Sharks. A key experience in my short career, this internship opened my eyes in many ways. It gave me insight into the difficulties that scientists experience when trying to translate key data in a way that decision makers can understand and use for conservation and management purposes. Understanding this made me re-think my research questions and the ideas that I had for the project in the Canary Islands. I wanted my research to matter and to have a positive impact on the conservation of angelsharks.

When I started exploring the social media channels I was surprised to find a lot of angelshark images, and on following them up I noticed that divers in the Canary Islands regularly posted amazing pictures of angelsharks. The next thing I had to do was find out whether anyone was already working with these sharks. A search of the Internet produced no-one, but it did lead me to the University of Las Palmas de Gran Canaria. I made a list of all the marine biology professors at the university and contacted each one, asking about shark research in the Canary Islands. Eventually one of them replied and invited me to come there and start working on angelsharks.

A few weeks after arriving on the Canary Islands, I discovered I was not the only one concerned about the conservation of angelsharks: the Zoological Society of London had been in contact with the University of Las Palmas de Gran Canaria. Together we set up the Angel Shark Project as a collaborative initiative between the University of Las Palmas de Gran Canaria, the Zoological Research Museum Alexander Koenig (where I was doing my Master's thesis in Germany) and the Zoological Society of London.

Citizen science

The University of Las Palmas de Gran Canaria set up a citizen science online database called Programa Poseidon that encourages divers and beach users to submit their sightings of any marine species they encounter during their recreational activities. The value of citizen science data has already been proven for studies into many species, initially those on land, but increasingly those in the oceans as well. We thus saw this online portal as a fundamental tool for gathering more data for our project. Almost every dive centre in the Canary Islands uses the angelshark in its logo, so at the same time we used the opportunity to engage divers in the conservation of their flagship species. Interestingly though, I was surprised that nobody seemed really aware of the angelshark's conservation status, nor did they understand how special and unique is its presence in the Canary Islands.

Wanting to see where the sharks are and speak to the people who were reporting them, I decided to visit the islands where dive centres had submitted sightings. Slowly we established a network of collaborators and I ticked one island after another on my list, finally realising that angelsharks were present at all of them! In 2017 we published the results we had obtained from the citizen science database and the underwater surveys I was conducting at each island. For the first time we had an overview of the species' distribution and preferred habitat in the archipelago. Our data showed a distribution gradient, with more sharks and more habitat suitable for them towards the central (Tenerife and Gran Canaria) and eastern islands (Fuerteventura, Lanzarote and La Graciosa). I had heard many dive instructors talk about seeing pregnant females at a certain time of year and about large male angelsharks coming closer to shore in winter. Finally, based on our results, we could confirm these observations. It seems that there is a mating season in the Canary Islands that overlaps with the winter months, while a breeding season extends through spring and summer.

We now have a better understanding about the distribution, population structure and habitat use of this shark. Of course, new questions then erupted. Where do the angelsharks go when the mating season is over? Can they move between islands? Are there specific breeding and nursery areas? Luckily, our curiosity has motivated us to develop new projects and start resolving some of these questions.

In the mood for love

Lanzarote, November 2016

Since the project began, Lanzarote has been one of our key sites for tagging and at least once a year, particularly during the winter months, we visit the island. The chance of finding angelshark aggregations here, and perhaps observing angels mating, is pretty good. After one particular dive we joined Carlos, the owner of the dive centre Oceanos de Fuego, for a beer. Excited and still in my wetsuit, I described to him what we had just seen.

'There was this male and then a female to our left, with another one behind. We saw three more at a depth of about six metres (20 feet). One of the females lifted her tail to entice the large male that was circling, but her charms failed to attract him. She remained in the sand, waiting for the handsome male to return, but he had apparently fallen for someone else. For a few minutes we followed him. My dive computer showed a depth of 17 metres (56 feet) and the visibility wasn't good. I looked to my right and left and was happy to see that I wasn't the only one with dirty thoughts – we all wanted to see some shark porn! Suddenly the male swam towards another female. What just happened? It took only a few seconds, but I think I saw the male biting into her pectoral fin, then a confusing scene of shark, sand, tornado, pirouette – and it's over. Repeat, please, but a little slower!'

Baby angels

Tenerife, November 2017

A 15-minute drive from Santa Cruz, the capital of Tenerife, lies the popular Las Teresitas beach. It's a long beach with golden sand, palm trees and a large selection of beach bars that compete to produce the best mojitos and reggaetón beats. What most people don't know is that this used to be a rocky beach with sparkling volcanic black sand and strong waves breaking on its shore. For years, the volcanic sand was removed and used in construction projects on the island. Las Teresitas was losing its charm, so in the 1960s a new design for the beach was proposed. Tons of sand were imported

Photo by Carlos Suarez

The destruction of sea-floor habitats impacts angelsharks: anchor damage, the building of infrastructure and coastal pollution can destroy important shark nurseries and aggregation sites.

from the Sahara Desert to cover the entire bay. To protect the beach and prevent the sand from being washed away by waves, two piers and a long breakwater were constructed, resulting in 'the most beautiful beach on Tenerife'. At the same time, the new design created something that wasn't foreseen in the original planning: the shallow and protected waters of Las Teresitas make a perfect marine nursery area where almost every Canarian fish species can be found in miniature. Protected from currents, waves and large predators, this natural aquarium has become a nursery for angelsharks too.

It's 8 pm and we are getting ready for our survey in Las Teresitas. Thanks to the support of the Save Our Seas Foundation and CRESSI Sub, the Angel Shark Project has been surveying Las Teresitas for the past three years to understand the importance of this area for angelsharks and to learn more about their ecology and reproductive behaviour. We discovered Las Teresitas in 2014, while I was diving around all the islands to find out where angelsharks may be present. Felipe, who hails from Tenerife and is a student at the University of Las Palmas de Gran Canaria and the founder of Especies de Canarias, brought me here. He's been coming to Las Teresitas to dive with his father since he was a child and has always known about the presence of angelshark pups at this beach. In fact, many beach users know about them, but pay no attention – except when somebody accidentally steps on one and gets a little nip!

When Felipe and I met, he insisted that I should come to Las Teresitas, saying it was unique and that I would not see this many angelshark pups anywhere else. And he was right! Since 2014 we have been coming to this beach for three consecutive nights three times a year to conduct surveys. 'We' are usually between eight and 10 people who come mostly from Tenerife and work as marine biologists or are students at the university, although we also get support from schoolchildren and other people who are interested in marine conservation but have no background in biology.

Since Las Teresitas is quite a large beach, we have divided it into four zones and each night we cover one or two of them in a two-hour survey. Our group is divided into the Water Team, in charge of snorkelling (sometimes diving) and catching the sharks, and the Land Team, which stays on the beach to work up the sharks that are caught and brought to the 'tagging station'.

It's not very difficult to catch angels if you use the right method. One of the advantages of working at night is that the sharks' eyes shine when a light is pointed at them, revealing the presence of their owners. We have tried to find angelsharks during the day, but not only are they less active then, they are also almost impossible to spot. In fact, we believe that during the day they may even move into deeper areas. At night, however, the juvenile sharks come close to shore, sometimes into water as little as 20 centimetres (eight inches) deep. Here they lie, still and patient, until one of the millions of sand smelt fish swimming around makes the mistake of coming too close. Immediately, the juvenile shark extends its jaw and sucks the fish into its wide mouth. The fish doesn't stand a chance. The shark then moves back to where it was and either remains as still as stone until the next victim swims by or buries itself in the sand, becoming one with its environment.

Nevertheless, our lights reveal the angelsharks and we catch them in small nets during their nocturnal feast. We measure and weigh them to estimate growth rates, which are currently unknown. Every shark caught is fitted with a PIT tag (microchip) so that we can identify individuals and record every centimetre and gram that they gain throughout the year. We are also able to monitor how long these sharks are staying at Las Teresitas. So far, our data indicate that juvenile angelsharks are using Las Teresitas as a nursery area for at least a year before moving away. The largest individual we have caught here was 55.5 centimetres (21.85 inches) total length, while the smallest was 23 centimetres (nine inches). The data also suggest that individuals that have reached the size of 40–50 centimetres (16–20 inches) are already a year old. Through long-term monitoring we are hoping to obtain more data on the growth rates and on the residency of the juvenile sharks in Las Teresitas. We also fit a visual ID tag to each shark so that future sightings of it once it has left the area can be reported to us via our online Angel Shark Sightings Map.

While working up each angelshark we take a genetic sample in the form of a clip from the back of the first dorsal fin. These samples are sent to Kevin Feldheim's lab in Chicago where Kevin is helping us to look into the mating behaviour of angelsharks. Collected over a number of years, the samples will give us an idea about parentage and female philopatry (females returning to the same site to give birth to their young). We are now also taking samples of mucus to see if we can extract DNA from them, which could be used where angelsharks are less common. What we have learnt so far is that as well as being a special habitat for angelsharks, Las Teresitas is a nursery area for the species and is thus essential for its population in the Canary Islands. We have passed all our information on to the government of the Canary Islands and to the Spanish Ministry of Environment in the hope that Las Teresitas will become a protected area for angelsharks in the future.

Our work in Las Teresitas has raised even more questions than we started out with. We now want to know if there are other places like Las Teresitas – and if there are, the pressure to get protection measures in place is even greater! We have received support from various donors to investigate potential nursery areas at Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa. If we do find another potential nursery area, we plan to apply the same methodology that we are using at Las Teresitas.

On this survey, however, we have caught 38 juvenile angelsharks, 17 of which are re-captures. One of them we have named Silvi, in honour of our new student Silvia, who is working with citizen science data and looking at the habitat use of adult angelsharks in Fuerteventura. We have also caught only 'larger' individuals of between 30 and 45 centimetres (12 and 18 inches). Could this mean that the breeding season is over and only juveniles aged between six months and a year remain in the area? For now our job is done and we have earned a mojito and a shwarma at the dodgiest place in Santa Cruz to continue our discussions on these findings!

Adult tagging

Fuerteventura, March 2018

Fuerteventura is different from the other islands in the archipelago. It and Lanzarote are the driest and windiest of them all and lie closest to the coast of West Africa. Fuerteventura's moon-like volcanic landscape and endless white beaches are stunning, while rich waters, cold currents and a large shelf around the island provide perfect conditions for angelsharks.

For the past four years we have tagged more than 60 adult angelsharks around four of the Canary Islands and some of the sharks have shown seasonal site fidelity to certain areas. We suspect that there are key aggregation sites at Fuerteventura, similar to sites we have discovered at Gran Canaria, Lanzarote

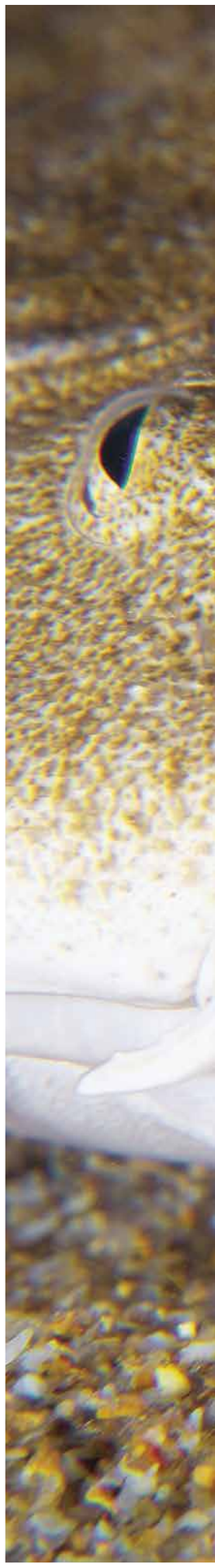


Photo by Michael J. Sealey

Initiatives like the Angel Shark Sightings Map are a bid to protect these species in the Canary Islands, East Atlantic and Mediterranean Sea. Citizen science contributes valuable information, but also makes more people aware of the presence and plight of these camouflaged chondrichthyans.

Photo by Michael J. Sealey

Life near the bottom of the sea makes angelsharks especially vulnerable to being caught as by-catch in trawling nets. The IUCN notes that early angelshark declines in the north-eastern Atlantic and the Mediterranean coincide with the intensification of trawling in these regions.

Photo by Michael J. Sealey

There is still so much to learn about how these sharks live their lives and where they're found, so that sound science informs the conservation measures that are better tailored to conserve them.

and La Graciosa. One of the Fuerteventura sites is close to the Dive Centre Deep Blue on the eastern coast, an area that is heavily urbanised and a tourism hotspot.

To tag adult angelsharks, we have developed a unique underwater methodology that minimises stress for the shark. While diving, we can sex, tag and measure the shark and take a genetic sample. The unique colour code of each tag enables us to monitor the presence and movement of the sharks at and between islands. The tags are also visible to recreational divers, who can report sightings to our Angel Shark Sightings Map.

On this particular occasion, immediately after entering the water we find a 1.3-metre (four-foot) female shark resting in the sand. She has a very light colour pattern and is fully covered by sand. The water is only four metres (13 feet) deep and we are a few metres from the shore. The shark doesn't move until she feels my needle in the base of her dorsal fin, injecting a coded tag: FV1379. As she whirls around she stirs up such a cloud of glittering sand that I can hardly see my own hands, but then I spot her as she glides away and disappears into the blue. During this particular dive, we tagged two more sharks and saw one adult male swim past. This is clearly a very important site for angelsharks and could be a key mating area, so we will monitor it closely over the next few years. Our next step for tagging is to introduce acoustic tags that will enable us to understand angelshark habitat use and movements better – watch this space!

Plans and strategy

The need for a coordinated approach and effort to protect angelsharks throughout their range is critical and long overdue. We have been given this exclusive opportunity to work in the Canary Islands to make significant advances in angel shark conservation. With the knowledge gathered so far and a local network established, we felt ready to develop an Action Plan for the conservation of angelsharks in the Canary Islands, which was done together with the IUCN SSC Shark Specialist Group, the Shark Trust and Submon. During a stakeholder workshop, we explored the threats to angelsharks and discussed specific actions to mitigate these threats and recommendations for strengthening formal protection of the species.

The Action Plan has subsequently guided the prioritisation of our work, particularly regarding the threats posed to angelsharks by recreational and commercial fisheries. 2017 has also been the year for looking beyond what is happening in the Canary Islands. With a better understanding of the species and a growing network of angel shark enthusiasts, we have started to draw a picture of the situation throughout the species' ranges. We have been involved in the development of the Eastern Atlantic & Mediterranean Angel Shark Conservation Strategy and jointly established the Angel Shark Conservation Network (*www.angelsharknetwork.com*). Here, a new collaborative citizen science database has been launched to collect data on the three Critically Endangered angel sharks – the sawback angelshark, the smoothback angelshark and the angelshark – throughout their ranges, including the Canary Islands. Anyone interested in working with angel sharks can join this network and new collaborative projects have been established. One example is our work with Natural Resources Wales in the UK.

I believe that by now you have probably begun to understand why I chose to work with angel sharks. Being a conservation biologist means that you do not just do science for the sake of doing science. In a generation where resources, time and political will are limited, science should focus on delivering the data that are needed to facilitate conservation and management decisions. I chose to work with angel sharks because I saw an opportunity to engage with a little-known group of species, where the data that I would be generating would directly benefit its conservation.

Acknowledgements

This article reflects a fraction of the extensive work the Angel Shark Project team has conducted together with partners, collaborators and volunteers. I would like to thank my partners in crime, Joanna Barker and David Jiménez Alvarado, with whom I jointly lead the Angel Shark Project. Many people are essential to the work we are conducting in the Canary Islands and although I would like to mention them all, to do so would take an entire page. I am grateful to the various funders that have facilitated the research in the Canary Islands, including the Disney Conservation Fund, the Shark Conservation Fund, Deutsche Elasmobranchier Gesellschaft, the Biodiversity Consultancy, CRESSI, the British and Irish Association of Zoos and Aquariums, the Mohamed Bin Zayed Species Conservation Fund, National Geographic, Oceanario de Lisboa, the Shuttleworth Foundation and the Ocean Tracking Network. The support of the Save Our Seas Foundation has been vital for this project and I owe much of my development as a scientist to it!

Angel Shark Project
CANARY ISLANDS

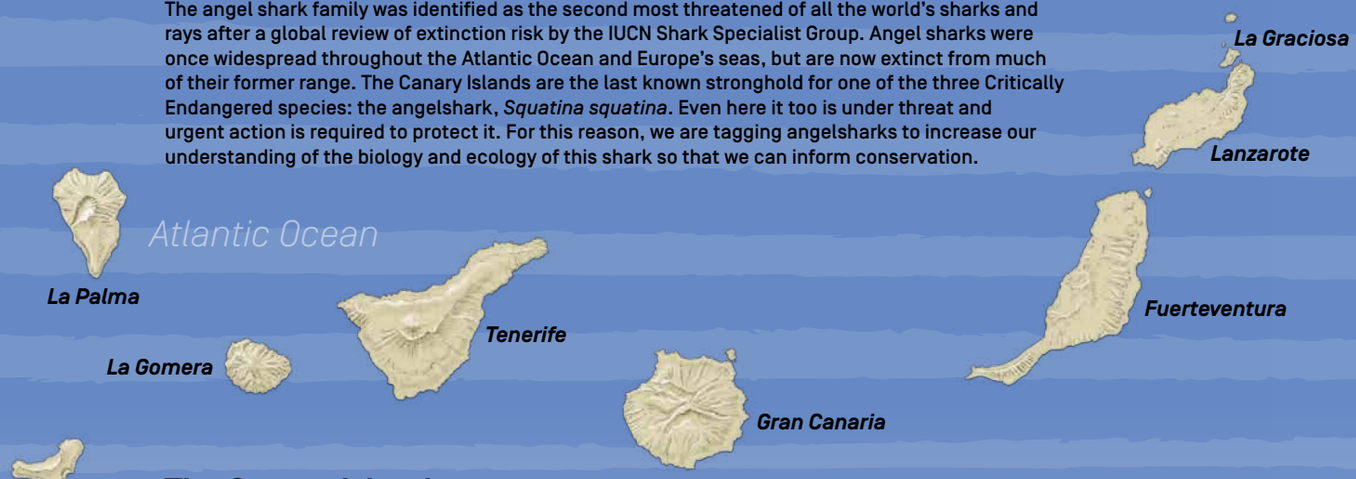
angelsharkproject.com

Photo by Michael J. Sealey

Secreted under the sand, angelsharks are successful ambush predators and often overlooked by an untrained eye.

ANGELSHARK TAGGING IN THE CANARY ISLANDS

The angel shark family was identified as the second most threatened of all the world's sharks and rays after a global review of extinction risk by the IUCN Shark Specialist Group. Angel sharks were once widespread throughout the Atlantic Ocean and Europe's seas, but are now extinct from much of their former range. The Canary Islands are the last known stronghold for one of the three Critically Endangered species: the angelshark, *Squatina squatina*. Even here it too is under threat and urgent action is required to protect it. For this reason, we are tagging angelsharks to increase our understanding of the biology and ecology of this shark so that we can inform conservation.

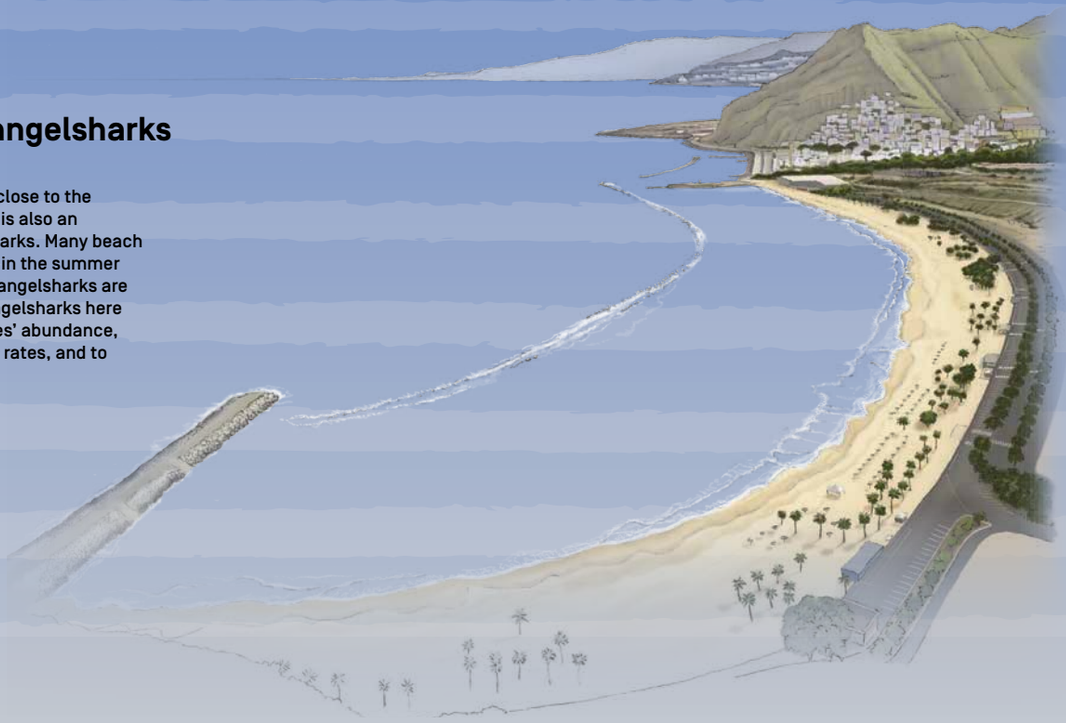


The Canary Islands

The Canary Island archipelago comprises eight islands that have emerged after successive volcanic events from the ocean basin. Although our tagging project covers the entire archipelago, we are focusing on the central and eastern islands (Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa), where angelsharks seem to be more abundant.

Las Teresitas, a nursery area for angelsharks

Las Teresitas is an artificial beach close to the capital of Tenerife, Santa Cruz, but is also an important nursery area for angelsharks. Many beach users visit it every day, particularly in the summer months when a greater number of angelsharks are present. We are tagging juvenile angelsharks here to get information about the species' abundance, seasonality, life history and growth rates, and to monitor this important habitat.



Now you see me, now you don't

Angelsharks are masters of camouflage. They bury their bodies entirely in the sand, leaving only their eyes uncovered. Here they rest or wait patiently to ambush prey that swims overhead.

Juvenile tag-and-release

Juvenile angelsharks are tagged in a different way to adult sharks and we have set up a robust protocol for possible nursery grounds. A skilled group of volunteers joins us for three consecutive nights for each tagging campaign.

We catch juvenile angelsharks in a small net while snorkelling or diving.

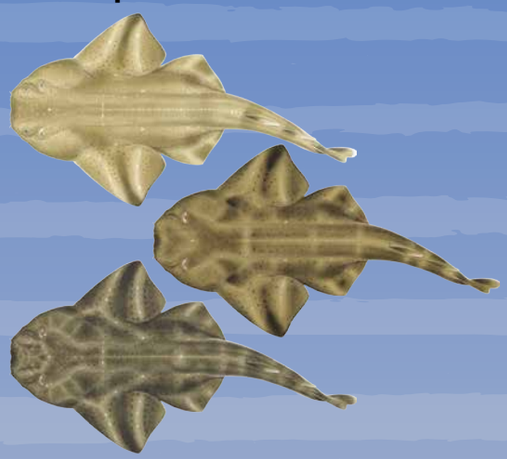
Once an angelshark has been caught, it is placed in a tray filled with water and brought to the tagging station on the beach for its work-up.

After the work-up, the tagged shark is released back into the water at the same place where it was caught.

The tagging station

A mobile tagging station is set up on the beach while the water team searches for angelsharks. Once a shark has been caught and brought to the tagging station, the beach team (two or three people) works it up. This includes taking photographs, measuring, tagging, taking genetic samples, determining the sex and weighing it.

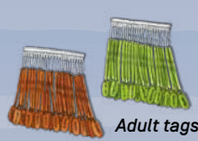
Variations in juvenile colour patterns



Tagging of young

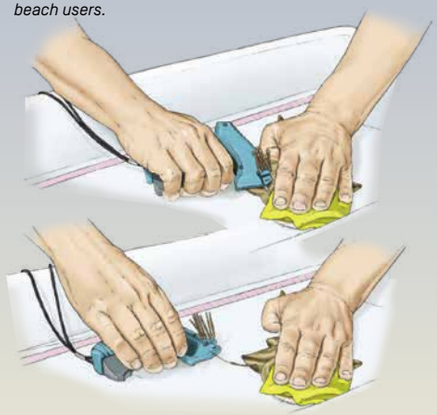
Tagging gun

Juvenile tags



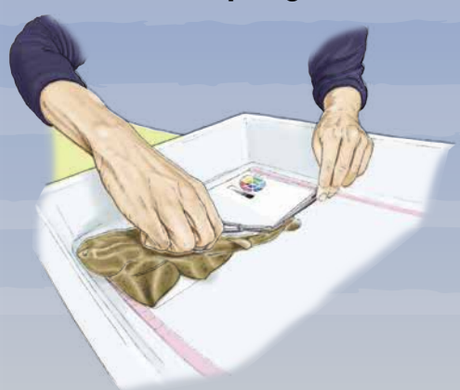
Adult tags

Neonate and juvenile angelsharks are tagged with smaller versions of the T-bar anchor tag used for adult sharks and with Passive Integrated Transponder (PIT) tags. For Las Teresitas in particular, we chose a light brown colour that is not easy to spot. This was done intentionally to protect sharks from being discovered by beach users.



Where the tag is placed also differs. Juvenile sharks are tagged in the muscle of the pectoral fin, whereas adults are tagged in the muscle at the base of the dorsal fin.

Genetic sampling



A clip is taken from the back of the dorsal fin and then sent to the laboratory for analysis. Through genetic analysis we hope to find out more about the reproductive strategy of angelsharks and whether populations around different islands are connected. For example, we would like to know if females return to the same place to give birth.

Growth rates

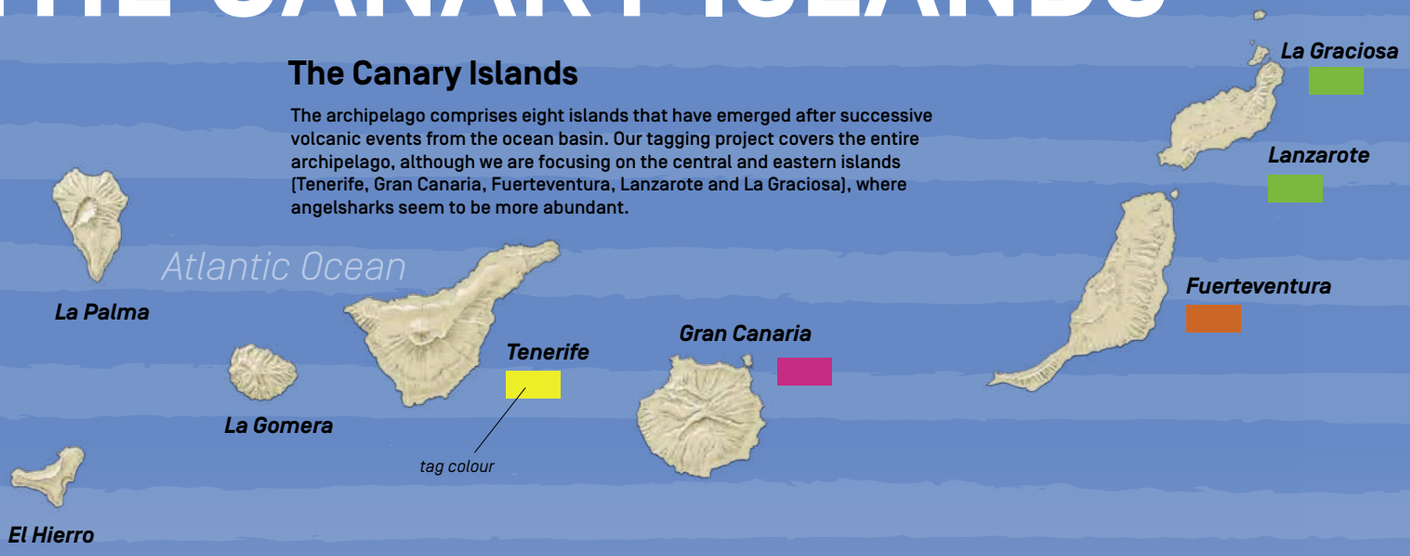
During the work-up, sharks are measured and weighed. This information will be useful to see how much they grow in time and to what size they continue to use this nursery area.

Artwork by Marc Dando

ADULT ANGELSHARKS IN THE CANARY ISLANDS

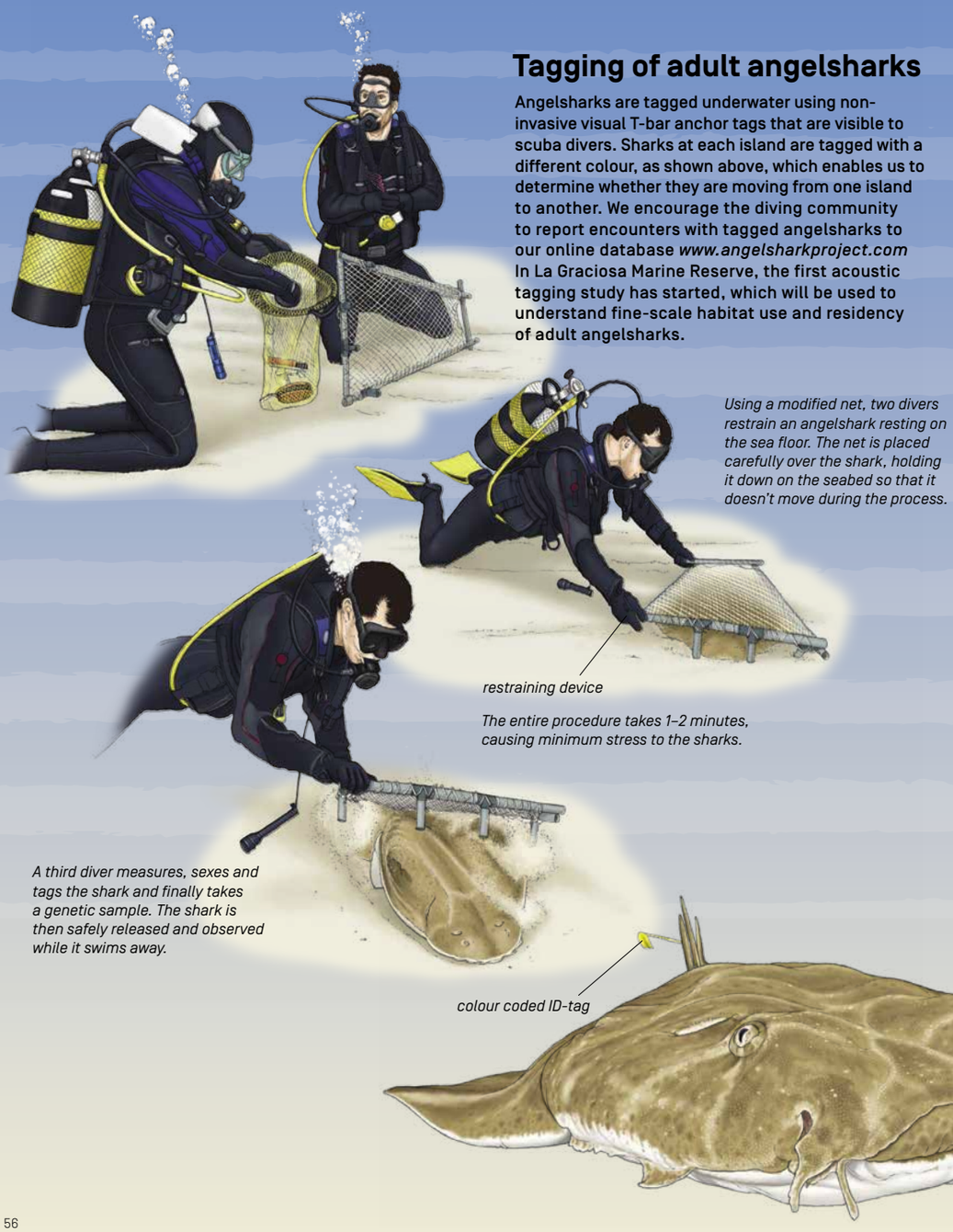
The Canary Islands

The archipelago comprises eight islands that have emerged after successive volcanic events from the ocean basin. Our tagging project covers the entire archipelago, although we are focusing on the central and eastern islands (Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa), where angelsharks seem to be more abundant.



Tagging of adult angelsharks

Angelsharks are tagged underwater using non-invasive visual T-bar anchor tags that are visible to scuba divers. Sharks at each island are tagged with a different colour, as shown above, which enables us to determine whether they are moving from one island to another. We encourage the diving community to report encounters with tagged angelsharks to our online database *www.angelsharkproject.com* In La Graciosa Marine Reserve, the first acoustic tagging study has started, which will be used to understand fine-scale habitat use and residency of adult angelsharks.



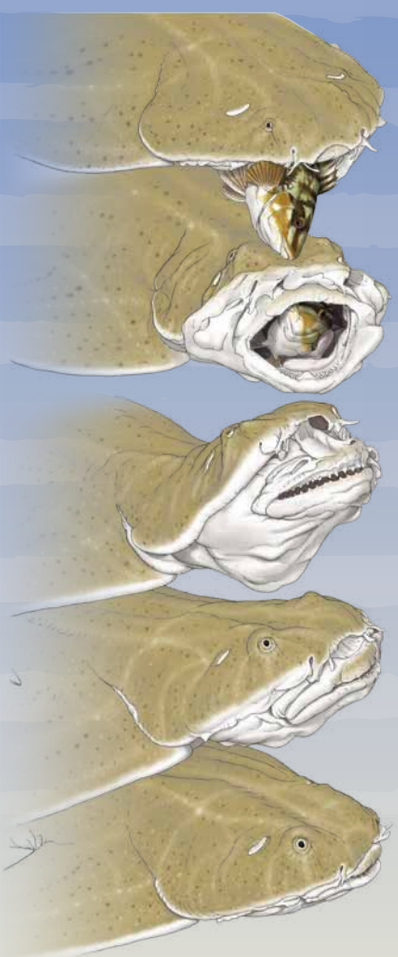
Using a modified net, two divers restrain an angelshark resting on the sea floor. The net is placed carefully over the shark, holding it down on the seabed so that it doesn't move during the process.

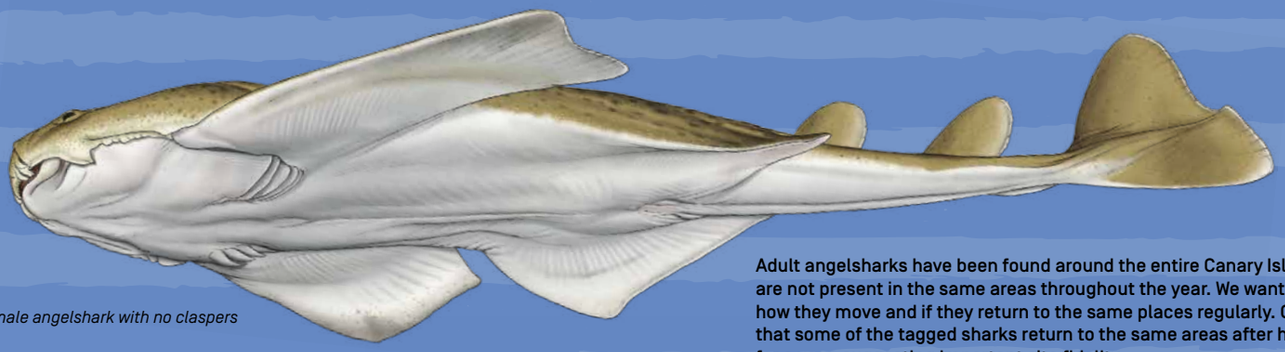
The entire procedure takes 1–2 minutes, causing minimum stress to the sharks.

A third diver measures, sexes and tags the shark and finally takes a genetic sample. The shark is then safely released and observed while it swims away.

How angelsharks feed

Angelsharks are ambush predators that wait in the sand for unsuspecting prey to swim within reach.



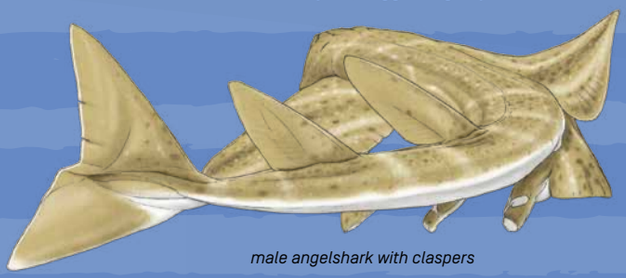


female angelshark with no claspers

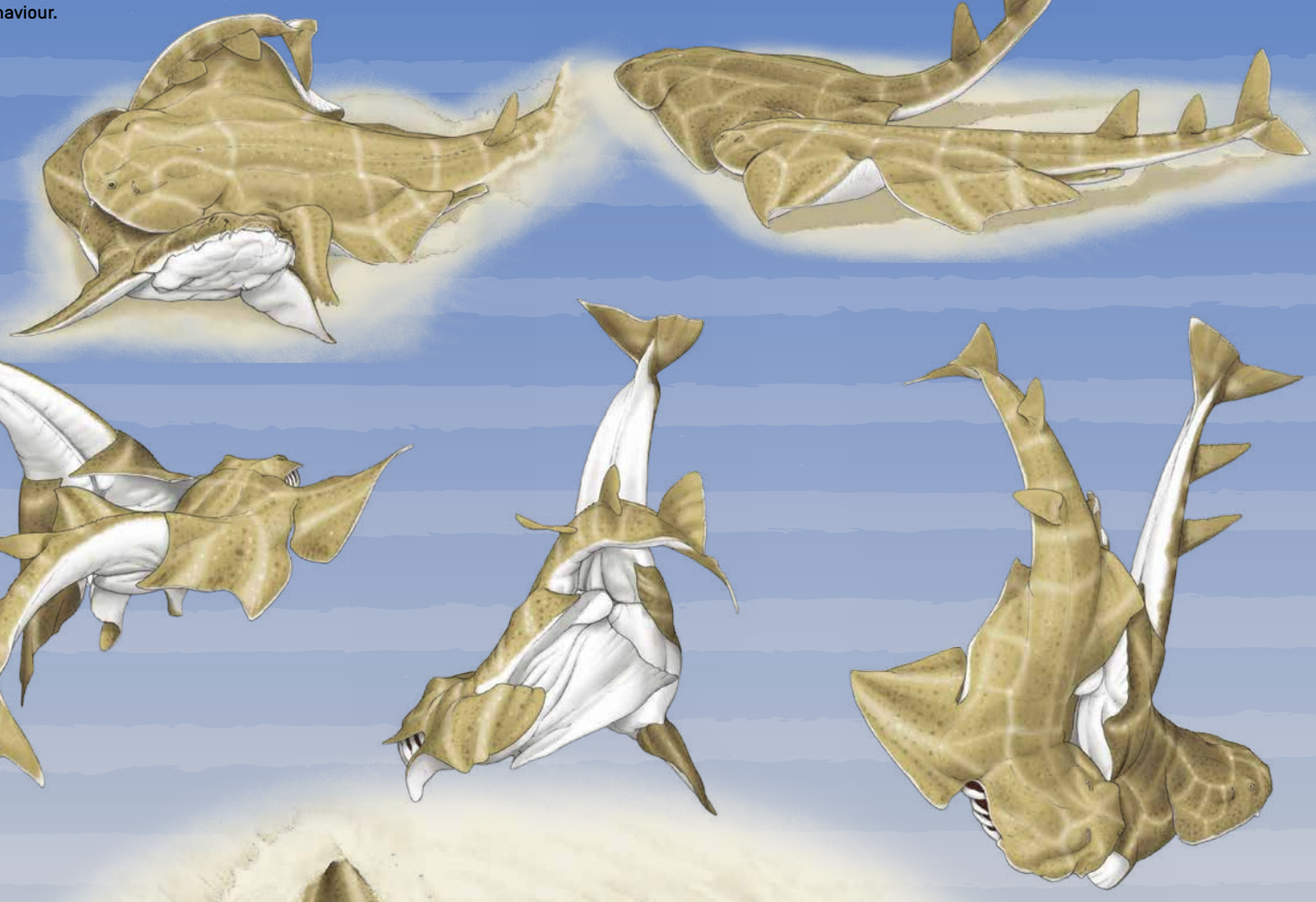
Adult angelsharks have been found around the entire Canary Island archipelago, but are not present in the same areas throughout the year. We want to know where they go, how they move and if they return to the same places regularly. Our data have revealed that some of the tagged sharks return to the same areas after having been absent for a year, suggesting important site fidelity.

Reproductive behaviour

Little is known about the reproductive behaviour of angelsharks. These sharks are reported to be mature at 80–132 cm (male) and 128–169 cm (female), reaching a maximum size of 183 cm (male) and 233 cm (female). Data gathered throughout our study have shown that there may be a breeding (spring/summer) and a mating season (winter). Data collected in this tagging project will provide a better understanding of the seasonality. The data will also help us to investigate the sharks' mating system and breeding behaviour.



male angelshark with claspers



gravid (pregnant) angelshark

Artwork by Marc Dando

FINDING SEA MONSTERS AT THE ENDS OF THE EARTH

Words by Ruth H. Leeney

Measuring a live sawfish is a moment of excitement and hope for researcher Ruth Leeney. The fishermen look on, unfazed by a sighting seemingly common in their waters.

Photo by Ruth Leeney

Photo by Tim Laman | National Geographic Creative

A river wends its way through dense rainforest in the East Sepik Province. Sawfishes swim to the mouths of such rivers to breed, navigating shallow coastal waters and riverways that frequently bring them into contact with people.

Fearing that she would be the researcher writing an obituary for sawfishes, Ruth Leeney turns her attention from Africa to Papua New Guinea in her search for these quasi -mythical creatures. They're no myth, she finds with relief, yet their standing in local culture seems to have become as shaky as their survival in real life.

Papua New Guinea. It's a place many people have never heard of and others associate with fearsome tribal cultures, cannibalism or the birds-of-paradise so beloved by David Attenborough. For me, it's a place that has changed the trajectory of my research and conservation work and given me hope. Well, cautious hope.

I have been conducting research on sawfishes for six years, mostly in Africa. Sawfishes are weird and wonderful creatures, with a shark-like body and a flattened head attached to a long, somewhat intimidating, tooth-studded 'saw'. They come into the mouths of rivers to give birth or, in the case of one species, actually swim up rivers and into fresh water. It is this behaviour that brings the third biggest fishes in the ocean – some can reach a length of seven metres (23 feet) – into shallow coastal and river waters, where they are then frequently encountered by people living and fishing in those areas. In the past, that meant that sawfishes swam their way into the folklore and culture of many coastal peoples; nowadays it simply means that they must navigate waters upon which expanding coastal populations rely and in which ever greater numbers of fishing nets are set. That doesn't usually end well for sawfishes.

Among sharks and rays, the sawfish family is now thought to be the one at greatest risk of extinction, and sawfish populations in many parts of the world have already disappeared. In

Photo by Ruth Leeney

four years of investigating whether they still exist anywhere off the coastlines of Africa where they were once common, I never once saw a live sawfish – or even a dead one. In some West African countries, fishermen and women mostly shook their heads and estimated that it had been 30 or 40 years since they had last seen a sawfish, if indeed they had seen one at all. If I was to avoid gaining the reputation of writing the obituary for sawfish populations in the developing world, I knew I needed to change tack.

There are five species of sawfishes globally and four are found in the waters of northern Australia. Papua New Guinea was once connected to northern Australia by a land bridge and, at their closest, the mainlands of the two countries are just 150 kilometres (93 miles) apart. This proximity to a known stronghold for sawfishes, and many historical records of sawfishes in the country, suggested that Papua New Guinea could be an important area for these endangered relatives of sharks. And so it was that, in April 2017, I found myself making the long trip from South Africa to a small town on the north coast of Papua New Guinea and from there along a bumpy track for several hours to the village of Angoram, on the bank of the Sepik River.

It was the tail end of the rainy season on the Sepik. I was staying with my research team in a guesthouse consisting of a shaky wooden building on stilts, divided into hot, stuffy

cubicles. The creaky veranda outside overlooked a stretch of marshy grass, which was mostly under water. In the middle of that was a rickety wooden construction housing the shower and a permanent swarm of mosquitos. It became perfectly normal to come out of the shower streaked in my own blood, thanks to all the mosquitos that had bitten me while I was washing and that I then squashed as I dressed. A visit to the toilet meant donning my wellies and splashing across the swamp to two stinking outhouses, where additional swarms of mosquitos waited to attack. Usually one to opt for natural remedies where possible, I suddenly found myself inordinately grateful for anti-fungal medication, religiously taking my prophylaxis and using DEET in copious quantities.

The Sepik River's landscapes were vastly different from those I have seen along rivers in West and East Africa. From our small fibreglass boat, wooden houses on stilts appeared at intervals, often perched entirely over the water. In narrow channels connecting one branch of the Sepik to another, we ducked under the overhanging prickly sago palm leaves that created a tunnel filled with dappled green light. In one small gathering of homes we stopped at, some 100 kilometres (62 miles) from the river mouth, we sat on a rickety wooden platform at the river bank with a small family group. A thatched roof offered some protection from the suffocating heat of the midday sun. As I asked questions about fishing activities and about sawfishes, a young woman brought a large bowl of plantains cooked in coconut milk, which we hungrily passed around the team. In these places, life seems to move slowly and quietly, as the river slips endlessly by. Looking back, I imagine I enjoyed the peace, but in truth I was in a constant state of near-dehydration, enveloped by the humid, heavy air. All energy drained, it was an effort even to muster the curiosity I needed to do my work.

'Have you seen this fish before?' I would ask. 'What is it called in your *tok ples*?'

Papua New Guinea is known for its multitude of tribes and languages – more than 800 of the latter, each called the *tok ples* (talk place) of a certain area and group of people. *Simarun, shigat, simie, warame, woreman, waruman, uruman*... As we moved from village to village, the name for sawfish changed, but everyone had caught sawfishes recently and confirmed that they were present in the Sepik River year-round. But after years of hearing the stories of old fishermen, I wanted proof. I was looking for living sea monsters.

When we reached Kopar, a village at the mouth of the mighty Sepik River, the locals told me that they caught sawfishes – *uruman* in their *tok ples* – every day, just beyond the river mouth. They invited me to join a group of fishermen the next morning to watch them retrieve their nets. They assured me there would be a sawfish in the catch. In years of searching, this was the most confident assertion I had heard; I needed no further encouragement. And so, after a night of broken sleep on the floor of a local house, I climbed into a boat in the pre-dawn shadows and held on tight as we crossed the churning waters where the muddy flow of the river met the blue of the ocean.

Just beyond that tumult, the fishers hauled in their 200-metre-long (650-foot) nylon nets, dexterously untangling one baby shark after another and dropping them onto the deck. I was momentarily distracted by small winghead sharks, like little aliens emerging from the depths. Keeping my toes clear of the heaps of net on deck, I held my breath and waited.

The first net brought up no sawfish. I wondered – have I come all this way to document the sea monster's demise even in this far-flung corner of the earth? And then, in the second net, a reddish glint in the sun, an erratic thrashing of something long and ungainly. A narrow sawfish! With an iridescent purple gleam to its skin, it lay on the deck like a jewel pulled up from the seabed. I held its tail while Jerry, the chief fisherman, expertly extricated the fish's saw from the snarls of net. There was fight in this little creature, so I worked quickly, taking measurements and photos, and then released it back to the sea. It disappeared under the waves, allowing me barely a moment to absorb that finally, after five years, I had found living proof of the existence of sawfishes in a place where no one had ever looked. The fishermen were nonchalant; I was beaming.

In the five nets we checked that morning, there were two narrow sawfishes, both just over a metre (three feet) in length. Adult narrow sawfishes can reach 3.5 metres (11.5 feet), so these were young animals. When we got back to Kopar, we were told that another boat had caught a bigger sawfish that same morning and I was handed the animal's saw, still bloody where it had been cut from the head, as proof. It was a largetooth sawfish, probably about three metres (10 feet) long based on the length of the saw. I hurried along the beach to where the team of fishers had landed the animal, but it had already been reduced to chunks of flesh. Its large, golden fins were laid out on a wooden rack to dry in the sun. Once dried, they would be taken down the coast to the nearest town, where shark fin traders would buy them and ship them to Asia.

My head still reeling from rushed encounters with the objects of my years of detective work, we made our way upriver. On a tributary of the Sepik, in the village of Kambot, master carvers Ignas and Sakarias Kram took me to the traditional carving house and told me about the local beliefs associated with sawfishes. The sawfish is a totem animal for their clan, they told me, just as animals like the cassowary and crocodile have special significance for other clans. Sawfishes were thought to have spiritual powers. Before leaving on a hunt or a fishing trip, villagers would bring food, *buai* (betel nut) or tobacco to the *haus boi*, the men's house, and ask the chief there to communicate with the sawfish spirit and request strength, or perhaps a plentiful catch of fish, on their behalf.

Kambot also has a strong tradition of carving storyboards, which depict local scenes of people and wildlife. Sawfishes feature in these storyboards, one of which was hanging from a post in the carving house. Sawfishes also used to be carved onto the prow of canoes belonging to those clans for whom the sawfish is a totem, but Ignas told me that canoes are rarely carved nowadays and there were no more canoes featuring sawfish in the village. It appears that traditional beliefs and practices that incorporated sawfish are waning, perhaps as Western influences more regularly reach these remote communities.

Travelling hundreds of kilometres along the Sepik and speaking with members of communities along its length, I gained a better understanding of the threats facing sawfishes in this remote corner of the world and of the lives of the people who regularly catch them. After five years of research on three continents, I found the sea monsters I had been searching for. Papua New Guinea appears to be only the fourth stronghold globally for sawfishes (after Florida, The Bahamas and Australia), which is truly good news for these highly threatened animals.

But on that fishing trip I had watched as many other sharks were brought to the river bank and I knew that, on any other day, the sawfishes I had released back to the sea would have met the same fate. These communities rely on sawfishes as a source of income, through the sale of their fins, and for food. The fate of the Sepik's mythical inhabitants is thus intertwined with the livelihoods of people who live simply, want to improve their lot and have few alternatives to fishing. What a loss it would be if both these mighty fishes and the human culture and creativity they have inspired were to slip unnoticed into the dark Sepik water and disappear.

Ruth Leeney's research in Papua New Guinea was supported by a grant from the National Geographic Society. The results of her study have been published as an Open Access article: Leeney R, Mana RR & Dulvy, N. (2018). Fishers' ecological knowledge of sawfishes in the Sepik and Ramu rivers, northern Papua New Guinea. *Endangered Species Research*. 36: 15-26

The hammer-shaped head of a winghead shark makes it vulnerable to a range of net mesh sizes, and it is listed as Endangered by the IUCN.

Photo by Ruth Leeney

Scientists suspect that Pacific white skates are laying their eggs near hydrothermal vents to speed up their otherwise lengthy incubation process.

Photo by Julye Newlin | Ocean Exploration Trust | Nautilus Live Copyright

Feeling the heat

Words by Lauren De Vos

A new publication brings to light a startling find and reminds us of how deep-dwelling sharks, rays and skates are brilliantly adapted to their environment. The deep sea remains one of our least explored and understood habitats on earth. As fishing and mining encroach into deeper waters, even the furthest reaches of our oceans are no longer safe from exploitation. The discovery by Pelayo Salinas de León and his team that the deepest-dwelling skate on earth makes ingenious use of hydrothermal vents in the Galápagos is, perhaps, a reminder that we stand to lose species and habitats before we've had a chance to document them in a realm that holds some of the clues to the origins of life on earth.

Sink 8,000 feet (2,400 metres) below the surface of the Pacific Ocean and light filtering from the surface dwindles to nothing, leaving an inky blackness. In the absence of life-giving sunlight, it seems improbable that our deepest oceans are anything but lunar landscapes. So when, in 1977, a remote-controlled camera sled gliding along the sea floor recorded a spike in ocean temperature, scientists dismissed it as a glitch. Only once they had retrieved the camera and started sifting through the stills it had captured did they realise that this 'irregularity' in the temperature readings matched a series of photos that revealed beds teeming with clams and mussels – a sea floor more alive than seemed possible for that depth.

On the equator and along the submarine lava plateau that is the Galápagos Platform in the eastern Pacific, 13 volcanic islands and a number of sea mounts emerge from the ocean. Lying 1,200 kilometres (745 miles) west of Ecuador, these islands, the Galápagos, have captivated scientists since Darwin pondered over their finches and formulated his first inklings of the theory of evolution. It was here that Rob Ballard and Richard von Herzen led the Galápagos Hydrothermal Expedition and discovered the reason for a surprising oasis of life at depth: hydrothermal vents belching water heated by magma where the earth writhes with growing pains. Their discovery changed the way science debates the origins of life on earth. The Galápagos, it seems, continues to challenge and shape the way we understand biodiversity, its evolution and its relevance to our lives.

Hydrothermal vents are found near sites of volcanic activity. They are typical of mid-ocean ridges, where the earth's tectonic plates are moving apart and away from each other as new ocean crust is formed. Sea water permeates the ocean crust, percolating into the rock through fissures, and is heated by magma boiling deeper down. Where it bursts to the sea floor's surface again through vents, the water might be at any temperature between 60 and 460 °C – much hotter than the ambient 2 °C typical of water at this depth. The process of heating causes a series of chemical reactions, as does the subsequent process of coming into contact with cool, surrounding sea water once again when the heated water bursts out of the vents.

The marine communities that proliferate around these hydrothermal vents do so because they can generate energy by chemosynthesis rather than deriving it from sunlight via photosynthesis. Black smoker chimneys (high-temperature hydrothermal vents composed of black iron sulphide deposit) can host whole ecosystems centred on animals that use chemosynthesis to convert heat, methane and sulphur to generate energy. These animals are called archaea and extremophiles, and they in turn are food for clams, tubeworms and more complex life forms.

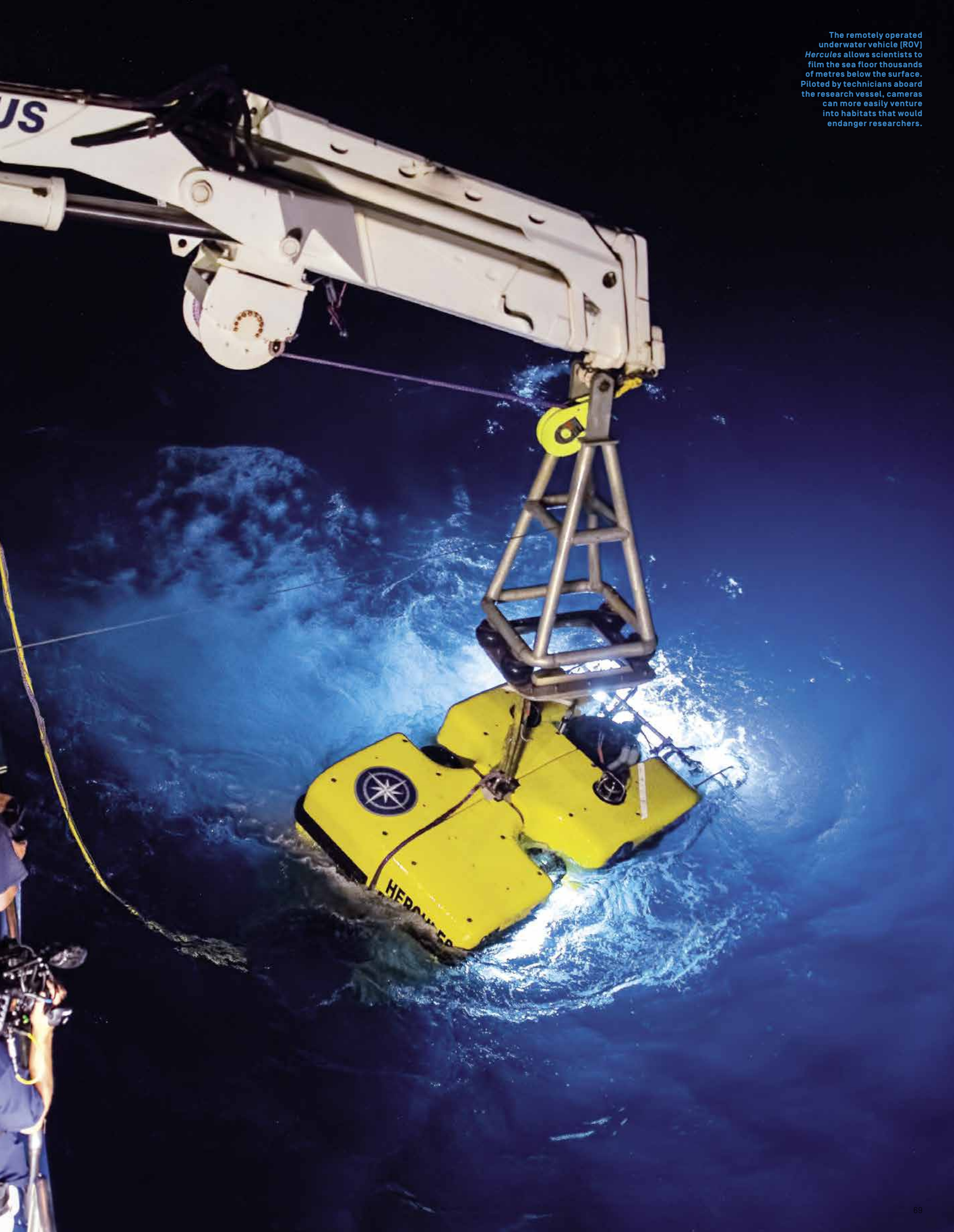
Nearly 40 years after the Galápagos Hydrothermal Expedition, in 2015, the remotely operated underwater vehicle (ROV) *Hercules* dived to more than 1,600 metres (5,250 feet) at the Iguanas-Pinguinos hydrothermal vent site in the Galápagos Marine Reserve. Here, Pelayo Salinas de León from the Charles Darwin Foundation made another surprising discovery. Secreted around these hydrothermal vents, at depths of between 1,649 and 1,660 metres (5,410 and 5,446 feet) were the eggs of the Pacific white skate *Bathyraja spinosissima*. Together with co-authors Brennan Phillips, David Ebert, Mahmood Shivji, Florencia Cerutti-Pereyra, Cassandra Ruck, Charles R. Fisher and Leigh Marsh, he published the findings in 2018 in *Scientific Reports*.

This is the first evidence of behaviour such as this in the marine world. Given that the water temperature near the vents where the eggs are laid is warmer than in the surrounding area, scientists believe that the skate is using the heat to incubate its eggs. Sauropod dinosaurs in the Cretaceous period are believed to have done the same, as do some species of megapode birds today. The Polynesian megapode *Megapodius pritchardii* on Niuafo'ou Island in Tonga, for instance, buries its eggs in volcanically heated soils.

'The first place the ROV landed on the sea floor was on a ridge, in the plume of a nearby hydrothermal vent that we had specifically come to investigate – a black smoker,' explained Charles Fisher in an interview for Penn State University. 'When we panned the camera down, we found something we did not expect: these giant egg cases, also known as mermaid purses. And we found several layers of them, indicating that whatever was laying these eggs had been coming back to this spot for many years to lay them. As the dive progressed, we saw more and more of these egg cases and realised that this was not the result of a single animal, but rather a behaviour shared by many individuals.' The scientists counted 157 egg cases, most of which lay within 150 metres (490 feet) of two active black smoker chimneys. Using the mechanised arm of the *Hercules*, they collected four egg cases that were DNA-tested to confirm the species they belonged to.

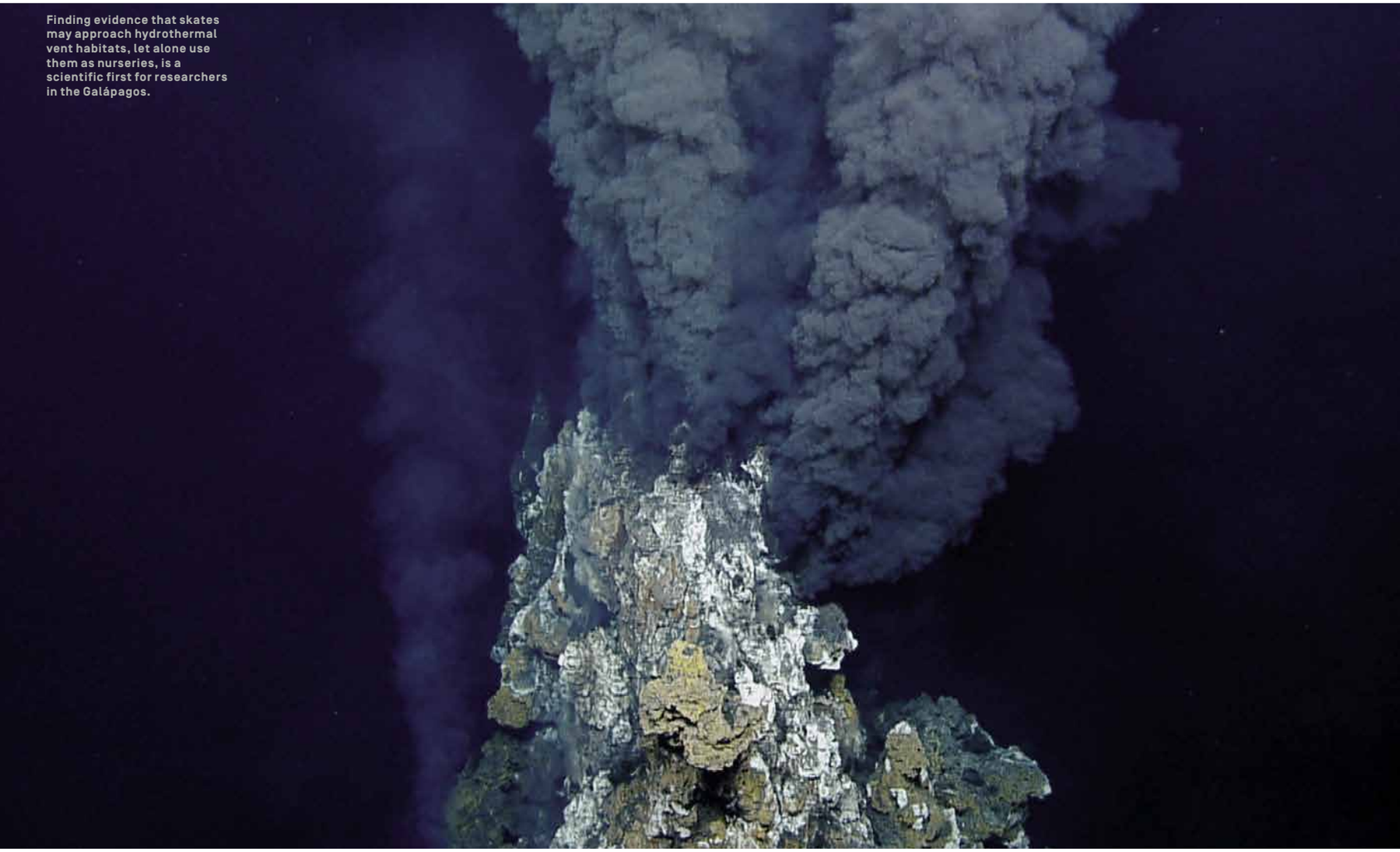
Why would an animal lay its eggs so close to a black smoker? The reason becomes clear when you consider that deep-dwelling skates like the Pacific white skate exhibit some of the longest incubation periods for any species in the animal kingdom. A similar species such as *B. parmifera* incubates its eggs in the Bering Sea for about 1,290 days at a water

Photo by Julye Newlin | Ocean Exploration Trust | Nautilus Live ©



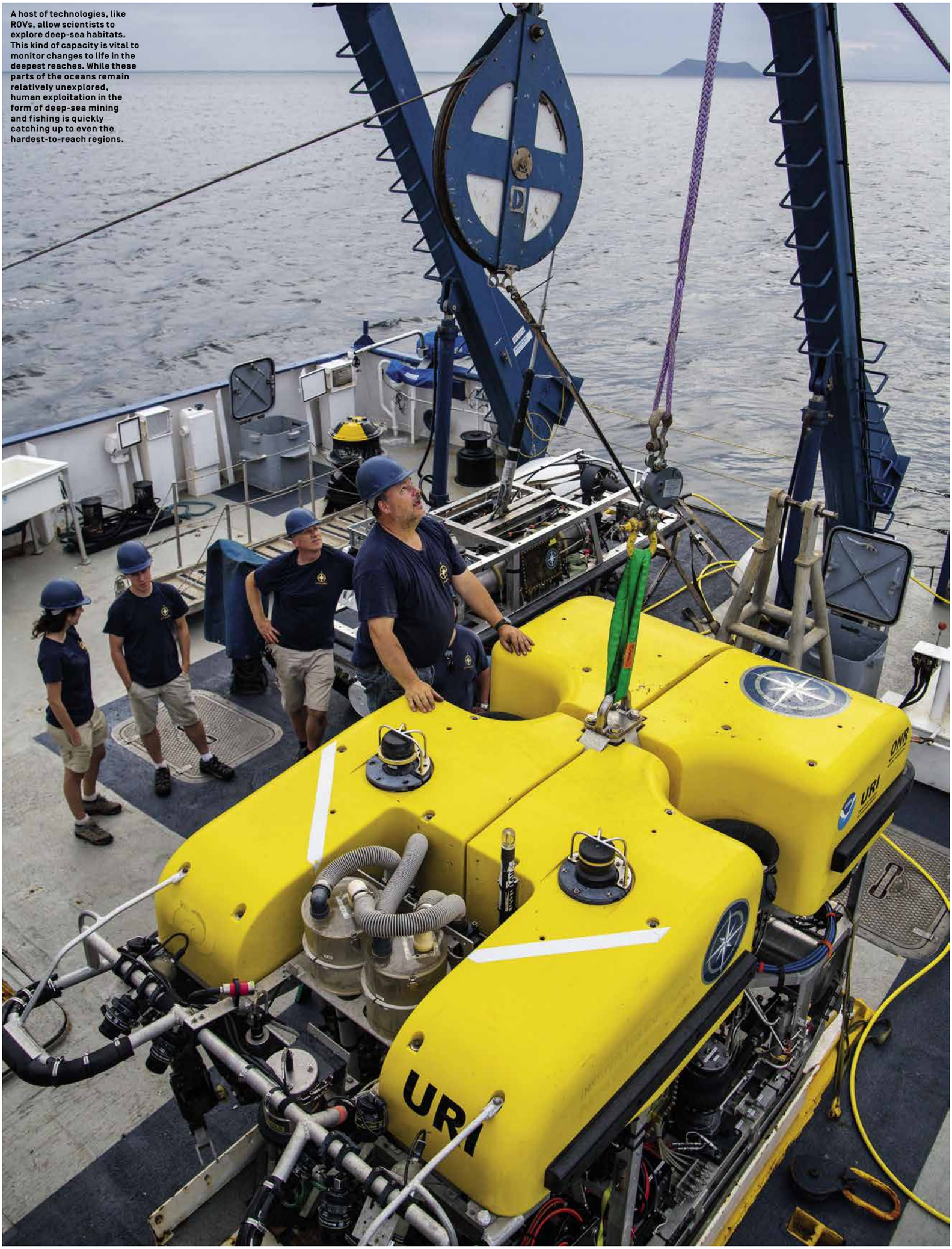
The remotely operated underwater vehicle (ROV) *Hercules* allows scientists to film the sea floor thousands of metres below the surface. Piloted by technicians aboard the research vessel, cameras can more easily venture into habitats that would endanger researchers.

Finding evidence that skates may approach hydrothermal vent habitats, let alone use them as nurseries, is a scientific first for researchers in the Galápagos.



Ocean Exploration Trust - Nautilus Live ©

↓ Photo by Julye Newlin | Ocean Exploration Trust ©



A host of technologies, like ROVs, allow scientists to explore deep-sea habitats. This kind of capacity is vital to monitor changes to life in the deepest reaches. While these parts of the oceans remain relatively unexplored, human exploitation in the form of deep-sea mining and fishing is quickly catching up to even the hardest-to-reach regions.

Ocean Exploration Trust - Nautilus Live ©

Researcher Pelayo Salinas de León peers into a halved sample of the Pacific white skate egg cases brought to the surface from a depth of more than 1,600 metres (5,250 feet).

Photo by Julye Newlin | Ocean Exploration Trust - Nautilus Live ©

temperature of 4.4 °C. Based on this, scientists estimate that a conservative incubation period for the Pacific white skate at an average water temperature of 2.76 °C would be more than 1,500 days – that's over four years! Laying eggs near the elevated temperatures of hydrothermal vents would potentially accelerate the embryos' development and decrease these lengthy incubation periods. It's a smart move, considering that the longer an egg needs to incubate, the longer it lies unprotected and vulnerable on the sea floor, with a lower chance of surviving and hatching.

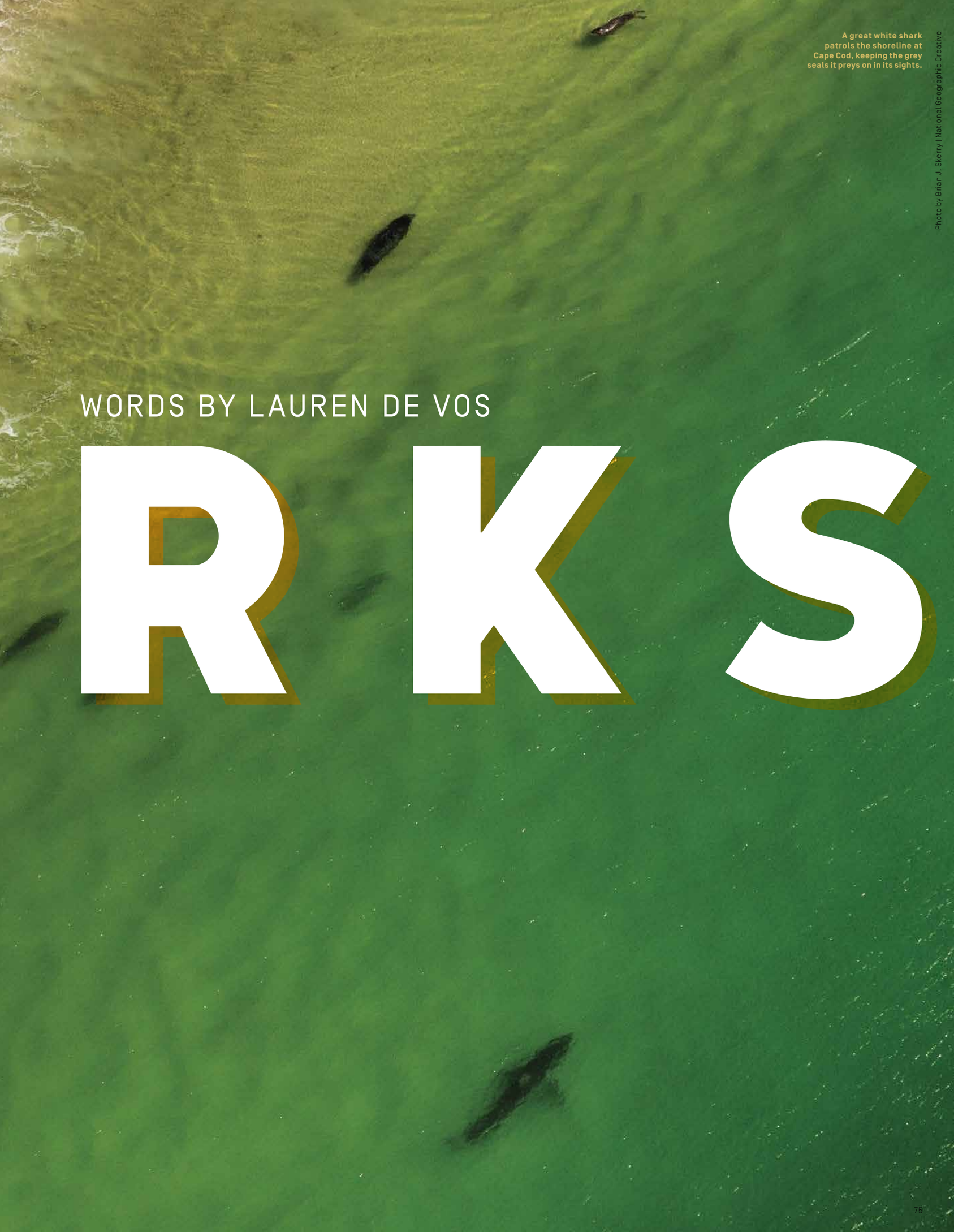
The finding is certainly valuable for its scientific interest, adding to our scant but growing knowledge of deep-sea environments and hydrothermal vent habitats. For Pelayo, though, there is something more urgent about our need to investigate these deep reaches. 'We have to dedicate more time and resources to exploring in our backyard,' he told Earther in an interview for its website. 'We're hoping to send rockets to the moon and Mars, but we have a whole alien world next to us that hasn't been explored.'

The reason for urgency lies in the conservation imperative. Almost one in four chondrichthyan species are threatened with extinction, so an understanding of these enigmatic creatures is critical if we are to be better equipped to manage and protect their populations. The Pacific white skate has adapted to its deep habitat by slowing down, which includes the incubation period of its eggs. Long-lived, slow-growing and slow-to-reproduce, it has the very life history traits that make deep-dwelling sharks, rays and skates so well adapted to surviving in an otherwise inhospitable environment. Yet these are precisely the traits that make them vulnerable to exploitation. Oil and gas exploration, deep seabed mining and the expansion of fishing into deeper waters threaten reaches of our oceans that once seemed immune from intrusion. Speaking to National Geographic, Pelayo points out, 'We know hardly anything about the deep sea, yet we are fishing and mining [in it] before we even get a chance to document what species live down there and what unique behaviours [they] could reveal [to] us.'

Understanding what creatures of the deepest oceans, like the Pacific white skate, need in order to survive and reproduce can guide scientists to critical information that informs more strategic conservation measures. Knowledge of how, and where, these creatures spend their lives could underpin the correct design of strategies such as marine protected areas. As the authors of the paper point out, Ecuador created a 40,000-square-kilometre (15,450-square-mile) marine protected area in 2016 around Darwin and Wolf islands in the Galápagos: a sanctuary that also protects the sea mounts, including the Iguanas-Pinguinos vent site.

Information just like this discovery by Pelayo and his colleagues is what motivates action to safeguard critical and vulnerable habitats. The fact that deep-sea skates actually create nurseries was first recognised in 2015 by the North Pacific Fishery Management Council when it declared eight nurseries in the Bering Sea as of 'particular concern'. It was the first time this habitat type was officially acknowledged. So what of the future? Pelayo and his co-authors mention these examples of protection and recognition as a basis to motivate for more research to identify, and highlight the protection of, deep-sea nurseries for sharks, rays, skates and chimaeras.


SEEKING ANSWERS FROM
SHA



A great white shark patrols the shoreline at Cape Cod, keeping the grey seals it preys on in its sights.

Photo by Brian J. Skerry | National Geographic Creative

WORDS BY LAUREN DE VOS

R K S

WORDS BY LAUREN DE VOS

New genetic studies suggest that understanding sharks and their DNA could benefit human medical research. The findings not only add to our scientific interest in these predators, but also increase their conservation importance. There is, it seems, much more to sharks than meets the naked eye.

If you'd stepped into the garden of the Augustinian Abbey of St Thomas in Brno (now in the Czech Republic) on a sunny day in the year 1865, you might have been forgiven for missing any clue that groundbreaking science was in action. The variously white or purple blooms of common pea plants *Pisum sativum* blushed under the studious gaze of a monk, their tendrils reaching like tentacles across the soil to where he stood, lost in his musing. Gregor Mendel and his garden were set to lay the foundations of a branch of science that is changing the world as we know it.

For conservation, Mendel's humble experiments may now be integral to how we understand disease, manage the effects of climate change for whole populations of animals and trace endangered species around the world. The monk kept meticulous notes on the height of his plants, the shape and colour of their pods, their seeds and the position and colour of their flowers. Over two years, he documented how the offspring in each new generation of pea plants inherited traits from their parent plants; how specific characteristics were passed from one generation to the next. Gregor Mendel set the basic rules for biological inheritance. The principles of Mendelian heredity, as they were later dubbed, laid the groundwork for modern-day genetics, long before anyone knew genes even existed. This unlikely gardener has been logged in the annals of history not for his spiritual contribution as abbot, but as the father of genetics – the study of genes, DNA and evolution.

At about the same time that Mendel was formulating his ideas of heredity, a Swiss chemist was well on his way to discovering DNA. In 1869, Friedrich Miescher, sifting through patients' pus-coated bandages that had been mailed to him at his request from a local clinic, discovered an entirely new substance that he called nuclein. Just as Mendel's discoveries of heredity weren't well accepted during his lifetime, it would take more than 50 years for the gravity of Miescher's nuclein findings to resonate within the scientific community. Nevertheless, the foundations had been laid and scientists would go on to discover genes, the unit of inheritance passed from one generation to the next that determines some traits of the offspring; and DNA, the deoxyribonucleic acid that carries genetic information.

Today, genetic research opens a new window into how life on earth works. Understanding genes has revolutionised conservation science, where now scientists recognise the importance of preserving genetic diversity in populations so that they are resilient to diseases, catastrophic events or even the murky effects of climate change. Genetics has opened avenues of conservation forensics, like the field of DNA barcoding, which has revealed that more than half of the dried shark fins and mobulid gill plates currently being traded originate from species classified as Endangered or Vulnerable by the IUCN. The conceptual leap from common pea plants growing in an abbey to the conservation of sharks today may seem vast, but for a geneticist the distance between species becomes a relative concept. If Mendel and Miescher could have had any inkling of the long-term potential of their discoveries, they might have sensed what Charles Darwin meant when he said, 'In the distant future I see open fields for far more important researches...'.

To truly appreciate why shark genetics is particularly interesting to scientists today, one has to go back in history much further than Darwin, Miescher or Mendel. Back, in fact, to when most land on earth was amassed into a super-continent called Gondwana and the seas were filled with an astonishing wealth of marine animals. About 450 to 470 million years ago, around the same time that the first plants made it onto land, odd creatures with even more eccentric names, like graptolites, trilobites, brachiopods and conodonts, shared the waters with red and green algae. Sixty per cent of the species in these ancient oceans would go extinct at the end of what palaeontologists dub the Ordovician period, but scientists believe that at some point during this time an arm of the genetic tree branched out, splitting sharks off from bony vertebrates such as the osteichthyes (bony fishes).

Their ancient history and their strategic position on the genetic tree make sharks interesting to geneticists because they provide a baseline for further study and understanding of the vertebrate genome. The genome describes the entire collection of genes in an organism, while vertebrates are animals with a backbone. Sharks are therefore a reference point for the study of which characteristics appeared after this evolutionary split. Elasmobranchs (that is, sharks, rays and skates) are also fascinating because some of their traits are simply so unusual. One such characteristic is the capacity for rapid wound healing that enables sharks to navigate bacteria-laden waters without risk of infection.

Another notable trait is their evolution of a primitive adaptive immune system. An adaptive immune system (the cells, tissues and organs in the body that defend against infection-causing invaders like bacteria) evolved so that our bodies can respond to the presence of pathogens (disease-causing agents) by producing antibodies and specialised defence cells that promote healing and combat disease. Sharks are the oldest group of vertebrates to have an adaptive immune system based on the same B- and T-cell receptor genes that underpin adaptive immunity in other vertebrates. B and T cells help the body destroy viruses, bacterial infections and parasitic invasions. The adaptive immune system detects a foreign intruder and this stimulates the production of antibodies (proteins produced by the body to combat infections) to fight back: B and T cells are specific to certain antigens (the protein produced by the invading virus or bacteria). The B- and T-cell receptors are what bind to specific antigens, stimulating an immune response.

Sharks, however, don't have bone marrow, which is where B cells usually develop. They possess different antibodies, including a unique one dubbed the new antigen receptor, or IgNAR. Many researchers are particularly interested in IgNAR for its potential in future human biomedical research. This interest aside, surprisingly little is known about shark immunity versus that of higher vertebrates (those vertebrates that evolved later on the genetic tree).

Another point of interest is that some shark species have

developed regional endothermy. Endotherms, also known as 'warm-blooded animals', maintain a constant temperature independent of their surroundings. Birds and mammals are warm-blooded animals, and it has recently been discovered that even a fish, the moonfish or opah, is warm-blooded too. Conversely, ectotherms are dependent on an external source of heat. Lizards basking on a heated rock in bright sunshine, or most fishes in the sea, are a good example of what we call 'cold-blooded' animals. Regional endotherms, however, strategically conserve metabolic heat by using vascular counter-current heat exchange.

Fish that are capable of regional endothermy have a few things in common: they are often pelagic (swimming in the open ocean); they undertake long migrations through oceans where they will encounter a range of water temperatures; and they are large, active species with high energetic demands. A good example is a tuna, which migrates across vast oceanic distances to follow prey and is capable of explosive bursts of speed and power for hunting. A counter-current heat exchange system works when arteries run parallel to a set of veins. In a fish like a tuna, cold blood courses through the arteries, bringing oxygen-rich blood from the heart to the active swimming muscles. In the process, the arteries take up some of the heat from the warmer blood in the veins, which is returning from the swimming muscles. In this way, fish like tuna, billfish and laminid sharks (such as white and shortfin mako sharks) can maintain their active swimming muscles at higher-than-ambient temperatures.

Nicholas Marra, a post-doctoral researcher at the SOSF Shark Research Center, and colleagues from the Guy Harvey Research Institute (GHRI) at Nova Southeastern University, Cornell University and Clemson University were interested in the differences between sharks and bony fishes (teleosts) at a genetic level. In particular, they wanted to understand the genetic mechanisms that give rise to these unique traits of sharks that may be significant to human beings. They also wanted to assess genetic differences between sharks and bony fishes, with a specific focus on genes linked to their immune systems. The researchers' paper, published in 2017 in *BMC Genomics*, looks at four elasmobranch and three bony fish species. The elasmobranchs were the white *Carcharodon carcharias*, shortfin mako *Isurus oxyrinchus* and great hammerhead *Sphyrna mokarran* sharks and the yellow stingray *Urobatis jamaicensis*, while the bony fishes were the swordfish *Xiphias gladius*, hogfish *Lachnolaimus maximus* and ocean surgeonfish *Acanthurus bahianus*. Of these species, the white shark, shortfin mako and swordfish are considered endothermic, capable of maintaining a constant temperature in their swimming muscles.

Mahmood Shivji, the director of the Save Our Seas Shark Research Center and GHRI, led the team of scientists. They asked three questions: what genetic differences exist between sharks and bony fishes that reflect their evolutionary history; are there differences in the genes expressed that relate to the functioning of their immune systems and capacity for rapid wound healing; and are there genetic differences between the endotherms and ectotherms? To answer these questions, the researchers looked at the heart tissue of their study species and focused not on DNA, which is the material of genetics and what the author Adam Rutherford calls 'a script in which genes are written', but on another essential genetic material called ribonucleic acid (RNA). RNA acts as a messenger, carrying the information locked in our genes to the rest of our cells. They looked at the transcriptome, which is the sum total of all the RNA molecules expressed from the genes of each organism.

So what did they find? The location and function of 45–50% of genes are shared by all seven species. There are, however,

Photos by Karen Kasmauski | National Geographic Creative

key differences between sharks and bony fishes and these are indeed related to their immune systems. Several genes relating to the immune system were found only in sharks and rays. These species also have more genes that are involved in determining the function of antibodies compared to the bony fishes. Two genes linked to shark immunity, dubbed *legumain* and *Bag1*, have equivalents in human beings. When a gene is expressed, the information coded for in our DNA is converted into instructions to make an end product, such as a protein. Sometimes, genes can be stimulated to over-expression, which is expression at higher than normal levels. The over-expression of *legumain* and *Bag1* in human beings is linked to cancer. That sharks have higher resistance to cancer needs more testing, but the researchers highlight this: the function of the proteins produced by these two genes in sharks has undergone changes that potentially make them more resistant to cancer. They stress that these findings don't show that ingesting shark parts will cure or prevent the disease. Eating shark products won't cure cancer, but if scientists can better understand how cancer works at a genetic level in species that are more resistant to the disease, their findings might inform more efficient treatment and cures for human beings in the future.

Some of the genetic differences between sharks and bony fishes may be related to their role in efficient wound healing. It seems that the genes specific to sharks may be a factor in both immunity and rapid wound healing. While many anecdotal reports claim that sharks, rays and skates heal quickly, how they achieve this is isn't clear. In mammals, various cells (macrophages, lymphocytes and neutrophils) would race to the site of a wound as part of an inflammatory response. Timing is everything in this process and the development of infection can prolong the inflammation, delaying healing. Says Nicholas Mara, the lead author of the paper, 'Genes and pathways associated with promoting and controlling inflammation, as well as those involved in clearing cellular debris and pathogens, are critical to the wound-healing process.' It seems that some of the genes involved in initiating inflammation and the destruction of invading pathogens, both important factors in avoiding infection and initiating a smooth wound-healing process, may have roles in wound healing that are complementary to their function in shark immunity.

Did the researchers find differences between the ectotherms and endotherms? Mara and his colleagues had figured that the heart transcriptomes of the swordfish, shortfin mako and white shark should share patterns in their genetic content that reflect the fact that all three species had evolved regional endothermy 'covergently' – in other words, the three species are not necessarily closely related, but they evolved similar characteristics independently, usually because they share a niche in the ecosystem. The researchers found that 19 genes are unique to the white shark, shortfin mako and swordfish. Many of these genes and their products are associated with cardiac muscle contraction. Other genes expressed only in the endotherms are important in metabolising (breaking down and using) lipids and fats, a rich source of energy.

So what might be the reason for these differences? If one thinks of a swordfish slicing through blue water, its heart, which is at the same temperature as sea water, is pumping oxygen-rich blood to the muscles that power its trajectory towards its prey. The expression of these particular genes in these species says something about their need to store energy efficiently, say the researchers. Metabolic genes, it seems, are important for proper heart functioning, so that regionally endothermic species can maintain a higher temperature in their muscles. This genetic pattern enables species like the

Photo by Cesare Naldi | National Geographic Creative

swordfish and the white and shortfin mako sharks to maintain high activity levels as they range widely through the oceans, ensuring they are capable of the bursts of speed needed to capture escaping prey.

Mahmood Shivji's take-home message about the relevance of this work in the wider conservation context is that its findings urge us to protect sharks more effectively. 'Now we have another important reason to make sure we don't lose these marvellous and ecologically critical animals to overfishing, as is currently occurring in many parts of the world,' he says in a press release from Nova Southeastern University. 'We've just scratched the surface in terms of learning what these ancient animals can teach us, as well as possibly provide us in terms of direct biomedical benefits.'

This philosophy is one with which Harvard professor and entomologist EO Wilson would concur. As science and technology evolve far beyond the imaginations of Darwin and Mendel, our capacity to learn from nature is broadened. However, what concerns many scientists today is the diminishing amount of nature left from which we can still learn. 'We have no idea how most of [the ecosystems on the planet] work, we have little idea what species are in [these ecosystems], and we don't know what will happen to the world if we remove such a large part of this ancient flora and fauna. We are tinkering in a way that could be injurious to our own species,' says Wilson.

The journey from Gregor Mendel's garden to the current state of genomics research has taken 150 years and the time period over which sharks have evolved their unusual immune systems and ability to heal is orders of magnitude longer. It seems strange, then, that our actions over the relative blink of an eye in geological timescales could undo the potential that lies locked in millions of years of evolution. Both the shortfin mako and the white shark are classified as Vulnerable on the IUCN Red List, the consequence of overfishing and a bad media rap. One wonders whether we'd look at sharks differently if we knew they are not simply a resource for food, or trophies, or loathsome monsters to be feared, but species that have survived millions of years of change on this planet and whose genes may guard ancient knowledge that we crave in order to solve many of our own very human conundrums. The key to deciphering that potential, this study hints, lies in the patient science that peels back layers of the most fundamental functioning of life on this planet: our genes.

For anyone who has battled illness or known the effects of cancer, efficient wound healing and potential resistance to the disease sound tempting beyond measure. Of course, the reality of this kind of research is far more complex and nuanced, but what it does point to is the sheer wealth of information we've yet to tap into. It is one thing to say that we must protect sharks not only for their ecological role, but also for the medical discoveries they may unlock for us. It is perhaps another to say – and with greater accuracy – that we stand to lose a wealth of knowledge we aren't yet aware of or can't even imagine the potential for.

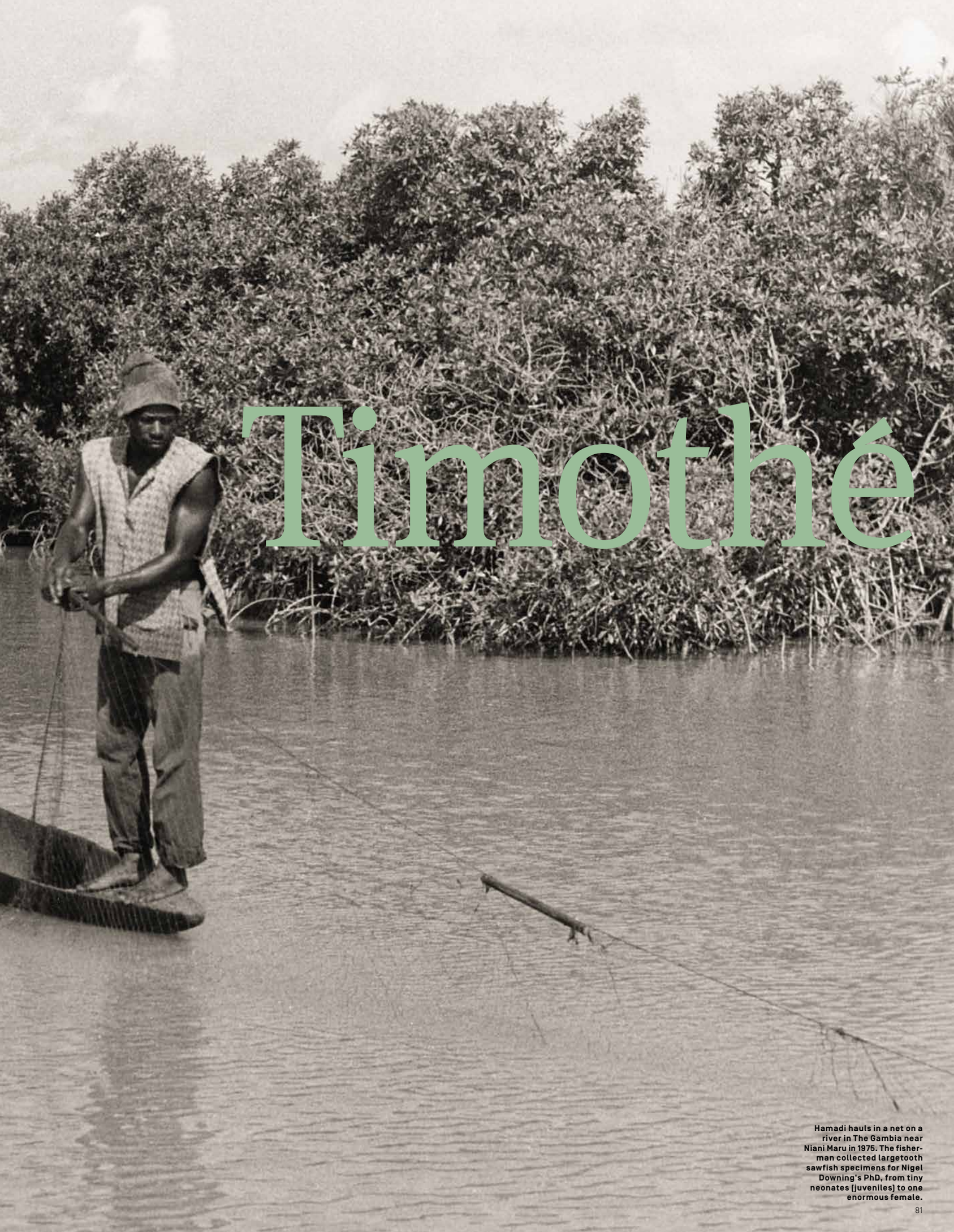
Just as Gregor Mendel worked so meticulously on his common pea plants, with little ability to foretell the enormity of what his contribution to science would be in the future, so much research today builds incrementally on our foundation of knowledge, with no real certainty where the next big breakthrough will appear or what this might mean 100 years hence. It is this very potential, however, that is worth protecting. EO Wilson speaks of the loss of biological 'genetic encyclopaedias' if we don't prioritise biodiversity conservation now. 'We study and save it to our great benefit,' he says. 'We ignore and degrade it to our great peril.'

Finding

Words by Nigel Downing

Forty years ago, Nigel Downing found himself drifting along the waterways of Senegal in search of sawfishes. His mission? To collect live specimens in order to answer a specific question: how do they move from salt water to fresh water and survive? Spurred on by speculation, Nigel had scoured fish markets and interviewed fishermen, but was no closer to catching enough animals for his study. His salvation came in the form of an enigmatic Senegalese fisherman named Timothé; together they would uncover an extraordinary population of sawfishes. When the time comes to return to Senegal four decades later, the question Nigel wants to answer is not only what has happened to West Africa's disappearing sawfishes, but also what has become of his friend who'd first made this research possible.

Photo by Nigel Downing Mukiwa



Timothé

Hamadi hauls in a net on a river in The Gambia near Niani Maru in 1975. The fisherman collected largetooth sawfish specimens for Nigel Downing's PhD, from tiny neonates (juveniles) to one enormous female.

As we walk silently along the sandy path through the shaded Casamance village, I tap the shoulder of Pierre Bassène who leads the way. 'Pierre, don't tell him,' I whisper. 'Let's see what he says!' Already overwhelmed by what he's about to witness, Pierre nods and points ahead.

This story began in the 1970s. As a 23-year-old PhD student I was searching for sawfishes in Senegal's Casamance River. I needed live specimens for my research, to understand how they balance their body's fluid and dissolved salt levels. I had still been an undergraduate at Cambridge University when I had eagerly challenged the claim by the head of the zoology department that sharks, rays and skates were strictly marine and never found in fresh water.

According to the theory at the time, their bodies only functioned in a narrow salinity range; they couldn't move from the salty ocean into the sweetness of fresh water. I, however, had a different idea – and so the topic of my research was born. I would investigate how some sharks, like the bull shark *Carcharhinus leucas*, and sawfishes *Pristis* spp. are able to move from salt water to brackish water and to fresh water. What do their bodies do to help them cope with these changes? How are they adapted so that the concentration of salts and ions in their blood stays balanced, despite changes in their environment?

In the simplest terms, when a fish such as a salmon is in sea water its body cells are more dilute than the surrounding sea. When it moves to fresh water the opposite happens; its body cells are more concentrated. Water then floods in and at the same time the fish loses precious body salts. We understood how salmon adapt while moving from one environment to the other. However, sharks and rays use a different mechanism, and no one knew how they could tolerate fresh water. I wanted to find out – but first I had to find my shark or ray.

Of course, my story actually starts before all of this. I was born in the sticky heat of Durban, a port city on the eastern coast of South Africa. There I grew up hearing tales of bull sharks that were known to swim right up the freshwater rivers that meandered to the sea along the coast. I left South Africa at the age of nine, packed off to boarding school in England, but the country of my birth had struck a chord deep inside me and the stories of its sharks never quite left my mind. So when I found myself at the age of 18 with a six-month gap between finishing school and starting at university, I shot back to South Africa, delighted to

Artwork by Raoul Delafontaine

have an opportunity to both be back in Africa and able to work with sharks.

I was employed at the Oceanographic Research Institute in Durban where, as an eager field biologist with a love of being out in the thick of things, I would go on field excursions in the estuaries of Zululand. We would go netting for samples and I learned even more about the unusual bull shark. I also learned that sawfishes were found swimming into rivers from the sea. My curiosity was piqued: the story of the sharks and rays that could rule the oceans and swim up rivers had caught my imagination and would not leave. It was still there, tugging insistently at the back of my mind, urging me to raise my hand when I found myself, months later, in that Cambridge classroom.

So this was how I eventually found myself in 1974 in the Casamance, a region of Senegal that shares the name of the country's southernmost river, and right on the border with Guinea-Bissau. I was not back in South Africa, but thrilled none the less to be working on the same continent. It was on the basis of speculation by French physiologist Dr Jean Maetz that there may be sawfishes in the region that I had sailed from Marseilles in a boat loaded to the hilt with equipment. Once in Africa, I had to apply myself to hunting for the evidence to support this supposition.

I had been searching for a while and had even found a live smalltooth sawfish *P. pectinata* upstream at Goudomp, ironically (pun intended) in unusually salty waters – an incredible 49.9 parts per thousand (ppt), well above the average 35 ppt of the ocean and the fresh 0.5 ppt typical of rivers. Occasionally I would find a dead specimen at the fish landing site at Ziguinchor, but sawfishes were hardly falling out of the trees. I asked the fishermen and locals on the coast, but no one seemed to know what their numbers were like or exactly where to find them.

On 7 September 1974, my luck changed. I came across a fisherman whom I had not seen before. After I'd introduced myself, he announced *'Je suis Timothé Bassène de Bandial'* – I'm Timothé Bassène of Bandial. And he knew exactly where to find the elusive fish. He explained that he would hunt for sawfishes if ever his village was short of food. It was not a fish of choice, but when you're hungry – needs must. To show me how he did it, he very carefully prepared a small scrap of a net and laid it out on the earth in a specific pattern that was soon to become very familiar to me. We borrowed a net and set out to put his method to the test. On 11 September we had our first

Artwork by Raoul Delafontaine

sawfish thrashing in the net – Timothé was hired!

For the next 15 months, he and I spent hours together on the Casamance, catching live sawfishes, carefully disentangling them from the net, putting them in a transport tank in the boat and transferring them to a special holding pen that we built in the shallows. Over the period we netted a total of 59 specimens. On one memorable day, we caught 11 in the space of four hours!

I looked after Timothé's daily needs when we were together and also paid him per sawfish caught. I calculated that by the time I had what I needed, he would have the wherewithal to buy his own canoe and motor and become an independent fisherman. But when the project ended at the close of 1975, Timothé headed for the bright lights of Dakar. He did not want to continue life as a fisherman. For about five years we stayed in touch by writing letters and then, abruptly, the communication ended.

The years rolled on and the sawfish went into a steady decline, particularly in the West African region. Decades of relentless exploitation of sharks and rays, especially by the Ghanaian fishing fleet based in The Gambia and Senegal, had led to the familiar story of a population crash. Is the sawfish, once common, now regionally extinct? Ask any local fisherman whether they have seen one and the answer is inevitably, 'It is very, very rare' – a euphemism for 'It has ceased to exist.' However, a glimmer of hope remained and I wanted to give it one last go.

So this is how I finally find myself back in the Casamance in October 2017. This time I am accompanied by my son Dominic, who is now older than I was when this adventure originally began. I am here to assess the feasibility of starting a study to find out whether sawfishes still frequent the waters of West Africa. What has happened in all the years since Timothé and I scoured the river for sawfishes?

A major part of finding those rays had come from the help of the local fishermen and their villages; fishermen like Timothé. It might be help that we'll need again if we are to even consider trying to ascertain the status of sawfishes in the Casamance today. The need to enlist the help of the villagers aside, I simply can't stop wondering about Timothé: where he might be and whether he is in fact alive and well.

I tell Dominic that I want to find out what has happened to Timothé, last heard of in Dakar. I feel the best bet is to visit his village, which in 1974 could only be reached by a track. I had never visited it myself, but always remembered that he was Timothé Bassène de Bandial. So we

head for the village, now served by a dirt road. An hour out of Ziguinchor and we're there. We approach a group of elders gathered under a tree. I carry with me a photo of Timothé.

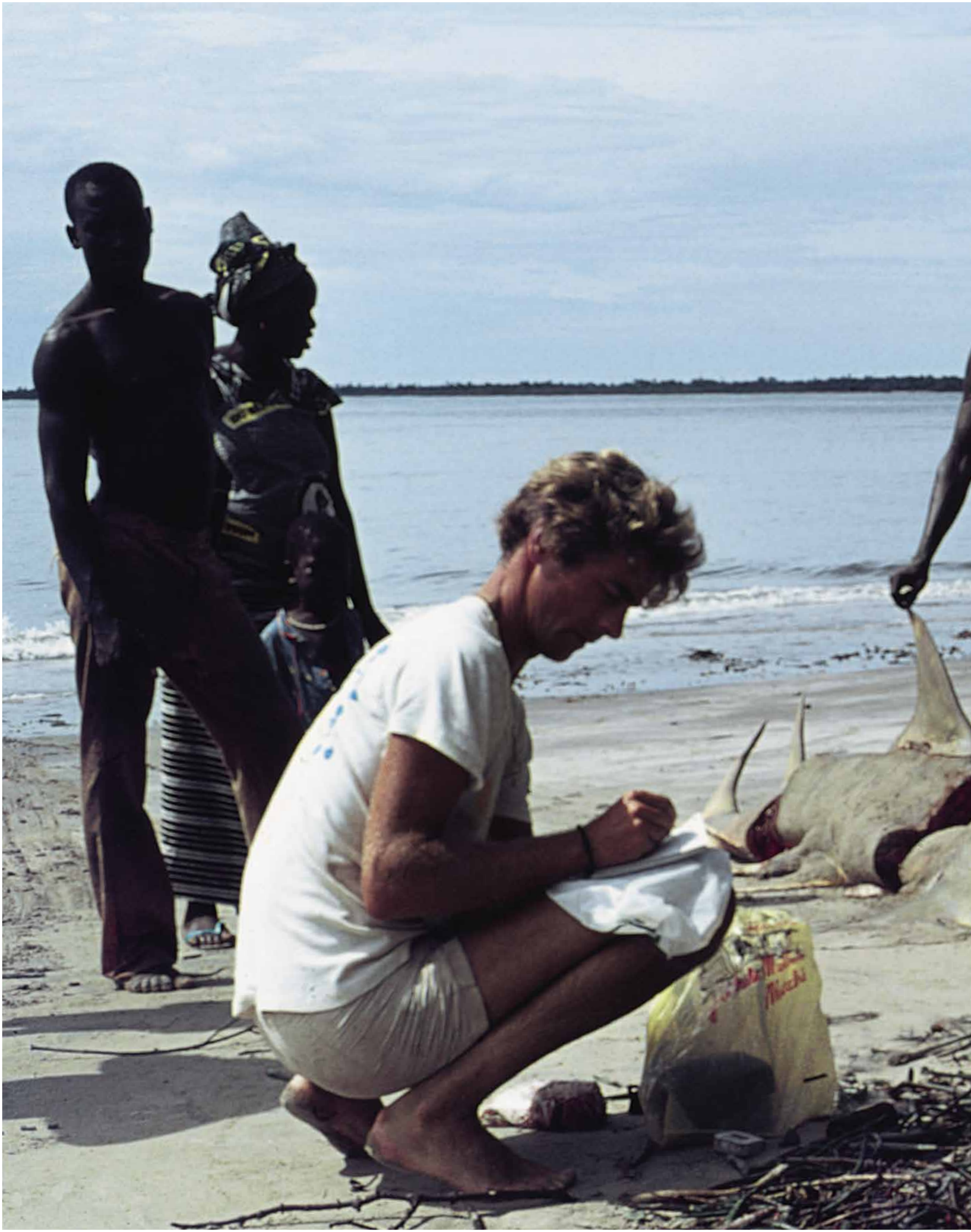
Having made the usual introductions, I tell them my story. I say that a particular fisherman from their village had helped me all those years ago to catch sawfishes. Did they know of Timothé Bassène? Of course, comes the reply. *'C'est le Grand Timothé!'* To be certain, I flourish the photo in front of them. They burst into laughter. 'That's him, all right! Only he looks so young then!' As it turns out, I'm talking to an uncle and two of Timothé's cousins, and furthermore Timothé is no longer in Dakar. He is a little unwell and staying with his cousin Pierre Bassène, the head of another village back the way we have come. They're thrilled at the possibility of a reunion. Out come the mobile phones as they desperately try to contact Pierre. That fails, but soon Dominic and I are heading back in the direction of the other village.

A while later we find Pierre, under the inevitable tree. Again I introduce my son and myself. Again the story is told. Pierre is dumbfounded. 'A *toubab* [white man]!' he exclaims. 'A *toubab* coming back to see his friend after all this time! I cannot believe this. Not even an African would do that. I cannot believe it!'

We make our way through the village and a few minutes later reach our destination. My eyes follow Pierre's pointing hand. Sitting quietly in his chair under a tree is Timothé, older now and absorbed in the book that lies open in his hands.

'Timothé,' I call out as I approach. 'Timothé, it's Nigel! Do you remember me?' His look of incomprehension and total bewilderment will stay with me for some time. Slowly he gets to his feet, searching back into his memory, trying to fit together the voice, the name, the time, the place. I step forward and give him a huge hug.

After four decades I am reunited with Timothé Bassène de Bandial, my Senegalese sawfish hunter.



Nigel reconstructs a freshly caught and chopped male largetooth sawfish at the mouth of the Casamance River, 11 October 1975. The sawfish measured 4.45 metres (14.5 feet), and was the only largetooth sawfish *Pristis pristis* ever caught near the Casamance during the 1974/1975 study. All the Casamance sawfish were smalltooth sawfish *P. pectinata*.

Inset photo: Timothé on the Casamance, 1974 or 1975.

Photos by Nigel Downing Mukiwa

Nigel buys fish from Hamadi, as the fisherman's young son clings to him, in Niani Maru in 1975. Volunteer Patrice Brémon stands watching the exchange.

Inset photo: Nigel and Timothé reunited in the Casamance, 2017.

Photos by Nigel Downing Mukiwa

immersion, observation and connection: detailing life on earth takes time, but choosing to see nature on its own terms often yields surprising rewards.

How we choose to see the sea has profound consequences for the way we will protect it. While statistics and mathematical models give us vital projections of the state of our oceans, there is a case for knowing the oceans in all the intricacy and familiarity of the natural history tradition. Lauren De Vos talks to conservationists about getting to know the ocean on its own terms.

THE NATURE OF SCIENCE

Words by Lauren De Vos

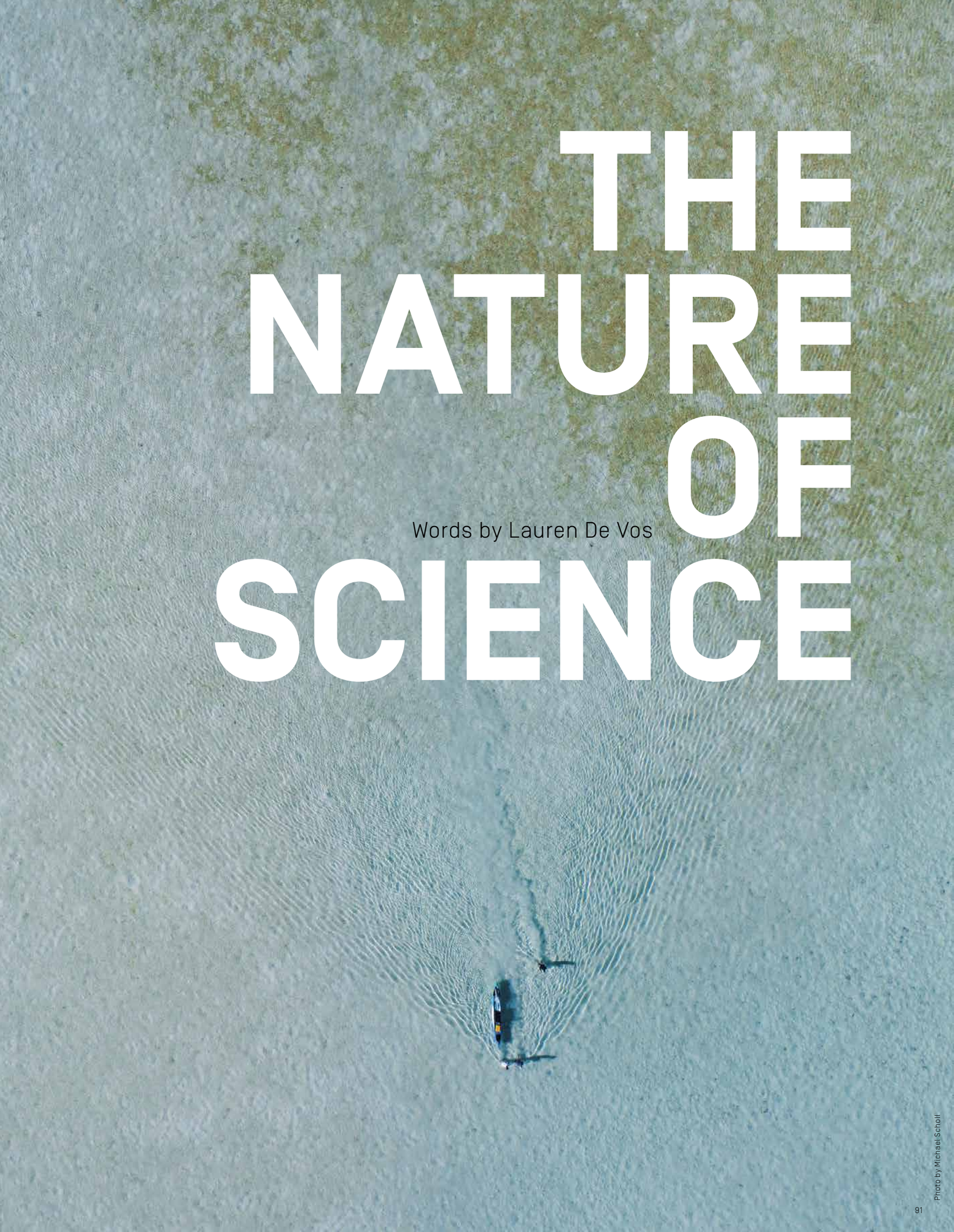


Photo by Michael Scholl

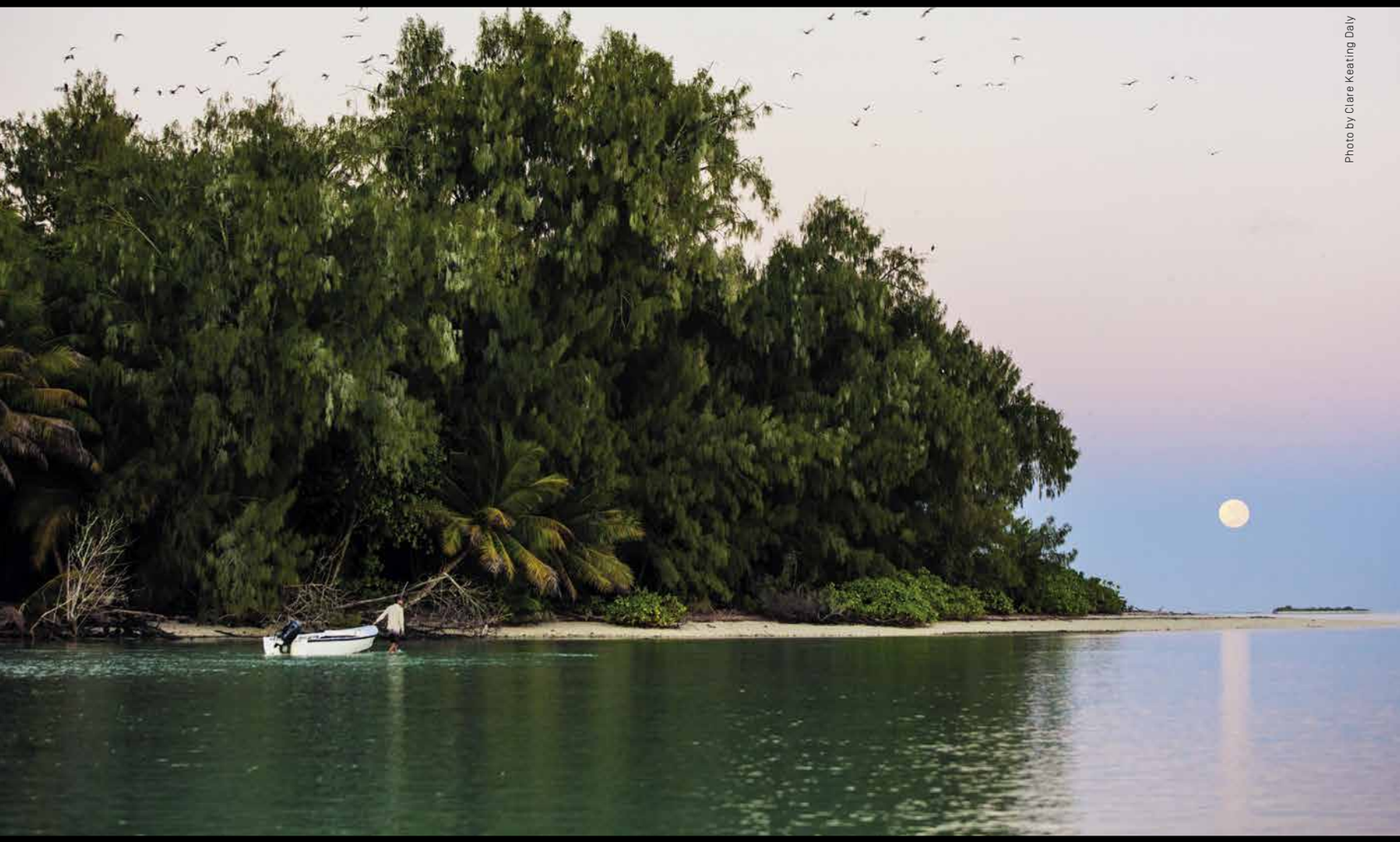


Photo by Clare Keating Daly

Photos by Olivier Born

The days, weeks and months spent on D'Arros Island and St Joseph Atoll in the Seychelles have seen Clare and Ryan Daly tuning into the subtle cues of the ecosystem, with startling results.

On 12 March 1940, the purse-seiner *Western Flyer* sailed for the Gulf of California. With shiny engines and a lick of green paint, the *Flyer* was taking her crew to document marine life in the Sea of Cortez. Together with self-taught biologist Ed Ricketts, the Nobel Prize-winning novelist John Steinbeck was behind the expedition and in *The Log from the Sea of Cortez* he gives an account of their six-week voyage. He details their foray into the natural history of the sea, seeking a connection to the ocean that conjured the curiosity of Darwin and the sense of adventure of Alexander von Humboldt.

The expedition this unlikely duo embarked upon was underpinned by three important pillars: immersion, observation and connection. Steinbeck states quite clearly that he wishes to watch and record, ignoring scientific 'strictures', and in doing so he evokes an image of a natural historian that is familiar, if a little antiquated. A lone figure wading through a stream, noting the birds in the trees that line its banks. Another striding the shorelines, bending to root around in a rock pool or tilting the head skyward to observe a gull wheeling above. Tidy boxes of specimens, labelled in a neat hand, and carefully pinned insect collections. In any image there is a common thread: attention to the details of life on earth. Some time before the filters of statistics and society colour our observations, there is clarity that stems from curiosity. Conservation biologist Thomas Fleischner writes of the value in this: 'Natural history helps us see the world, and thus ourselves, more accurately. Moreover, it encourages and inspires better stewardship of the Earth.'

'I see it very much as in the Aristotelian approach to science. It's a case of "look at the evidence and take it from there", rather than conjuring up wild ideas and trying to impose them on what you see,' explains Colin Attwood, an associate professor of marine biology at the University of Cape Town. The definition of natural history research is broad, he says. Simply put, it's the study of animals and plants in their environment, with the emphasis on observation rather than testing hypotheses. 'It's much wider than just taxonomy. It really is about the life of the animals and the plants. It's providing the details of their existence.'

It's in those details that a mind like Colin's revels. His office shelves are filled with well-thumbed books with titles like *Sharks of the World*, while a skyline of student reports rises from his desk like a haphazardly built paper city. The unmistakable scent of ethanol seeps from countless jars preserving everything from the ear bones of fish to the ghostly remains of gobies and spiny dogfish.

There is, however, a problem. There's a good chance that our idea of the biologist as someone immersed for years in the wilderness deciphering an ecological puzzle will be replaced by the image of a deskbound scientist. Reed Noss sounded the alarm in 'The naturalists are dying off', his 1996 editorial for *Conservation Biology*. He was concerned that natural history had been sidelined. 'Scientific abstractions and fancy technologies are no substitutes for the wisdom that springs from knowing the world and its creatures in intimate, loving detail,' laments Noss. His views are echoed across editorials and discussion pieces in the scientific literature that detail the loss of funding – and favour – for natural history, where university field trips are increasingly scant and a natural history focus is considered 'a relict discipline, a holdover from the era of Victorian cabinets and private butterfly collections'.

'People just don't have time to do what Jane Goodall did,' muses Colin. 'As much as I'd like to sit on the ocean every day, I wouldn't be able to pay my way. Of course, there are people who do that, but they tend to be fishermen or others who have a job out there.' As Noss notes, the reality of current funding models, universities and the hypothesis-driven approach means that scientists find themselves less often in the field and more often at a desk, teaching in classrooms and attending to institutional and funding administration.

Another shift that has minimised natural history lies in the abashed reticence modern scientists have when they call

themselves ecologists or biologists, but rarely natural historians. Charles Darwin, Alfred Russel Wallace and Alexander von Humboldt had no problem calling themselves natural historians; how did it become so unfashionable?

'Part of the problem started when statisticians told us [biologists] that our raw observations were unreliable,' observes Colin. 'Though we saw it in front of our eyes, it didn't paint the general picture because there was some bias in our observational structure. And therein crept the need for rigorous statistical treatment of absolutely everything that we observe and measure. Now we find that students spend more time trying to get to grips with the statistical treatments than with the observations themselves. They're told that before they can trust their observations, they've got to learn all this other stuff. So it has downplayed the prevalence of the actual natural history activity itself. I'm not saying that the move to the quantitative sciences was misplaced. It is absolutely necessary, but it should never have been at the expense of natural history.'

Much of natural history has to do with how we choose to see nature. 'Seeing versus looking at,' notes Clare Daly, the programme director of the D'Arros Research Centre in the Seychelles. 'One of the things that has been so interesting about living on D'Arros full-time has been the chance to see the slight-

In trying to understand the species she studies, Félicie Dhellemmes has become a firm advocate for the conservation of sharks.

Photo by Sirachai Arunrugstichai

est fluctuation in daily happenings, having the chance to really immerse ourselves. That means that we find things: the first national record of a seabird, potential new species of fish, the first regional record of a parasitic leech and even, can you imagine, a blue whale!' Clare lives on the island with her husband, research director Dr Ryan Daly. 'This is just from being here, present, and opening our eyes. If we had come as researchers focused on a specific project, we might have missed these things.'

Colin echoes her point. 'Hypothesis testing has made scientists focus on an idea they have and then go out and test it in a very narrow way. All kinds of other information enter that data-collection process, but it is not useful for that investigation. So people have an idea of what they're looking for, but if they went in there with a blank cheque, they might absorb a lot of other information.'

'Knowing a place well enough to know what's out of place, and having the time to look at, and within, the ocean every single day, makes a difference,' maintains Clare. Her and Ryan's experience of this on D'Arros has led to some startling new discoveries. 'Suddenly we stumble upon a fish we can't identify. Then, oh my gosh, we find out maybe it's even a species new to science.' She understands that sometimes there is a sense of urgency that fuels hypothesis-driven research and that in today's conservation climate, where a strong basis of scientific evidence is critical to underpin management decisions, such research is without doubt a necessity. It is not, however, the only way to make leaps in our knowledge. 'We would have never imagined discovering new fish species just by being more observant. You think you'd have to go on an expedition to do that, but now we're collecting specimens and speaking with taxonomists. It's pretty exciting.'

Clare is animated about the full spectrum of information available when not testing precast ideas. 'I believe that the only way you can do this is through immersion in the ecosystem,' she says.

Natural historians have been synonymous with travel and long periods in wilderness. Biologist George Schaller titled one of his memoirs *A Naturalist and Other Beasts: Tales from a Life in the Field*. How different his contribution to our understanding of lions, gorillas and giant pandas might have been if his biography had been called *A Life at my Desktop*! With time, funding and truly wild places at a premium nowadays, the 21st-century equivalent of experiences like those of Schaller, Goodall, Darwin and Von Humboldt might lie in the biological field station. Long-term monitoring sites like D'Arros Research Centre keep a steady stream of natural

There is delight in the details, and in the diversity, that observing nature brings to the fore. Clare Daly's passion for ornithology has blossomed on D'Arros Island, where the astounding birdlife is but one piece in the complex ecological puzzle that is the Indian Ocean archipelago.

Photo by Olivier Born

history research going. This idea of accumulated knowledge is a topic of importance for Félicie Dhellemmes, a PhD student based at the Bimini Biological Field Station in The Bahamas. Known affectionately to resident students past and present as the Shark Lab, the field station is one of the longest-running shark research stations in the world.

Félicie investigates personality in juvenile lemon sharks and aims to understand what the ecological consequences of personality might be. 'My entire project relies on the strong foundations provided by the long-term work of the Bimini Biological Field Station,' she explains. 'Working on shark personality is like working with icing: you need a cake to spread it on. My research is one of the last elements needed for a clear picture and it can usually only be done when knowledge about the behaviour of the study species is already available. I rely heavily on this accumulation of knowledge.' The baseline established by decades of work at Bimini Biological Field Station – that steady, cumulative stream of information that is only possible when an area and its inhabitants are observed for long periods of time – provides the perfect springboard for Félicie to launch into more daring questions.

'I believe that I get a better grip on my project and am able to understand things that are still hidden by statistics at that point,' says Félicie of spending immersive periods of time in the field. The haze of statistics provides a necessary quantitative basis for what biologists observe. Less often emphasised is what Félicie speaks of: having spent enough time observing her study site and subjects to have a gut feel that enables her to interpret the numerical results run through the gamut of statistical wizardry. This gives Félicie the ability to trust her dataset (Do the numbers actually reflect what I've observed? Does this make both mathematical and ecological sense?). It also gives a little wiggle room to detect other happenings in the environment that may be outside the scope of her current study, but could prove useful in ways she's not yet figured out.

Reed Noss argues that the value of natural history lies not only in science, but in the conservation ethos it engenders. 'Empathy for living things comes from many years of observing them in their natural environments, which is why field biologists have always been among the most adamant defenders of wild Nature,' he writes in the same editorial. Félicie agrees that her time at the Shark Lab has changed the way she sees sharks: 'I advocate for them at family dinners, in the bus, at the bar... I even recently went to talk to 250 kids at a school!' She also points out that many scientists do good work in spite

of obstacles to immersive field time. 'I'm very lucky to have intensive field work and great contact with sharks,' she says. 'Many scientists don't have this opportunity, but their science is just as important. I'm always impressed by scientists who rarely get to meet their study subject and are still such important actors in the conservation of their species.'

Marine researcher Peter Musembi knows only too well that time spent immersed in an ecosystem can result in deep knowledge about the ocean. Based in Watamu, Kenya, Peter works with faith-based organisation A Rocha to restore degraded natural areas. Rather than being aimed solely at publication in scientific journals, Peter's research is fed back to local community members. 'About 70% of the work we do is with people,' he notes. 'Most of these people are highly dependent on natural resources, so we cannot separate them from their environment.' It is perhaps not the same kind of connection that biologists have with the ecosystem, but it is a connection no less intimate. In an age when biologists are more often in front of their computers than at the helm of a research boat, there is a case for addressing how to unlock natural history knowledge embedded in those who spend their lives connected to the ocean.

Peter's work has given him unique insights into how people in Watamu interpret the ocean. 'Our connection to the ocean is through biology: measuring, counting,' he offers. 'Some of these locals have never gone to school, but they can describe the tides in such a way that's comparable to a tide table. I don't think biologists fully understand how they can do this, but they've grown up observing the ocean.'

For Peter, acknowledging the depth of knowledge that comes from a lifetime of observation is as much about respecting different ways of seeing the sea as it is about its value for biologists. 'This is information that, for a scientist, is sometimes very easy to push away. But I think it's very useful.' Peter and his ilk are biologists of a different kind; not, perhaps, spending time in the field as natural historians themselves, but realising that all of us are, innately, natural historians to begin with and may have insights to offer.

In Peter's experience, combining local knowledge with modern science is powerful. For the people of Watamu, *zambarani* is the tiger shark and *papashilingi* is the whale shark, whereas most other sharks are lumped together as a group. 'I think that's because they have a special connection to the species they've named, either through cultural or spiritual affiliation or because they're target species,' he explains. He conducts his own biodiversity surveys in the region and shares his findings on the full spectrum of species with the community. 'I think that there should be a connection between the two,' he says of these disparate knowledge reserves. 'If we observe coral bleaching, the local people have seen that too and know that when the water is warm, the coral bleaches and becomes white. What we can do is add to that, explaining what it is that happens, and that feeds into and develops their knowledge base. It's important that the two knowledge systems feed into one another and maintain some holistic view of the general field.'

Clare's quiet personal philosophy ties all these insights together to make the simplest, but perhaps strongest case for a return to natural history. 'As children we were taught that it wasn't just a tree; it was always an oak, or an elm, or a maple tree. I think that has stuck with me. I don't know how to get more people to be like that, but I'd imagine that this way of seeing nature, rather than glazing over and saying "I know this place", could be important.' Her point speaks to the spirit of Steinbeck and Rickett's expedition nearly eight decades ago. Giving something a name is to acknowledge it. It establishes a vital connection. The more disconnected from nature we become, the greater the need to cultivate an ability to observe deeply and therefore acknowledge other species. 'I remember hearing the Zulu greeting *Sawubona* for the first time when I moved to South Africa. It means "I see you",' adds Clare. 'I think this applies to the natural world: I see you for what you are, not what I think you are. I think it's so much more enriching to take a perspective of discovery rather than familiarity.'

On 13 April 1940, the *Western Flyer* and her motley crew charted a new course to the north. The little purse-seiner pitched and rolled homeward as the sky darkened and Steinbeck reflected on truths he had gleaned from the expedition. New insights into other species' lives helped Steinbeck and Ricketts find something that human beings battle with most today: our place in the ecosystem alongside Nature and its inhabitants. When we choose to look carefully enough, we can relate our life to other life on this planet and find our place within its complex fabric. Moulded by his foray into natural history, Steinbeck's philosophical insights cut gently to the core of a profound truth and prompt us to think about the route that we shape for a future for all life on earth: we are nothing more extraordinary than the starfish, or the urchin, or the humpback whale, and yet we are just as extraordinary as these other lives.

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With wilderness at a premium today, natural history finds its place in the museums and university cabinets around the world. In a strange juxtaposition, the Hayden Planetarium and American Museum of Natural History forms a kind of time capsule to house the intricacies of hundreds of years spent deciphering life on planet earth, set against the backdrop of a neon New York skyline.

Photo by George Steinmetz | National Geographic Creative

In conversation with Andrew Chin

Dr Andrew Chin is a scientific adviser to the Save Our Seas Foundation and a coastal fisheries scientist based in Queensland, Australia. An AIMS@JCU Postdoctoral Research Fellow, he is one of the founders of the Ocean Chondrichthyan Society. Andrew is particularly interested in coastal fisheries: the ecology and biology of their target and by-catch species, how the fisheries and communities who rely on them 'work', and how the fisheries can be sustainable into the future. Lauren De Vos spoke to him about his research interests and his insights into conservation, its present and its future.

Where did your particular interest in sharks and rays begin?

Frankly, it's probably Jacques Cousteau's fault! I grew up in Singapore, which is a metropolitan city, but I read dive magazines and watched all the marine documentaries I could find. Sharks have always just fascinated me. At that stage, they were a hidden issue; there was no major conservation interest in them in the 1980s. I remember visiting fish markets as a child in Singapore and seeing lots of stingrays and thinking, 'I wonder how they're faring?' That question has always been in the back of my mind. When I came to Australia, I wanted to work on the Great Barrier Reef. At the Great Barrier Reef Marine Park Authority I was involved in everything from impact assessments to coral surveys and citizen science projects, but there wasn't much that was specific to sharks being done. Still, I worked hard at the time to raise the issue of sharks within the agency. When the opportunity eventually came up to focus on sharks at James Cook University, I took it.

What is your current research focus?

I'm lucky enough to be working on a project with Dr Michelle Heupel where we are satellite tagging hammerhead sharks to look at population connectivity across northern Australia. It's the project I wanted to do for my PhD and it didn't work out then, but here I am almost a decade later – so it's fantastic! I also launched a new programme last year called Shark Search Indo-Pacific. This is something that's been slowly building since 2012 and it's now at the stage where it's gathering momentum. We want to build a species checklist and status overview of sharks and rays for every country and territory in the Pacific by 2022. The reason this started was that a colleague from the Solomon Islands had noted that the government wanted a plan of action but had no data. So Shark Search uses this logic: first you assess the biodiversity, then you analyse the pressures and threats, and then you do a preliminary desktop review that can be used as a springboard to open conversations with stakeholders and government. It's that first health check: what do we know, what don't we know, and where do we want to go?

This kind of applied science seems to balance ecology with a lot of communication with people. Where did this start for you?

At the end of the day, conservation and management come down to people and that means you need to engage and communicate with communities and stakeholders. That also means listening to them; communication needs to go both ways. I started learning about science communication in my first job. I was a 'biologist' at a tourism resort in the southern Great Barrier Reef and my task was to interpret the quite complex reef ecology around Heron Island into stories that helped guests understand what they were seeing. That was a really interesting and enjoyable experience because you had to understand the science and break it down into simple terms, and then engage people in the story so that they

could appreciate what was going on. Later on at the Marine Park Authority, I was able to bring science and scientists into tourism and get the tourism industry involved in collecting meaningful data. That's one of the key things with citizen science: people have to know that what they're doing is useful. I've always been interested in doing science that has a tangible output or use for people. I think that comes in part from the experience at the Marine Park Authority that helped to instil those values in me, but it's what I really enjoy.

Working in conjunction with local communities is receiving increasing attention because it's being recognised as important. What has been your experience?

I work with some indigenous communities in Cape York, but through the lens of a fisheries scientist. I'm not a social scientist and I don't have the expertise in that area but, through my lens, I have seen that indigenous groups have incredible knowledge about the resources of their country. They have knowledge that scientists aren't aware of yet. They also have a real sense of connection and stewardship, and their way of understanding their 'place' within their land or sea country is completely different from how we 'Westerners' understand it. In some remote areas, chances are they're the best option for doing on-the-ground conservation. In places in the Pacific, the centralised fisheries management agencies don't have the resources to enforce fisheries regulations across the country; in many places the only chance for conservation comes from local people or indigenous communities.

Communication and trust seem key. How has your background in citizen science informed what you do today?

If we're doing conservation science, local people need to be involved and genuinely engaged. Not superficially, but genuinely engaged in research and conservation projects. That's if we're to have any hope, I believe, of their success. This said, I think that as researchers we're naturally interested in different things and will have skills in different areas, and we should be clear about who on the project team has the skills and capacity to engage with stakeholders and communities. These sorts of community projects need a genuine willingness on the part of the researcher to engage on a deep level, and this can take a long time. It took years to build a relationship with the Yuku Baja Muliku community before we got a project off the ground in Cape York. I think that if you're unable to really work at that level with local collaborators, you need to think very carefully whether that particular project is viable. There are gaps: there aren't a lot of people working deeply with communities, and there are communities who are quite reluctant to cooperate with researchers because they've had bad experiences in the past. One thing I've been taught by social scientists is that indigenous communities have their own knowledge system and Western science is seen as a parallel system. It's not about one subsuming the other, but rather about bringing both knowledge systems together on an equal footing to build a richer understanding of the natural world. That means having respect for local and traditional knowledge, and humility in your role as a scientist working in their country.

What do you consider important for marine science?

As scientists, we sometimes get caught up in what's new. I think we need to remember that simply because something isn't novel, it doesn't mean it's not important. Look at some foundational research, for example. A lot of the applied research that I do isn't considered ecologically 'sexy'; it's not the kind of research that's going to be published in *Science*. But it is what I call 'bread 'n butter' research, the kind that managers need: which species are there, where they occur, what the pressures are that they face. Take taxonomy, for instance. Without it, we're all lost. We're still grappling with which species are out there; our taxonomic capacity isn't nearly what it should be. The same applies for physiology, anatomy, microbiology. So I think we sometimes just need to pause to remember that foundational science is just as crucial as the more novel, visually interesting work.

From your point of interest and expertise, what comes to mind as some of the challenges to coastal fisheries in the future?

I think that as our reach as scientists grows and remote locations become more accessible, we're going to be finding new species and rediscovering species. I also think we're going to be finding that the patterns and trends that we thought were quite uniform are more complex and variable in different places. We'll see complexity among populations and even among individuals. Of course, I think technology will enable us to start doing some analyses with a big scope. For instance, rugged, high-quality cameras are now affordable enough that every second marine biologist has a BRUVS! Technology also allows us to store and share that imagery and come up with big projects like the Global Finprint. More mega-scale datasets and some really interesting analysis of diversity and distribution patterns and threats are now within reach.

However, we still face massive challenges in coastal fisheries. Population pressure, poverty, governance problems and climate change all come to mind, especially for some of our poorest and most vulnerable communities. Poverty traps are real, and as a fishery scientist I hope to work more and more in interdisciplinary teams that look at fisheries issues within the larger social-cultural-ecological-political context.

A colleague of mine, Dr Robert Styles, is an organisational psychologist who unpacks complex situations for fisheries management. He's introduced to me concepts such as fore-sighting and poly-centric governance. While we can bring the technological solutions, Robert can help us unpack the social context and find the space to apply the fisheries science we do. I believe that the only way we're going to deal with these wicked challenges is through interdisciplinary teams that tackle all sides of a problem. I'm also a big fan of the idea of 'fail early, fail often, fail forward'. These are complex issues and things will go wrong. But we have to have the courage to try and test solutions, otherwise we're not really doing applied science.

The Save Our Seas Foundation (SOSF) is proud to support research and conservation in different ways. While it funds many individual projects that start and finish over the years, several key relationships with partner organisations have been fostered to continue into the future. Research and education are the focus of the three centres that the SOSF manages directly. Cutting-edge science and long-term scientific observation are the mainstays of the Shark Research Center in the USA and the D'Arros Research Centre in the Seychelles. Nurturing the marine conservationists of the future falls to the Shark Education Centre in South Africa. The success of these centres underpins the SOSF's work on the ground, extending its conservation footprint and cultivating a wider community of ocean stewards.

Photo by

Photo by Jean-Michel Mille (Biosphoto

INSIDE STORIES

The SOSF also partners with a collection of five independent NGOs that share a common goal: tackling head-on the challenges of global ocean conservation. The Bimini Biological Field Station (also known as the Shark Lab), Cetacea Lab (North Coast Cetacean Society), the Manta Trust and the Shark Spotters NGOs, as well as the Acoustic Tracking Array Platform (ATAP), each bring unique insights that weave together different realms of expertise. All are carrying out long-term research and conservation work. In terms of funding and communication, the SOSF partners closely with this community. Read on to explore and be inspired by the phenomenal work carried out by these centres and partners.

Consider the wrasse

Words by Clare Keating Daly

It's not often that a chance to wrangle a wrasse comes up. Nor is it a common perception that fishes – outside the realms of animated film – are endowed with charisma. Yet when the team at the SOSF-D'Arros Research Centre did find themselves tagging humphead wrasse, they came to the conclusion that this was very much more than merely an extremely large fish.

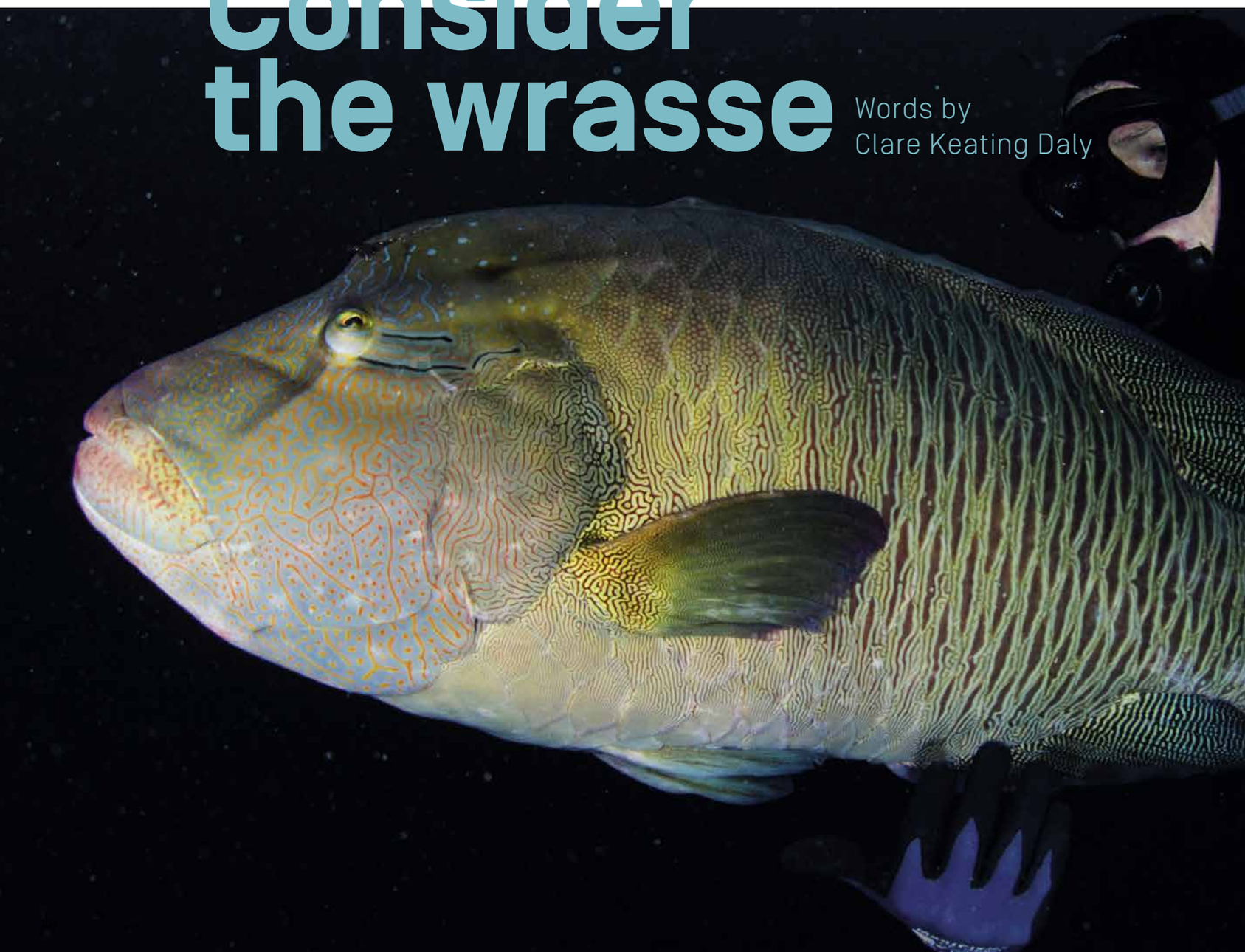
The facial expression of the humphead wrasse can fairly be described as one of concern. First there is its furrowed brow, made by the fish's namesake forehead hump; then its mouth, downturned and slightly agape. But look more closely at those chameleon-like eyes and you'll find an essence of curiosity and astuteness that pushes this reef fish's charisma arguably past that of Nemo.

Listed by the IUCN as an Endangered and conservation-dependent species, the humphead wrasse has reason to be concerned. The species is naturally uncommon and faces a significant and increasing threat from the food trade in live reef fish, where it is one of the species with the highest market value. At the SOSF-D'Arros Research Centre in the Seychelles we were also concerned. And curious.

During annual coral reef and fish surveys, we had observed humphead wrasse but had very little understanding of the species' population size and structure. Was it common or were we just seeing the same five individuals? A 2014 study near Farquhar Atoll, in the southernmost island group of the Seychelles, found a remarkable abundance of humphead wrasse. The numbers suggested that Seychelles waters may host the highest known densities of the species in the world. Were these healthy populations limited to the country's most remote reaches or would we find a similar number around our little island as well? And if we did, which marine habitats provide refuge for them? Making the most of the acoustic receiver network around D'Arros Island and St Joseph Atoll, we set out to answer these questions by embarking on a study to acoustically tag humphead wrasse.

A meaningful study would need a decent sample size to answer our questions accurately, so we set the tagging target at 20 wrasse. Even then I worried that this was too ambitious a goal; the humphead wrasse we'd seen were shy and we still didn't know how many there were. The team at the SOSF-DRC has worked on tagging sharks, rays and other fish for years, but humphead wrasse would be a different kettle. Expert help was the only way forward.

We first reached out to researcher and friend Andrew Gray from the National Oceanic and Atmospheric Administration (NOAA), who had been involved in a study of humphead wrasse at Palmyra Atoll in the Pacific. He was encouraging, but warned us about the challenges. 'First off, don't try to catch any until you are fully



prepared,' he wrote. 'They are smart and wary and you only have one chance per wrasse. If you try and fail, you're never going to get that wrasse again – it will just swim off when it sees you.'

One chance per wrasse. For a viable study, we needed to tag a minimum of 10 wrasse. If there really were only five of them, the project was doomed. If we discovered large numbers but bungled attempts to catch more than six, we'd fail.

With little room for mistakes, we knew we needed more help. The study would have to be led by the best. We'd have to find the person with the most experience of tagging humphead wrasse in the world, preferably in an environment similar to that of D'Arros Island and St Joseph Atoll. Someone with a passion for these fish, the kind of person who would go so far as to shave his hair into an outline of a humphead wrasse. That could only be Dr Kevin Weng, lead researcher for a landmark study of the species at Palmyra Atoll. Lucky for the D'Arros Research Centre, he accepted the position of project leader and fine-tuned the research proposal into an SOSF-funded project. When asked to assemble his team, he called on Andrew Gray as chief wrasse wrangler.

Our expert Kevin and wrangler Andrew joined us in the Seychelles in October 2017. With the help of SOSF-DRC research assistant Luke Gordon, we'd done our best to prepare for these wary fishes. But challenges arose from the start: schedule changes crunched our window for field work from one month to just under three weeks and Andrew's luggage had been lost somewhere along his four connecting flights. The pressure was on: 20 tags in 20 days. Actually, less than 20 days – before deploying any tags we had to complete surveys to establish the population and develop a reliable catch method.

INSIDE STORIES

Photo by Ryan Daly

Early surveys went well. It turned out we hadn't been seeing the same five fishes on every dive. On one survey we saw a group of 11 individuals, upending the premise that humphead wrasse never congregate in groups of more than seven. Data from MantaCam, a remote underwater time-lapse system installed on a local manta cleaning station, revealed five humphead wrasse in one frame. The fishes were there, but could we catch them?

Humphead wrasse are often caught on hook and line in catch-and-release fisheries. But after half a day of watching clever wrasse sceptically eye our hook and line while tiny reef fishes devoured our bait, we switched gears. To catch these fish, Kevin and Andrew trained us in what can best be described as a 'diver-capture' method. Making the most of each day, we started at dawn, searching caves and crevices for the wrasse. Given dive depths of less than 10 metres (33 feet) and the considerable time necessary to track down an individual, dives often lasted more than two hours; chief wrangler Andrew's dive watch frequently ticked past the 240-minute mark. But eventually a day's effort would yield a humphead wrasse to tag and soon we knew we'd get our minimum of 10 tags out.

As relief took over from my worry, other emotions soon emerged. My job and field-work experience include working up sharks from the size of my forearm to nearly the length of the boat, rays with whiptails and spines, and seabirds with beaks adapted to skewer fish. Which is to say, field work usually involves high levels of stress and vigilance to ensure the welfare of the animal and the safety of the people involved. But the humphead wrasse was different. Of course, there was the heightened pressure of maintaining the well-being of an Endangered species, and the strength of a humphead wrasse is formidable, but the feeling was different when we worked with these charismatic fishes. Without anthropomorphising too much, I felt a level of intimacy and closeness with each brilliant wrasse we tagged. Maybe this feeling of tenderness was due to their lack of sharp teeth, sandpapery skin, barbed tail or stabbing beak. But I couldn't help thinking that there was something beyond these emotions. As Andrew had said, humphead wrasse are smart, observant and curious.

And they're hip. Humphead wrasse have facial tattoos, the technical term for the fingerprint-like markings on the cheeks of each fish. Each work-up included photographing these tattoos to provide a record of the individual and thus the chance to identify it later. When the tagging, measuring and photographing were done, we slid the fish back to waiting divers, who in turn released each wrasse into the cave or crevice where it had been found.

In the end, we released 20 healthy adult humphead wrasse equipped with acoustic tags. With these fish, our study is the largest telemetry survey of this Endangered species in the world. Moreover, the largest wrasse – 'Gerald' measuring 133 centimetres (four feet four inches) total length – broke the record for the world's largest tagged humphead wrasse. The smallest, but not least, was 'Wrassesaurus', which came in at less than half the size of Gerald – a mere 52 centimetres (20 inches).

In any tagging study, a scientist effectively asks an animal to confide its secrets, to unveil its mysteries. In this one, we've perhaps uncovered a refuge for the humphead wrasse and we've asked this enigmatic fish to show us what we need to protect it and to help us understand its place. By the time you read this article, we will have begun the process of piecing together the first dataset from the study. Humphead wrasse will still look concerned, but these data may give us a chance to minimise the threats facing them. Perhaps they, like me, are curious about what scientists, conservationists and policy makers are capable of when armed with an animal's inside story.

Actions speak louder than words

The Manta Trust

Words by Isabel Ender

Recent years have seen successes in casting the spotlight on mobulids and a strengthening of will to protect these graceful but endangered marine species. And while huge effort was made to get them included on CITES and CMS listings, that's only half the job done. The real test – to implement the conditions of those listings – is just beginning.

I have always loved the French philosopher Jean-Paul Sartre's quote that 'commitment is an act, not a word'. If there is no follow-up on goals or action plans, if there is no commitment once the dust of excitement has settled, nothing will change. Last month, while I was taking part in a CITES implementation and capacity-building workshop in Sri Lanka, Sartre's quote popped into my mind. An unlikely place for philosophical thought I hear you say, but it was apt for the moment. Here I was in a room full of people truly committed to making a change.

I listened to government representatives speaking out boldly for conservation, showing their commitment to finding solutions that include working together with other nations in the region. I saw colleagues from a range of NGOs and other organisations who for many years have been committed to making a positive change for sharks and rays. And I was aware of my own contribution, of being part of this journey with the Manta Trust to drive forward the effective implementation of legislation over the past four years. I felt very honoured to be part of this initiative of 'words turning into actions'.

In 2013, the giant manta ray *Mobula birostris* and reef manta ray *M. alfredi* were listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II. A few years later, in 2016, all devil ray species *Mobula* spp. were given the same international protection. This means that any international trade in mobulid products may occur only if the take is carefully regulated and monitored and is not detrimental to the species concerned.

All mobulid rays are also listed on the Convention for the Conservation of Migratory Animals (CMS) Appendices I and II. This means that CMS Parties are obliged to protect mobulids within their waters by prohibiting their capture; by conserving and, where appropriate, restoring their habitats; by preventing, removing or mitigating obstacles to their migration; and by controlling other factors that might endanger them. It took hard work to achieve the listing of these species in the first place, but that was only the beginning. It has become obvious that implementing the conditions linked to the listings requires further effort and dedication.

Thankfully, some governments in particular have taken bold steps to support the effective implementation of legislation. In March 2018, Sri Lanka hosted the second regional CITES implementation and capacity-building workshop to help the region's customs, fisheries and environmental officers to enforce international trade regulations on CITES-listed sharks and rays. Representatives from seven South Asian countries attended the workshop, where they were able to share and learn best practices while developing the skills they need to enforce shark and ray trade regulations. Participants were trained to identify shark fins and mobulid gill plates and were provided with resource materials, including quick-reference posters with visual tips for identification, by the Manta Trust, the Blue Resources Trust, the PEW Charitable Trusts and Florida International University's Tropical Conservation Institute.

A day after the regional workshop, a national elasmobranch working group meeting was organised by the Manta Trust and the Sri Lanka-based Blue Resources Trust as part of a domestic workshop. A multidisciplinary group of government representatives, researchers and NGOs active in Sri Lanka gathered to discuss and identify the key challenges to conserving shark and ray species in national waters and to define what action needs to be taken to drive forward the conservation and management of these species domestically. This workshop included an additional training session specifically on the identification of shark and ray species. Led by the Blue Resources Trust and the Pew Charitable Trusts, the session was aimed at representatives of the Ministry of Fisheries and Aquatic Resources Development and the National Aquatic Resources Research and Development Agency.

Indonesia is another role model leading the way for conservation in South-East Asia. Historically a key fishing country for mobulid rays, it now recognises the

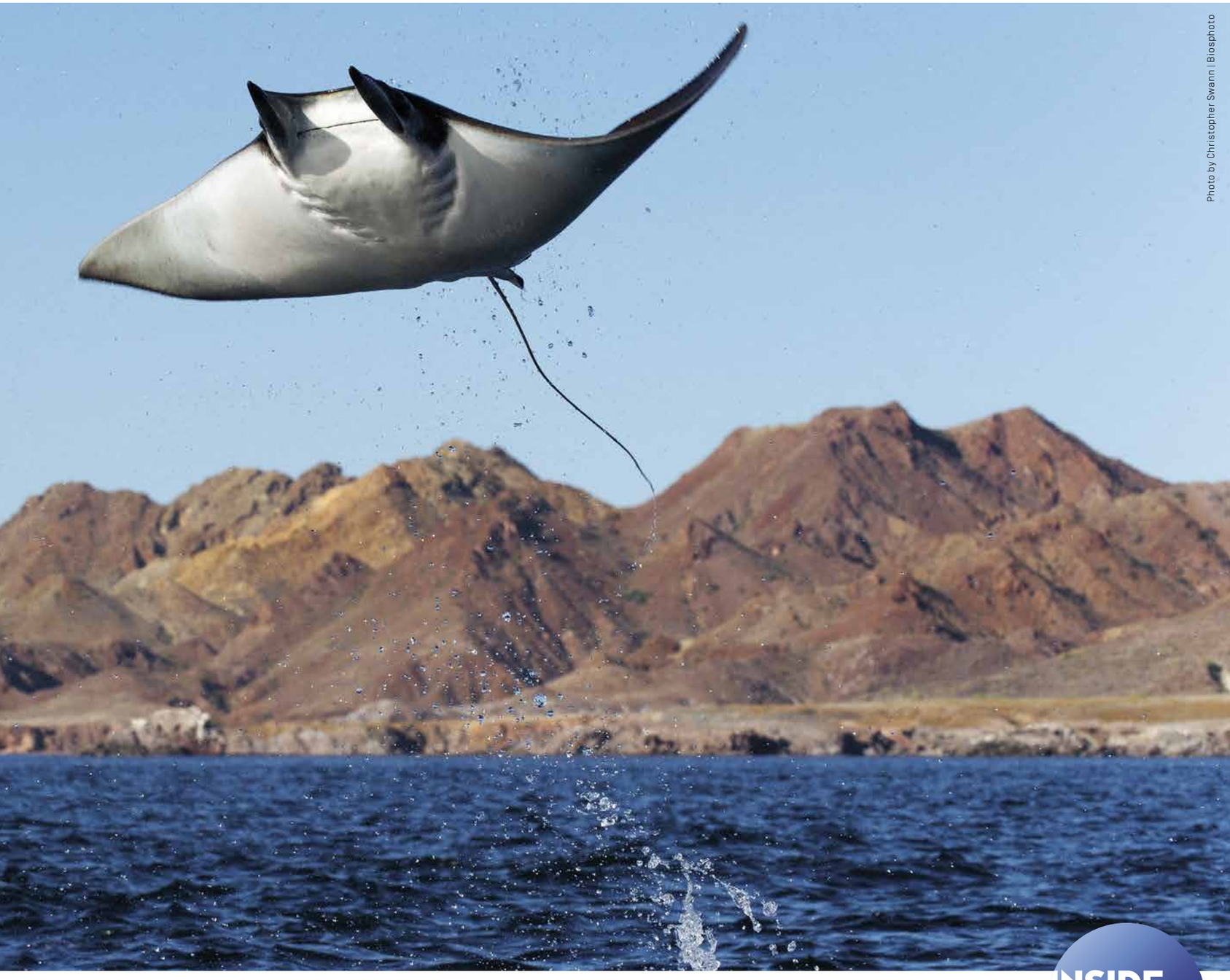


Photo by Christopher Swann | Biosphoto

INSIDE STORIES

incredible value of these species – they're worth more alive than dead, especially in view of the thriving manta-watching tourism industry – and in 2014 the Indonesian government declared manta rays nationally protected. Even before this, in 2012, the Raja Ampat region was declared a shark and ray sanctuary. Moreover, the government has been adamant about enforcing protection for mantas and the CITES-related conditions, and over the past few years its capable customs and trade officials have successfully prevented several illegal deals. These efforts are supported by an array of NGOs and other organisations, as well as some incredibly passionate individuals, all of whom work closely together to drive forward shark and ray conservation.

In March 2018, Conservation International, WWF and the local Misool Foundation, with the support of the Manta Trust, organised a domestic mobulid research and management workshop in Indonesia. Representatives from governments, research organisations and NGOs participated to share their knowledge about mobulid ray habitat and distribution in Indonesian waters. The overarching aim was to support the implementation of objectives set under the National Plan of Action (NPOA) for sharks and the Global Mobulid Conservation Programme. The workshop included a follow-up discussion with the national elasmobranch working group to identify current challenges in managing domestic fisheries and by-catch, discuss future research objectives to drive mobulid conservation forward, and define capacity-building needs that would support conservation efforts. The workshop was followed by a two-day national shark and ray symposium.

The list of countries taking action to support sharks and rays goes on… The Maldives, for example, spearheaded the proposal to add the silky shark to CITES Appendix II in 2016, co-sponsored the proposal of several other shark listings and hosted a number of workshops as well as a regional ministerial symposium on shark and ray conservation in the Indian Ocean. The leadership shown by South Asian and South-East Asian countries in driving the implementation of legislation will have a much-needed positive impact on shark and ray species, whose declining populations have yet to recover. The efforts put in by these countries will hopefully inspire others to step up to their commitments, too, and turn their words into actions.

It won't be an easy road and to drive real change will require long-term effort and dedication. But there is no other way. These incredible species – sharks and rays – need to remain in our ocean for future generations, whether for their tourism value, their ecological role or their intrinsic right to exist in this world. Of course there will be challenges. But there's always a way – if you are committed.

Shark Spotters

Words by Tamlyn Engelbrecht & Sarah Waries

On balance: humans & sharks

For 13 years, 'shark spotters' have been scanning the waters of False Bay, South Africa, to warn water users of the presence of white sharks. The innovative programme has been acclaimed in many quarters, but what has been its effect in real terms?

As the global human population continues to expand, balancing the needs of people with the conservation of threatened wildlife species has become increasingly challenging. One of the most difficult of these balancing acts is that between ocean users and large apex predatory sharks, especially in an area such as Cape Town, where one of the largest aggregations of white sharks in the world lives on the doorstep of a bustling metropolis and world-renowned tourist destination.

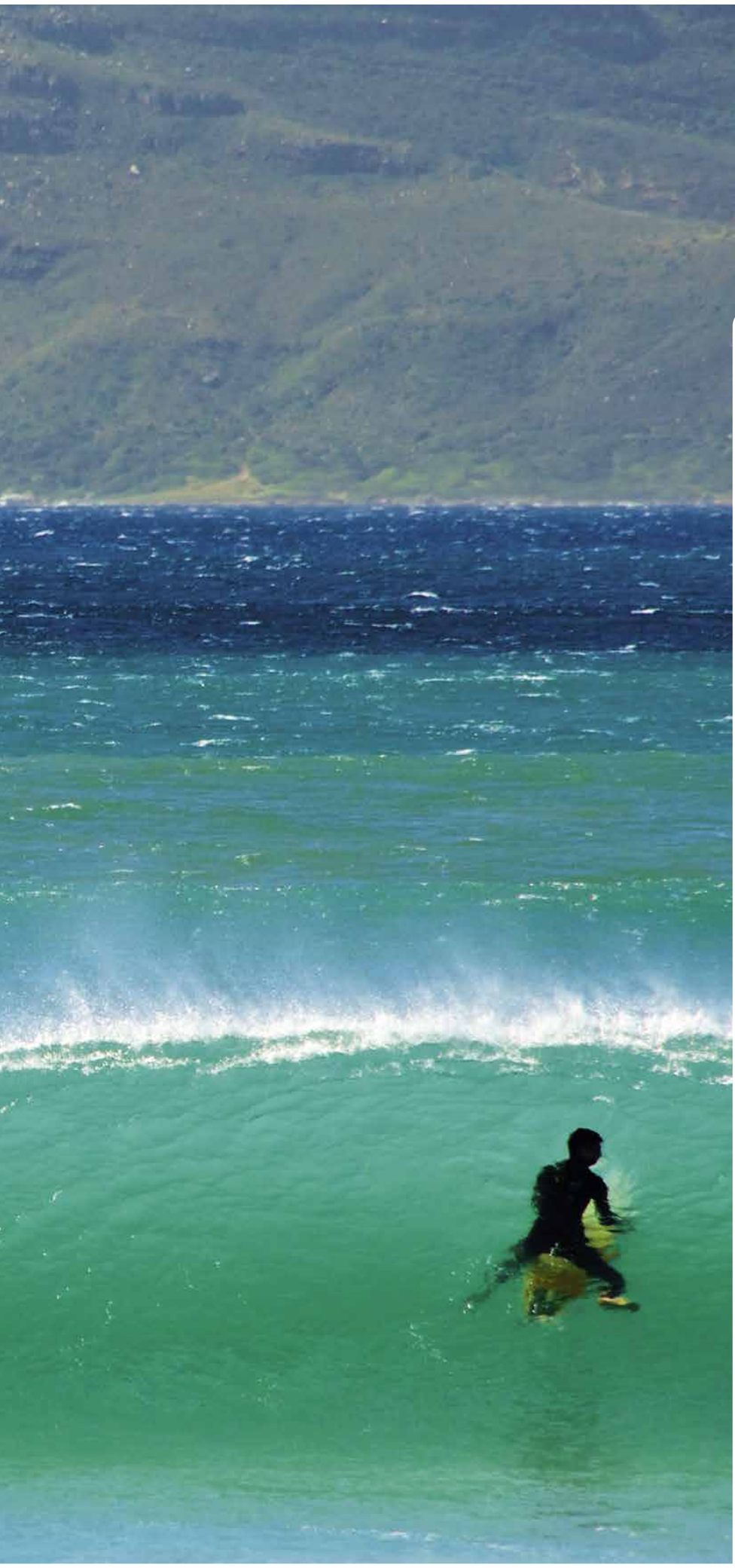
For the past 13 years, the City of Cape Town has adopted a shark safety strategy unlike any other: Shark Spotters, a programme that seeks to maintain a balance between people and sharks in the waters around the Cape. This unique approach to mitigating shark risk currently operates at eight of the most popular beaches along False Bay and the Cape Peninsula. Trained spotters act as sentinels on the mountainside above these beaches, constantly scanning the waters for the tell-tale dark shadow of a white shark cruising along the inshore zone. Their goal is to reduce the overlap between people and sharks by providing an early warning system for water users when a shark comes a little too close for comfort.

But is the programme achieving its objectives of balancing the needs of people and sharks in the waters around Cape Town? A study recently conducted by the University of Cape Town's Institute for Communities and Wildlife in Africa (iCWild) aimed to answer this question by looking at how sharks and people overlap in the inshore zone at popular beaches in False Bay, and how effective the shark spotters are at reducing this overlap when the risk of conflict between sharks and people is highest. The study made use of data recorded daily by the shark spotters at two popular beaches in False Bay (Fish Hoek and Muizenberg) over an eight-year period, analysing patterns in shark sightings, water-user numbers and the impact of different shark warnings on the number of water users present after a sighting.

The first key finding of the study was that sharks and people have similar patterns in their use of the inshore zone on a daily and seasonal basis, with the numbers of both peaking between midday and early afternoon in the spring and summer months. Although the reasons for white sharks frequenting the inshore zone at these times are unrelated to human presence, the fact that hundreds of people share the coastal waters of False Bay with an opportunistic apex predator on a daily basis over the warmer months means that there is an increased risk of conflict between these groups. The next step in the study was therefore to examine the effectiveness of the shark spotters in mitigating the risk of conflict presented by this high level of overlap between people and sharks.

First to be assessed was the ability of spotters to detect sharks in the inshore zone. Visibility depends to a large extent on the prevailing weather conditions, as factors such as wind, cloud cover, sun glare and water turbidity can have a negative

Photo by Heather Perry | National Geographic Creative



impact on spotting conditions. For these reasons, the most common flag utilised by spotters in False Bay is the black flag, which indicates suboptimal spotting conditions. A promising finding, however, was that the black flag does not necessarily mean that spotters are blind to sharks cruising along the inshore zone. In fact, 85% of shark sightings recorded at Fish Hoek and Muizenberg beaches took place when the black flag was flying.

Next came the impact of shark warnings on water users. When a spotter detects a shark, he or she will follow one of two warning protocols, depending on the behaviour of the shark and its proximity to water users. In the case of a high-risk sighting, the spotter will fly a white flag and sound a siren to alert water users to the presence of a shark in their immediate vicinity. The good news from the study is that this combination of visual and auditory cues was shown to have a significant impact on water users, immediately reducing the number of people in the water. Another positive finding was that despite the high impact of the siren warning on water users, it did not appear to scare people off from getting back into the water. In fact, within an hour of the spotter giving the 'all clear', water-user numbers were right back up to where they were before the sighting.

In the case of a lower-risk sighting, in which a shark is seen well outside the water-user area, the spotter will raise a red flag with no accompanying siren. This warning is used to inform water users that there is an increased risk of a shark entering the surf zone, but the threat is not immediate. Unfortunately, this warning was shown to have no impact on water users' behaviour. Although the red flag signifies a lower risk category than the white flag and siren do, it is still important for people to be aware of the increased danger of being in the water under a red flag and to adjust their actions accordingly. Ongoing education about the meaning of the red flag is therefore an imperative part of the programme, as is feedback from water users about their perceptions of risk when the red flag is flown.

This is vital in order to lessen the already low risk of a shark bite as, although rare, when it does occur it has considerable impact and a highly detrimental effect on local communities. The study shows that a fatal shark bite significantly reduces the average number of water users at both Fish Hoek and Muizenberg for up to three months following the incident. This reduction in beach tourism has a negative impact on local businesses that rely on beach goers to generate income. A fatal shark bite also has the potential to lead to demands for the lethal control of sharks in Cape Town. The Shark Spotters programme is therefore constantly being adapted and new improvements are being added to ensure that it stays on top of its game in mitigating the risk of a shark bite.

All in all, Shark Spotters fits the bill as a proactive, environmentally responsible and sustainable shark safety strategy. The programme successfully mitigates the risk of conflict between water users and white sharks during times of peak overlap between these groups, when the risk of a negative interaction is highest. By significantly reducing this risk, the programme is able to protect people, sharks and the local economy from the negative repercussions of shark bites.

Photo by Lisa Larsson | OrcaLab

The lone stranger

Words by Janie Wray | Cetacea Lab

For whale researchers off the coast of British Columbia, humpbacks and orcas are run of the mill and are identified by the sounds coming from hydrophones. So when quite different clicks were heard the scientists knew that an exciting newcomer was visiting.

When I first heard the message from Lisa, I was certain that something was amiss. She was looking after OrcaLab, a remote whale research station at the northern end of Vancouver Island, and for the past three months had been its only occupant. Her message was cryptic; she didn't want to tell me on voicemail about what had just happened. When I finally did make contact with her, I was puzzled by her words. 'You won't believe what I've been listening to over the hydrophone for the past four hours,' she said. Of course I had no idea – it was obviously not the call of an orca or a humpback, as they are quite common in the area. It must have been something she hadn't heard before.

Suddenly it hit me. 'Please tell me you're listening to a sperm whale!' She confirmed with an excited 'Oh yeah!' Lisa and I are lucky in that we live in the company of orcas and humpback whales, but we shared a hidden desire to one day see or hear a sperm whale. Stories of these lone giants were surrounded by mystery and had stirred a yearning in our hearts since childhood.

The sperm whale has a culture all its own, quite different from that of the humpback or orca. The females maintain strong bonds with one another and are known to spend their entire lives in pods, generally in warmer waters near the equator. They are the care-givers for the calves. Males born into these pods stay with the group until they are between four and 20 years old. When they depart, they may form groups with other males roughly the same age that have also left their families and together they mature and grow larger. By the time they reach their early 20s, individuals are ready to split from these male groups and become loners, often frequenting higher latitudes.

The largest of the toothed whales, the sperm whale can measure up to 18.3 metres (60 feet) long, although this is true only of the males; at maturity they are 30% to 50% longer and three times heavier than the females. The species' shape is quite unusual, making it unlikely to be confused with any other whale. From the massive, square-shaped head a straight horizontal line leads down the back, where the vertebrae stick out slightly above the rest of the body, ending in a surprisingly large dorsal hump. Beyond this hump the tail and flukes usually hang below the surface. Even more telling is the shape of the blow – I have always found it interesting that you can identify a whale from a distance by its blow. In the case of the sperm whale, the blow is bushy and, since the blow hole is located on the left at the very front of the whale's head, it is angled 45 degrees to the left (if not affected by wind).

We assumed that this lone sperm whale arriving in Johnstone Strait in early February was a male. Lisa, who had first heard him on one of the many hydrophones of the OrcaLab array, sent the recording to Paul and Helena (the founders of OrcaLab 47 years ago and the inspiration for Cetacea Lab). They forwarded it to a few colleagues and soon everyone was in agreement – these were indeed the clicks and creaks of a sperm whale. Excitement spread through the communities along the coast – a sperm whale had not been seen or heard in these inside waters since 1984, when John Ford recorded one but never saw it. We all assumed this whale would hang around for a few days and then be on its way. Fortunately, this was not the case.

Jared Towers, one of British Columbia's top orca biologists, lives in a small coastal town called Alert Bay, 30 minutes by boat from OrcaLab. He asked Lisa to call him the next time she heard the whale on the hydrophones. He didn't have to wait long. At first light the following day she called to say the sperm whale was back on the easternmost hydrophone. It took Jared less than an hour to pack up the boat and fetch Lisa. Fortunately, the weather was sunny and fairly calm, perfect for trying to see the blow of this lone whale.

Second only to beaked whales as deep divers when foraging, sperm whales can

dive up to two kilometres (1.2 miles) for up to an hour at a time. Their diet comprises mainly giant and medium-sized squid, but they are also known to feed on octopus and some fish species; in the open waters of British Columbia sable fish is a favourite. Since their dive time is so long, when they return to the surface to breathe and rest they remain there for quite a long time before diving again. This is what Lisa and Jared were hoping for, so that they could take a few identification photographs before the whale left the area. They also had a portable hydrophone so they would know when the whale would most likely be at the surface. After a couple of anxious hours of looking for blows and listening for clicks, they finally made out in the distance a bushy blow – it had to be the sperm whale!

He was resting motionless at the surface, his ribcage like two big barrels to the sides behind the slightly elevated bump at the very back of his head – a head that contains the largest brain on the planet – and his skin was a dark greenish grey. When he dived, he showed four perfect nodes in a line before the second smaller dorsal hump appeared, and then that perfect grand tail, with a little notch on the right side, rose high in the air before sliding straight down into the depths.

Lisa and Jared stayed with the whale for most of the day, finding it difficult to leave because they assumed this would be their one and only opportunity to view a sperm whale in Johnstone Strait. But later that night, when Lisa was back at OrcaLab, he continued to vocalise, emitting a steady series of 'hammer on rock' clicks and occasional faster creaks when his echolocation locked onto prey. Paul suggested that they should give the whale a name and without a second thought Lisa knew what it should be: Yukusam, which is what the First Nations call the island where he was first sighted and where OrcaLab is situated.

Lisa didn't know it at the time, but for the next month she would get hardly any sleep. She, the lone winter caretaker of OrcaLab, and Yukusam, the solitary sperm whale of Johnstone Strait, were about to spend a lot of time together. By the time I finally arrived, Lisa was exhausted but glowing, hanging on to every moment she could hear the whale. She spoke of Yukusam as of a dear old friend – and I understood why. There is something magical that can happen when you spend months alone on an island listening only to whales. In this case it was one whale, a sperm whale, and she was hooked.

I was affected in the same way on my first night there. I had the scanner on the pillow beside me, listening, trying not to sleep. I can't explain how clicks, creaks and other brief rhythmical sounds can inch into your heart in such a mysterious manner. I can't even imagine what Lisa must have felt after five weeks of this vocal connection to a creature we know so little about. We became so accustomed to the daily routine of Yukusam going east, then west, back and forth in Johnstone Strait, always returning. Occasionally he would disappear for a few days, but he'd always return.

Then one day turned into two, then three. It was suddenly so quiet, a loneliness filling the air as we realised he may have left. Lisa and Helena listened to the last recording, trying to work out which hydrophone had picked up his last vocalisation so that we could determine his direction. It sounded like he had gone to the east, which meant he should return. Two weeks later we heard that a sperm whale had been spotted near Vancouver – Yukusam! He had travelled south down the entire length of Vancouver Island and had last been seen near Haro Strait, which meant that he was heading for the open ocean.

Now that spring has arrived, I will travel north and set up the whale research station on Fin Island. This station is also connected to a series of hydrophones and you can be sure that I will be listening for the powerful hypnotic clicks of a sperm whale. If Yukusam should arrive, the entire coast of British Columbia will be hearing about it. Lisa, who has returned to Sweden, would probably be on the first flight back to rejoin her companion of the sea – Yukusam, the lone sperm whale.

INSIDE STORIES

Words by Eleanor Yeld Hutchings
Shark Education Centre

One man's trash is another's treasure, as is convincingly demonstrated at the SOSF Shark Education Centre, where the staff are also recycling that most precious commodity, water.

Photo by Grant Atkinson | Fresh Air Crew

Going, gone green

The Save Our Seas Foundation Shark Education Centre does amazing work in marine environmental education, teaching thousands of learners about our incredible oceans and how to be environmentally responsible citizens of Planet Ocean. But it does seem a little strange to be teaching everyone what they can do to lessen their harmful impact on the environment without 'walking the talk' ourselves. So over the past couple of years the Shark Education Centre has undergone a process to make it a best-practice example of green living.

Our first step was the addition of an outdoor sustainable living courtyard. The back garden, where visiting groups take their snack breaks, was turned into a showcase of up-cycling, recycling and re-using. The swimming pool was covered with a removable deck, both as a safety device and to provide extra seating. The walls around the courtyard were designed to feature all sorts of ideas for how to use space and create new items from waste: a decorative mural made from glass bottles; two vertical wall gardens with water-wise succulents planted in plastic bottles and old coffee sacks; pallet gardens; and planters made of painted car tyres. A seascape mosaic path, made of plastic bottle caps set into cement, was inlaid into the paving stones leading from the back door of the centre to the newly built and installed recycling station.

This large recycling block has containers for metal, plastic, paper and glass (collected weekly by Clearer Conscience) and, as a gesture of goodwill – and an incentive to get more people recycling! – we have invited members of our local Kalk Bay community to bring their recyclables to it. The uptake of this service has been incredible and very positive within the community, which has been amazing to see. We have even had to increase the frequency of collection to accommodate the locals' response.

Also found in the back garden are a smack of water-bottle jellyfish, a large succulent-and-pantyhose turtle, a car-tyre orca, a number of plastic-bottle crabs, a car-tyre seal pup and a bicycle-tyre hammerhead shark – all made from up-cycled trash objects!

The front garden has been entirely replanted with water-wise indigenous vegetation and is now thriving. A special section was created of plants that together look like a coral reef, and this was done to prepare for the arrival of one of our most spectacular commissions: a four-metre-long (13-foot-long), anatomically correct sculpture of a great hammerhead shark! Made entirely out of recycled tyres, the artwork is entitled 'Should tired tyres retire?' This huge shark has taken pride of place on the corner of Main and Dalebrook roads and is a major visitor attraction, as well as an example of how we can re-use items rather than send them to a landfill.

Probably the most significant change in our quest to 'green' the centre was the replacement of the garage roof (the double garage was converted during 2014 and 2015 and now operates as a large, ship-themed classroom). Made of asbestos and thus deemed a hazard, the existing roof was removed and replaced with metal sheeting specially designed to support 57 solar panels, which were installed on the new structure. These photovoltaic solar panels provide electricity for the centre's operations, massively reduce our carbon footprint, ensure that we have a steady supply of electricity and, when we generate more than we consume, enable us to feed back into the municipal electricity grid. This is monitored on our Solar Edge monitoring platform and will in future be displayed in the centre as a teaching tool for sustainable living and renewable energy uses.

One of our most successful environmentally conscious changes has been in how we use water at the centre. The entire Western Cape of South Africa is facing an extreme and critical drought, with dire consequences for the whole province. This is due to very low rainfall during our 2015, 2016 and 2017 winter seasons. In addition, the demand for water has been increasing steadily every year due to the province's rapidly growing population and economy. This, plus rapid climate change and unpredictability, has added significantly to pressure on the water supply. Currently, Cape Town is under level 6B water restrictions, whereby individual use of potable water is restricted to 50 litres (11 UK gallons; 13 US gallons) per person per day. There is a very real risk that Cape Town will run out of water if everyone doesn't adhere to the limitations.

This has, of course, also affected the daily operations of the Shark Education Centre. We have managed to cut our water use substantially by collecting all 'grey' water; reducing toilet flushing (and using only rain or grey water to do this; the toilets have been disconnected from the municipal supply); cutting down on dish washing; asking visitors who stay at the centre to take extremely short showers and to collect their shower water for toilet flushing; and catching as much rain water as possible by diverting downpipes into barrels, buckets and outside sinks. We have also installed rain water tanks, with a combined storage of 3,800 litres (835 UK gallons; 1,004 US gallons). This water is used for flushing toilets, washing wetsuits and other equipment used in our education programmes and for garden and household maintenance. We are super proud to say that we have reduced our water use from a previous monthly average of 10,000 litres (2,200 UK gallons; 2,642 US gallons) to 1,300 litres (286 UK gallons; 343 US gallons) at our last monthly meter reading.

We are looking forward to constantly finding new ways to improve our carbon footprint and to leading by example when it comes to helping people make the best choices for sustainable living.

Island School Seychelles
Words by Terence Vel

With a new BSc course in environmental science, the University of Seychelles is forging ahead in a bid to create leaders who will protect the precious ecosystems of the Seychelles – and beyond.

INSIDE STORIES

A DEGREE IN PARADISE

Visitors who come to the Seychelles often liken it to the Garden of Eden and you can see what they mean: a tropical climate all year round; crystalline turquoise waters with diverse marine life; forest-clad mountains where rare tropical plant species abound. Where else on earth can you find such an idyll?

One of the most interesting facts about the Seychelles is that, unlike other oceanic islands, they are composed of continental rock rather than oceanic basalt or reef limestone. The granite of the main island of Mahé is about 650 million years old, dating back to the Precambrian age. It is believed, though, that long-distance dispersal – by sea, wind and birds – was responsible for bringing plants and animals to the Seychelles, and in this respect our islands are similar to other oceanic outposts. This combination of similar and dissimilar ensures that the environment of the Seychelles is one of the most intriguing in the world to study.

And now there is an added attraction to the Seychelles – not only can you live in the Garden of Eden, but you can study it too! The University of Seychelles (Unisey) is offering a BSc degree in environmental science. The three-year course makes full use of the archipelago's unique local environment and gives students the opportunity to explore this fantastic living laboratory.

The most pressing environmental issues faced by the Seychelles are addressed during the course, enabling students to analyse these issues and develop solutions for them, while at the same time gaining qualifications that are relevant to the Seychelles' situation and in a broader context, both regional and international. The programme covers subjects such as climate change, natural resource economics, environmental law, sustainable development, global environmental change and marine and fisheries science. The lectures are complemented by practical work in the field and in laboratories, as well as work attachments that enable the students to apply theoretical perspectives to practical situations. In this way, they are exposed to the Seychelles' well-preserved environment and ecological diversity.

Through collaboration with local NGOs and international partners and guest lecturers, the course offers students an opportunity to participate in forward-looking conservation action taking place both locally and internationally. It also enables them to study and participate in issues relating to Small Island Developing States, tropical ecology, climate resilience, education for sustainability and fisheries science, as well as coastal management.

To pursue the goals of the BSc environmental science course, the Unisey Centre for Environment and Education (UCEE) has been created in partnership with Wildlife Clubs of Seychelles (WCS) and the Save Our Seas Foundation (SOSF). The centre is located at Anse Royale university campus, an idyllic place with excellent facilities and equipment. It houses live aquatic animals and natural history artefacts and is surrounded by four different ecosystems – coastal, mangrove, river and terrestrial – that provide a natural resource for the students' field studies. With a key message of 'Discover, Investigate, Learn', the centre encourages students to discover and investigate their local environment and to uncover the amazing world they live in.

With the technical support of WCS and a keystone grant from the SOSF, Unisey's course in environmental science now has a strong experimental research and analysis component. The SOSF recently donated new field equipment, Vernier sensors and microscopes for this purpose. Once the UCEE had got off the ground, attention turned to setting up the course's module on research methods and skills. This introduces students to the collection, analysis and interpretation of environmental data by applying physical and chemical theories to their investigations.

Effective education and outreach are essential for promoting conservation policy, creating knowledgeable citizens and changing people's behaviour. The UCEE is therefore encouraging students and teachers to embrace environmental challenges and is building their capacity to do so. It welcomes visits from WCS members, youth groups and primary, secondary and post-secondary schools and is continually looking at ways to ensure that all its programmes have relevance and value for schools.

Unisey's BSc environmental science course has already borne fruit: graduates from its first course (2012–2016) are already employed in disciplines relevant to the environment within the government and in NGOs. Two of these graduates have been accepted by international universities for MSc degree courses.

More and more businesses are expected to employ environmental professionals to help them develop practices that minimise environmental impact by managing waste and pollution and conserving resources. There is a growing need for qualified people who are able to advise and oversee the construction of sustainable buildings, developments, utilities and transportation systems and who know how best to protect and conserve our natural resources.

Danielle Jupiter
I was one of nine students belonging to the first cohort of BSc environmental science hopefuls at Unisey. The three-year undergraduate course was the foundation for achieving an in-depth knowledge of marine science. Shortly after successfully completing the degree, I was encouraged by one of my lecturers to apply for a scholarship for an MSc in sustainable fisheries management at the University of Alicante in Spain. My application was successful and I completed the first year in Spain before returning home to conduct my research for the second year. I have just finished the MSc and feel so proud for having made it this far.

Photo by Terence Vel | UniSey

Photo by Fabrice Guérin | Biosphoto

Crackling, grunting, humming, thrumming and soaring: the ocean resonates with song. From fish that sing at dawn to the haunting refrains of whales separated across oceans, in our next issue we explore the soundscapes of the sea and how scientists are learning to listen. We also ask important questions about the impact of human activities – from shipping traffic to seismic surveys – on the symphony of the sea. Join us as we dive into an ocean of intelligence to understand cognition in marine animals, and look to the future in a discussion on the fundamental field of shark taxonomy.

next issue

Dive in with the *Save Our Seas* magazine on a digital exploration of the world's oceans, voyaging with marine scientists and conservationists who share the latest insights, news and innovations. You can find all our magazine stories on our dedicated website, *SaveOurSeasMagazine.com*, as well as access to exclusive web content that includes interactive features, videos and unpublished images. Catch up on the latest in shark science on the go, with handy access to the magazine from your tablet or phone on *issuu.com* or *zinio.com*.

About the Save Our Seas Foundation

A commitment to protecting our oceans and their rich biodiversity is at the heart of the Save Our Seas Foundation's (SOSF) work. In a bid to achieve this, the foundation offers funding and support to research, conservation and education projects around the world that focus primarily on charismatic, threatened marine wildlife and its habitats. From its origins as a small not-for-profit organisation, in just 15 years the SOSF has grown from funding just five projects to supporting more than 300 worldwide. It functions not as a research institute itself, but strives to sustain the many and varied efforts of scientists, conservationists and educators through generous contributions of financial, practical and scientific support. The SOSF is proud to form part of a growing and committed community of ocean stewards and, through its work, to help shape a sustainable future for our seas.

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

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