THE SAVE OUR SEAS FOUNDATION MAGAZINE

saveourseas

MIAMI | BIMINI | BY-CATCH | CITES

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Shin is an award-winning photographer based in Bangkok, Thailand. With a background in marine biology, he initially used photography to document coral reef biodiversity for researchers and later began shooting as a freelance photojournalist for several organisations and publications, such as the IUCN, International Court of Justice, Freeland Foundation and *National Geographic Thailand*.

JUSTIN GILLIGAN
Justin is a freelance photojournalist with an Honours degree in marine science. He strives to combine his scientific background and his artistic flare to create images that draw the viewer's attention to the beauty of the natural world and its issues. Several of Justin's images have received acclaim in international photography competitions.

PHILIPPA EHRLICH
As conservation journalist for the Save Our Seas Foundation, Philippa has spent more than three years working with passionate researchers and conservationists, listening to their stories and helping them to share their work with a popular audience.

DEAN GRUBBS
Dean is a fish ecologist with interests in the biology of exploited and poorly studied estuarine and marine taxa. He is currently the associate director of research at the Florida State University's Coastal and Marine Lab, where he mentors graduate and undergraduate students and maintains an active research programme on the ecology of deep-water and coastal fishes. His research has been featured in many television documentaries, including National Geographic TV, National Geographic Wild, Discovery Channel and the US Public Broadcasting System.

Cover: Photo by Rodrigo Friscione

16 ISLANDS IN THE STREAM

Until quite recently, Bimini in The Bahamas was a quiet wilderness in comparison to its more commercial Caribbean neighbours, but the wind of change has caught up with the little islands. Shin Arunrugstichai and Philippa Ehrlich investigate the impact of development on the islands' human community and native ecosystem.

42 URBAN PIONEERS

What happens when a rich marine wilderness is absorbed into a booming concrete metropolis? The coast of South Florida has become a hub for researchers and conservationists who are investigating how wildlife is navigating its way through this rapidly changing environment. Justin Gilligan and Philippa Ehrlich explore the realm of Florida's urban wildlife.

Photo by Justin Gilligan

An aerial perspective of Stilltsville in Biscayne Bay, South Florida. The urban footprint is obvious enough through the absence of sea grass around the man-made structure.

ISSUE #6

Photo by Thomas P. Peschak

As long as there

are people who care,

we can and will

make a difference.

THE FOUNDER I
SAVE OUR SEAS
FOUNDATION

Michael Scholl with his three year-old son Elliot reading *Shark Doc, Shark Lab* book in Aya's Spot with six juvenile lemon sharks.

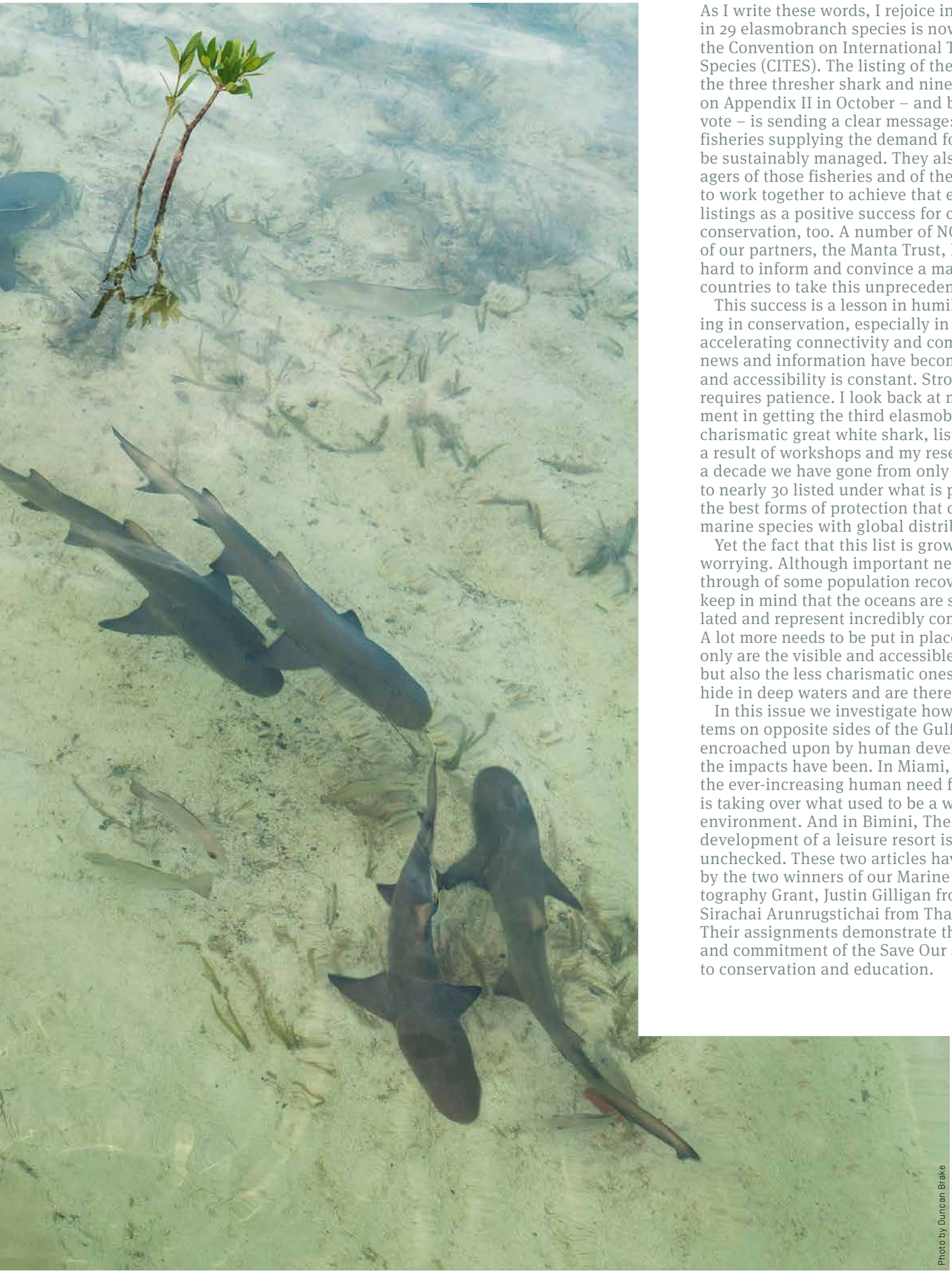


Photo by Duncan Brake

As I write these words, I rejoice in the fact that trade in 29 elasmobranch species is now regulated under the Convention on International Trade in Endangered Species (CITES). The listing of the silky shark and the three thresher shark and nine devil ray species on Appendix II in October – and by a huge majority vote – is sending a clear message: countries want the fisheries supplying the demand for these species to be sustainably managed. They also expect the managers of those fisheries and of the trade world-wide to work together to achieve that end. I view the listings as a positive success for collaboration in conservation, too. A number of NGOs, including one of our partners, the Manta Trust, have worked very hard to inform and convince a majority of signatory countries to take this unprecedented step.

This success is a lesson in humility for people working in conservation, especially in a world of ever-accelerating connectivity and communication, where news and information have become instantaneous and accessibility is constant. Strong conservation requires patience. I look back at my remote involvement in getting the third elasmobranch species, the charismatic great white shark, listed back in 2004 as a result of workshops and my research. In just over a decade we have gone from only two elasmobranchs to nearly 30 listed under what is probably one of the best forms of protection that can be afforded to marine species with global distribution.

Yet the fact that this list is growing longer is worrying. Although important news has come through of some population recoveries, we need to keep in mind that the oceans are still mostly unregulated and represent incredibly complex ecosystems. A lot more needs to be put in place to ensure that not only are the visible and accessible species protected, but also the less charismatic ones and those that hide in deep waters and are therefore poorly known.

In this issue we investigate how two fragile ecosystems on opposite sides of the Gulf Stream have been encroached upon by human developments and what the impacts have been. In Miami, South Florida, the ever-increasing human need for habitable space is taking over what used to be a wild and unfriendly environment. And in Bimini, The Bahamas, the development of a leisure resort is continuing unchecked. These two articles have been illustrated by the two winners of our Marine Conservation Photography Grant, Justin Gilligan from Australia and Sirachai Arunrugstichai from Thailand, respectively. Their assignments demonstrate the importance and commitment of the Save Our Seas Foundation to conservation and education.

Michael C. Scholl
Chief Executive Officer
Save Our Seas
Foundation

WHERE WE WORK 2016

Photo by Ralph Lee Hopkins | National Geographic Creative

SOSF Centres

1 D'Arros Research Centre | Rainer von Brandis
2 Shark Education Centre | Eleanor Yeld Hutchings
3 Shark Research Center | Mahmood Shivji

AFRICA

4 Sawfish Children's Book | Ruth Leeney

GUINEA
5 Elasmobranch Artisanal Fisheries | Framoudou Doumbouya

KENYA
6 Elasmobranch Biodiversity | Peter Musembi

MADAGASCAR
7 Sawfishes | Ruth Leeney

SEYCHELLES
8 Bonefish | Paul Cowley & Emily Moxham
9 Forest | Rainer von Brandis
10 Juvenile Sharks | Ornella Weideli
11 Lemon Shark | Ryan Daly
12 Oceanography | Phil Hosegood
13 Reef Manta Ray | Lauren Peel & Guy Stevens
14 Shearwaters | Danielle van den Heever
15 Stingrays | Chantel Elston
16 Turtles | Jeanne Mortimer
17 University of Seychelles | Karl Fleischmann

SOUTH AFRICA
18 Shark Spotters | Sarah Waries
19 ATAP | Paul Cowley
20 BRUVs | Lauren De Vos
21 Sharks on the Urban Edge | Alison Kock

OCEANIA

AUSTRALIA
22 Deepwater Sharks | Sam Munroe
23 Sawfishes | Barbara Wueringer
24 White Sharks from the Air | Lachlan Fetterplace

AMERICAS

ARGENTINA
25 Sharks from Peninsula Valdes | Alejo Irigoyen

BAHAMAS
26 SOSF Marine Conservation Photography Grant 2016 | Bimini, Bahamas | Shin Arunrugstichai
27 Bimini Biological Field Station | Tristan Guttridge & Samuel Gruber
28 Nassau Grouper | Krista Sherman
29 Predator–Prey Interactions | Mariana Fuentes
30 Sawfishes | Dean Grubbs
31 Shark Personality | Félicie Dhellemmes

BELIZE
32 Deep Sea Sharks | Ivy Baremore

CANADA
33 Cetacea Lab | Janie Wray & Hermann Meuter
34 Great Bear LIVE | Diana Chan

CHILE
35 Lost Fish of Easter Island | Naiti Morales

COLOMBIA
36 Elasmobranch Artisanal Fisheries | Camila Caceres

ECUADOR
37 Sharks in the Galapagos | Euan Harvey

MEXICO
38 Capacity Building for Mobulids | Josh Stewart

USA
39 SOSF Marine Conservation Photography Grant 2016 | Florida, USA | Justin Gilligan
40 Sharks & Rays | Diana Churchill
41 Stingray Navigation | Kyle Newton
42 Thresher Shark | Frances Kinney
43 Turtle Tumours | David Duffy
44 Urban Sharks | Neil Hammerschlag

EUROPE

ITALY
45 Turtle Tracking | Giulia Cerritelli

SPAIN
46 Angel Sharks | Eva Meyers

SWITZERLAND
47 Shark Phylogeography | Nicolas Salamin

UNITED KINGDOM
48 Mako Sharks | David Sims

ASIA

MALAYSIA
49 Sharks & Rays Assessment | Mabel Matsumoto

PALESTINE
50 Giant Devil Ray | Mohammed Abudaya

UNITED ARAB EMIRATES
51 Sharks & Rays Red List Assessment | Rima Jabado

WORLDWIDE

- The Manta Trust | Guy Stevens
- White Shark Finprinting System | Michael Scholl

CONFERENCES & EVENTS

52 American Elasmobranch Society (AES) Conference | New Orleans, USA
53 Biology and Ecology of Sawfishes Symposium (AES) | New Orleans, USA
54 Eugenie Clark Award (AES) | New Orleans, USA
55 European Elasmobranch Association (EEA) Conference | Bristol, UK
56 Oceania Chondrichthyan Society (OCS) Conference | Auckland, NZ
57 Paving the Way for Devil Ray Protection at the CITES CoP 2016 | Johannesburg, ZA | Isabel Ender
58 WaveScape 2016 | Cape Town, ZA | Frylinck Ross

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 200 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*

WHALE AND WINGHEAD SHARKS NOW ENDANGERED

Image by Sandra J. Raredon | National Museum of Natural History | Smithsonian Institution

ocean view

From 1 to 10 September 2016 decision makers from 184 countries met in Hawaii to discuss current conservation challenges and solutions at the IUCN World Conservation Congress. The congress, which is held every four years, had as its theme this year 'Planet at the Crossroads'. Major announcements included the assignment of the whale shark and the winghead shark (a species of hammerhead) to Endangered species status on the updated IUCN Red List of Threatened Species. According to this new listing, the populations of these species have more than halved in the past 75 years.

The Red List is a global assessment of species' conservation status that indicates a relative scale of threat – from Least Concern to Critically Endangered – and these updates signal where serious intervention is needed to prevent a species from going extinct. Continued declines in whale shark numbers are linked to fisheries by-catch and ship strikes, while winghead sharks are prone to getting entangled in fishing nets. The change in listing is of major concern and should push conservationists and fisheries managers to mitigate threats.

Other marine conservation issues were also in the spotlight, with angel sharks, sawfishes and tunas featuring in discussions. Fourteen new Hope Spots – regions deemed of high priority for protection – were jointly announced by the IUCN and Mission Blue. IUCN members also supported a call for the listing of the silky shark, three species of thresher shark and nine species of mobula ray on Appendix II of CITES. The support of the IUCN on this issue is an endorsement of the high priority of the proposal.

SOUND BITES

Could music, integral to influencing the mood of a film, be subtly but significantly reinforcing our negative attitude towards sharks? A study published this year by Andrew Nosal from the Scripps Institute for Oceanography indicates that it might. Nosal and his colleagues found that people perceive sharks negatively when footage is paired with ominous music. The concern, he says, is that when this music is used in a documentary, which audiences tend to view as an objective illustration of the natural world, associating sharks with threatening music may undermine education goals.

Nosal and his colleagues looked at our perceptions of sharks relative to the mood of background music and whether this influences our willingness to conserve them. In three experiments, people watched shark footage set to uplifting music, ominous music or silence. Overall, people viewed sharks more negatively when they were associated with ominous music. The results relating to their willingness to conserve sharks were slightly more complex. When asked in the first two experiments if they were willing to support shark conservation, people generally answered yes, regardless of music type. However, in the third experiment, the researchers gave people specific options: would you rather donate to shark conservation, dolphin conservation or a discretionary fund? In this instance, people were more likely to want to donate to shark conservation if they'd watched sharks with uplifting music.

That background music is anything but inconsequential is corroborated by the many people who still trace their shark phobia to the 1975 film *Jaws*. As Nosal points out, that soundtrack was highly emotive and is entrenched in popular culture. He explains that *Jaws* ensured that film-viewers would hear that staccatto cello and immediately conjure an ominously circling dorsal fin in their mind. The dorsal fin is threatening because the film's storyline suggests a fin breaking the surface is a precursor to a panicked swimmer's legs and a lot of blood. In short, the film employs a leitmotif: a repeated, short musical phrase that is always coupled with the film's 'baddie', linking the two. In the end, we have only to hear that music and the ghost of *Jaws* surfaces again in our minds.

Nosal argues that something as subtle as music is important in an educational context. People still fear sharks, which undermines the animals' conservation potential. According to him, film-makers need to realise that whatever entertainment value they may gain from using stereotypical 'scary shark music' could impede any educational objectives they may have. He also points out the need for public awareness: it's music, rather than actual experience, that may be darkening our thoughts about sharks. Only when this is understood, he suggests, might we banish the power *Jaws* wields in our imaginations and open ourselves to supporting shark conservation.

A champion for sharks at CITES

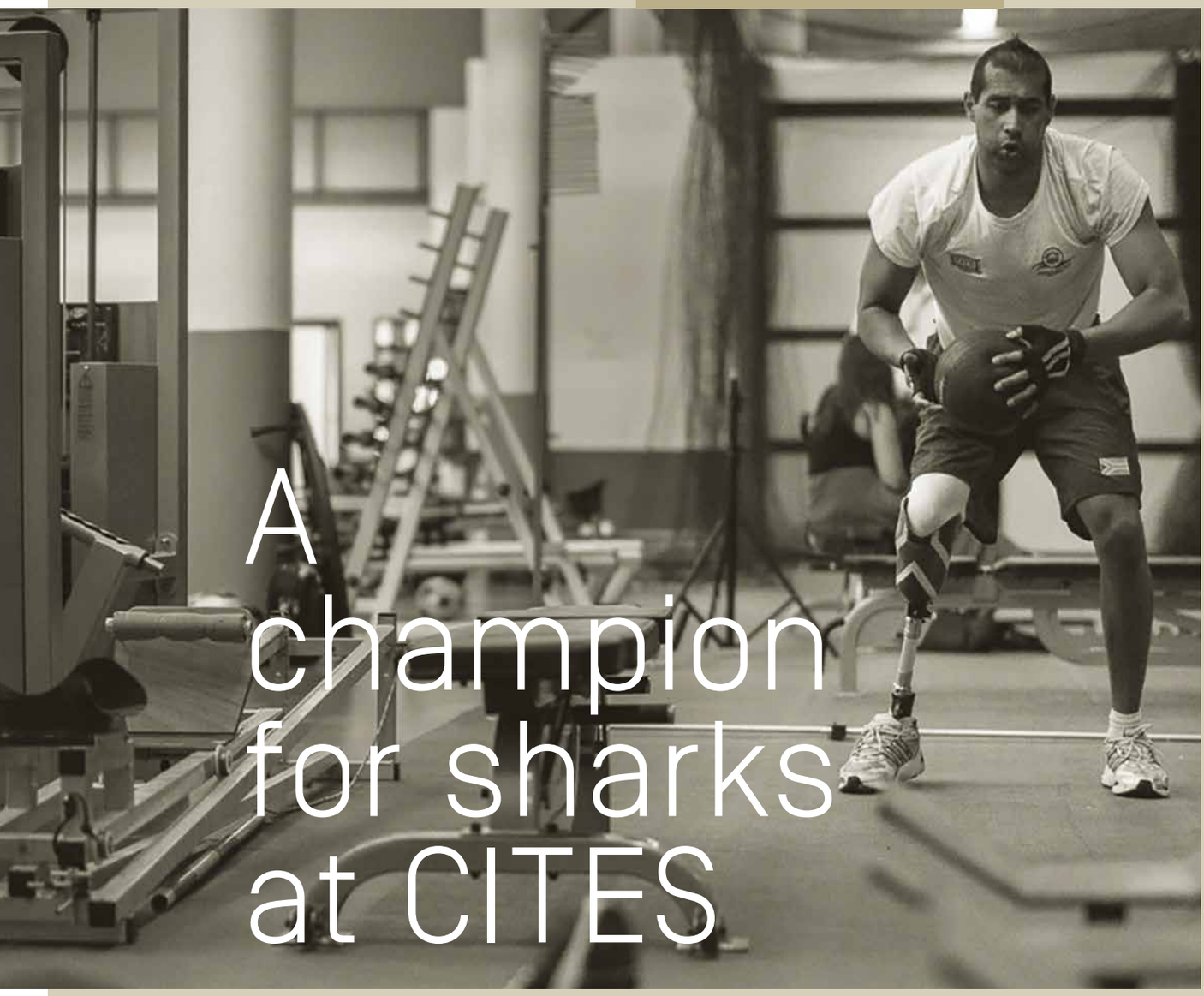


Photo by Mac Stone

Achmat Hassiem, the South African swimming sensation who lost his leg to a shark incident in 2006, is among the loudest voices championing stricter protection for sharks and rays. He attended the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in September this year in Johannesburg, where he urged parties to vote for the listing of silky and thresher sharks and mobula rays. Misconceptions and a poor public image hinder effective shark conservation, a situation that Achmat is eager to address. Approached in 2010 by the PEW Charitable Trusts to act as an advocate for shark conservation, he worked closely this year with the Manta Trust and partner organisations to mobilise (or is that mobulise?) for CITES.

Achmat lost his leg to a great white shark in Muizenberg, Cape Town. He holds an admirably positive view of his shark encounter, believing that he has been afforded many opportunities as a result of it. He went on to represent South Africa as a swimmer at the Beijing Paralympics in 2008, won a bronze medal at the London Paralympics in 2012 for the 100-metre butterfly and competed at the Rio Paralympics in September this year, just ahead of CITES CoP17.

He says the past few years have taught him much about the vital role sharks play in our oceans' ecosystems and how important it is to ensure their continued existence in all their diversity. This makes him an enthusiastic advocate for stricter protection of vulnerable species. Standing up for sharks, he says, is his way of giving back for where his life has taken him since 2006. His swimming success has given him a platform from which to speak 'on behalf of sharks all around the world'. Achmat has spoken at engagements globally, in more than 120 nations, to emphasise the importance of protecting sharks.

The positive result for sharks and rays at CITES comes from years of work by diverse organisations and people, but no doubt the visible and vocal work of this motivational speaker and passionate shark advocate has gone a long way to ensuring a successful outcome.

Photo by Rainer von Brandis

CORALS IN CRISIS

Media coverage of the coral bleaching event that rocked reefs in 2016 has been widespread and grave. Along Australia's Great Barrier Reef there has been concern that negative messaging may deter visitors from a major tourism site. Researchers and journalists, however, argue that as bleaching occurs more frequently in our warming world, media coverage and public awareness are crucial to conservation solutions.

Coral bleaching events are triggered by raised sea temperatures. Tiny algae called zooxanthellae live inside coral polyps and produce energy, but are ejected by heat-stressed corals. Devoid of the algae that give these coral animals their colour, the white coral skeleton is exposed and the animals begin to starve. If temperatures cool sufficiently, the algae can return and corals recover. But if heat stress persists over a long period, bleached corals can die – and it can take reefs decades to recover. El Niño episodes, when warm water spreads across the Pacific Ocean roughly once every five years, can lead to coral bleaching.

El Niño events are complex and researchers are still grappling to understand them fully. This most recent episode saw raised sea temperatures lead to bleaching on reefs worldwide, although the extent and intensity of the bleaching differed at individual sites. In 2016, Australia's National Coral Bleaching Taskforce reported that 81% of the Great Barrier's northernmost reefs were severely bleached and estimated that 93% of the entire reef was affected. This has been called the longest – and on the Great Barrier Reef perhaps the worst – bleaching event in history.

Observations from D'Arros Island in the Seychelles echo this disturbing trend. Dr Rainer von Brandis, scientific director at the D'Arros Research Centre, and his research team have documented the bleaching event and he estimates that between 50 and 80% of all hard corals around D'Arros and neighouring St Joseph Atoll have been lost. There is, he believes, good reason for the concern shown for other bleaching sites and that the extent of media attention is well founded. When asked about the monitoring plans for D'Arros and the possibility of salvaging the region's corals, Von Brandis is resolute: 'Assisting in the recovery of these corals is difficult and time-consuming, but we will monitor coral cover and recruitment into the future.'

The question of whether it is possible to recover after an event of this scale and intensity plagues researchers. In many cases, scientists are concerned that recovery in highly affected areas (like the Great Barrier's northern reaches) is unlikely. Von Brandis is cautious about what this means for D'Arros. Like other researchers, he is keenly hopeful but must be realistic: 'The severe bleaching event of 1998 all but wiped out the corals here. It's taken a long time, but the reefs were recovering well until this most recent event.' Each region will differ in terms of how badly affected its corals were and its subsequent rate of coral recruitment and recovery. Past bleaching events have shown that recovery is possible. Right now, it's up to researchers to monitor affected reefs – and for us to wake up to the impact that warming oceans will have on reefs in the future.

ocean view

Photo by Daniela Vilema | Charles Darwin Foundation

WINNING HEARTS AND MINDS IN THE GALÁPAGOS

ocean view

'Protect the fins and the ocean wins' is a catchy title for a campaign and one that rings true for environmental educator Daniela Vilema and senior ecologist Pelayo Salinas de León of the Charles Darwin Foundation (CDF) in the Galápagos Islands. Bad publicity plagues shark conservation efforts in the region, where misconceptions mean that fear triumphs over facts. This happens even though sharks are integral to life in the Galápagos: during its lifetime, a shark in the region generates US$5-million from ecotourism. Two of the islands, Darwin and Wolf, host the largest shark biomass on the planet.

To highlight the connections between humans and sharks, the CDF, with sponsorship from the Save Our Seas Foundation and Lindblad Expeditions, launched an environmental education campaign in July. At its heart was the message that 'sharks need the Galápagos and the Galápagos needs sharks'. Workshops geared to children between the ages of nine and 12 were hosted at schools on the islands of Santa Cruz, San Cristóbal, Isabela and Floreana. Central to the campaign was the understanding that to engage children workshops need to be fun and creative. Enter Guillo the hammerhead shark and Ramona the whale shark, two of the five iconic shark species that were used as cartoon 'ambassadors'; they certainly made winning guides into the world of sharks. Virtual-reality glasses gave children an immersive experience of underwater Galápagos, while a story-writing and drawing contest focused on sharks and the Galápagos. The prize for the young winners? A snorkelling field trip with the CDF team and famous free divers like Guillaume Nery and Ocean Ramsey.

The foundation also hosted a festival for the local community, with outreach activities across the age divides. Based on its success, the CDF hopes to make events like this one a more regular feature in future.

SNAPPY NEW APP TEACHES KIDS ABOUT SHARKS

ocean view

Curious about sharks? Keen to delve into their world but won't be diving with the real deal any time soon? No problem – there will soon be an app for that. Technology is shaping new learning paths and the Sharks4Kids programme has been quick to harness their value for its target audience: the next generation of shark advocates. Jillian Morris and her colleagues want to create a generation of shark-savvy young people who are fascinated by these creatures rather than fearful of them.

The app is the latest tool in the team's arsenal of education, outreach and adventure programmes. Gates the Robo Shark leads children into his world to explore shark anatomy and biology. The app will enable kids to choose their own adventure and delve deeper into educational videos, but the content is usable in a stand-alone format for classrooms too. This looks like an exciting tool for teachers – and to lead kids into discovering the captivating world of sharks.

A short interview with Ana Sobral

Photo by Maya Santangelo

from the field

Describe the first time you saw an aggregation of devil rays.

It was in 2012 at Princesa Alice sea mount, 45 nautical miles from Faial Island in the Azores. There was a group of four devil rays, three males chasing a female, and they were performing a coordinated, choreographed ballet. They are so beautiful and graceful. After having had a few encounters with mantas, I had never expected these mobulas to look so big or to be so keen to interact with divers. They come really close and look directly into our eyes. It is a mesmerising experience every time.

What does your 'office' look like?

Most of my field work is done at Ambrósio, a sea mount six nautical miles from the harbour at Santa Maria Island in the Azores. The top of the sea mount is about 42 metres (140 feet) below the surface, so we basically hang on a cable in the blue while watching the devil rays and other pelagics swim by. The water is crystal-clear and the deepest blue I have ever seen.

What are some of the challenges your field work entails?

Our field work is completely dependent on the sea and weather conditions, which in the Azores are very unpredictable. Rough seas can really limit our ability to get the work done and sometimes it is completely impossible to go out at all. For these reasons the field work is limited mainly to the summer months (June to October). Also, really strong currents are common and sometimes that too makes it harder to get work done. Basically we are always being reminded that we are in the middle of the Atlantic Ocean.

How would you describe the culture of the Azores, especially with regard to marine life?

The Azorean culture has always had a close relationship with the ocean, from the economy to architecture, art and conservation. The livelihoods of the archipelago's people have always depended on the ocean. For example, from 1850 until 1987, when whaling was an important activity, sperm whales had a special role in shaping the local culture. Today the resources are the same, but now they are exploited in a sustainable way. The Azores have been a pioneer in Portugal when it comes to the creation of marine reserves. The Formigas Islets and Dollabarat Reef, for instance, have been protected since 1988.

How has the Azores' diving industry changed during your time there?

Since I came to the Azores in 2011, there has been exponential growth in the diving industry. In the first years growth was estimated to be between 30 and 40% a year. This rapid development was due mainly to the emerging shark and mobula ray diving industry in the region, especially around sea mounts near Faial, Pico and Santa Maria islands.

Islands in the

Photography by Sirachai Arunrugstichai
Words by Philippa Ehrlich

Bimini was the inspiration for Ernest Hemingway's famous novels *The Old Man and the Sea* and *Islands in the Stream*. When he lived here in the late 1930s, the islands were the domain of big game fishermen and other adventurous souls who wanted to be close to nature. Seventy years on, Bimini is moving in a very different direction.

At Triangle Rock, a spot famous for shark diving, a Caribbean reef shark *Carcharhinus perezi* cruises below the surface with a school of Bermuda chub *Kyphosus sectatrix* in the late evening light. As high-order predators of marine ecosystems, sharks are indicators of biological abundance. At Bimini they highlight the productivity of the waters around the islands, which showcase a plethora of elasmobranch species.

stream

A juvenile lemon shark *Negaprion brevirostris* swims along the channel leading to a sheltered mangrove habitat, which young sharks use as a safe refuge from predators, including adults of their own kind. The mangrove ecosystem is a critical habitat and nursery ground for countless species of marine organisms.

A bird's-eye view of a mangrove island, with the Bimini Bay development in the background. As the only mangrove system on the western edge of the Great Bahamas Bank, this productive habitat makes a considerable contribution to the biological abundance of this region. A large section of mangroves has already been removed for the resort and ongoing development threatens the remainder.

Behind piles of discarded shells of queen conch *Lobatus gigas*, a luxury yacht flying the US flag cruises past North Bimini. Fisheries and high-value tourism have long been the key components of this island's economy, which depends on productive marine ecosystems.

Denver Stuart, a 26-year-old Bahamian with an accent that falls somewhere between an American basketball player's and a 17th-century pirate's, is agitated as he steers us across the bright blue sand flats off the island of East Bimini, or East Wells as it is known to locals. As is often the case with tropical lagoons, we are at the mercy of the tide and need to time things carefully to find what we are looking for. Denver pauses occasionally to point out a large shark or stingray that propels itself away from the boat, sending up a plume of sand. The tide is high and there are large predators everywhere, taking advantage of the deeper water that gives them access to the vast mangrove system on our left.

Denver is both pleased to have someone to vent his anger to and nervous of what I am writing down. He was hesitant to speak at first but, like a can of soda that has been left in the sun for too long, now that his words have started to flow, they are streaming out like red-hot lava. We are closing in on a spit of bright white sand dotted with seagulls and a pair of large brown pelicans. Denver gestures towards it. 'All this land here was added in the last 10 years or so. It looks like nature itself what formed this pretty beach, but it ain't nature. What really formed this is the dredging what they did on the west side of Alice Town and the west side of Bailey Town,' he explains. The sand bank runs parallel to a flat mangrove island fringed by large pines. Between the two is a channel, the gateway to 'God's own nursery' as Biminites refer to the island. As our boat starts to move slowly along the channel, I reflect on the symbolism of the narrow passage that limits entry into this special place, a hidden network of mangrove waterways that functions as the womb of the Great Bahamas Bank. This is East Wells Island, the smallest of the three tiny land masses that make up Bimini, an archipelago in The Bahamas.

Denver points towards the trees on our left and sighs. 'These mangroves are so big and so massive, they could have been here from when the dinosaurs was here,' he says. 'Nature put them here. Man ain't put them here, but man wants to rip them out. This land was supposed to be protected, you know? It's supposed to be land for our generations to go on here on the island.' I peer over the side of the boat to watch the ripples of light moving over the sea grass below us. We are here to experience the magic of East Wells, but also because, if local rumours are true, it is under serious threat.

The boat cruises to a halt and Denver ties up to the mangroves. We disembark and follow him onto the island, taking a path that leads back out to the lagoon. He wades into the ankle-deep water and points triumphantly when he finds what he is looking for. Submerged in the shallows is a concrete cylinder with a pipe sticking out from its centre. Despite its benign appearance, this bit of concrete could spell disaster for East Wells. It is a land marker and, as Biminites have learnt, land markers are a precursor for development. On Bimini, East Wells is the final frontier. We walk further inland and find another concrete cylinder. 'Whoever put that marker there, either they did it with the government's permission or they did it without the government's permission,' Denver says wryly. We have seen the flashy pamphlets that advertise 'Rockwell Island' and promise 'ownership of beach and island estates for a privileged few'. The exclusive estate will boast US$3-million private homes, a wellness centre 'with meditation garden' and an 18-hole golf course.

The Bahamian economy is almost entirely dependent on the tourism industry, which employs about half of the local workforce and earns 60% of the country's gross domestic product. Despite lying only 77 kilometres (48 miles) from Miami and being the inspiration for Ernest Hemingway's *Old Man and the Sea*, Bimini has remained surprisingly little known and undeveloped, attracting the kind of tourists who were drawn to its excellent fishing and authentic 'Caribbean island flavour'.

In the late 1990s, however, things started to change. A wealthy property developer from Florida bought up a failed development at the north end of North Bimini in 1997 and began the construction of Bimini Bay, a large resort with multiple bars, swimming pools and, most recently, a Hilton hotel and casino. Over the past two decades, appeased by promises of economic prosperity and renewed infrastructure, Biminites have watched their island evolve from a sport-fishing paradise into a party destination for wealthy Americans. The local population has doubled as people have come from elsewhere in The Bahamas to find jobs at the new resort. Denver works independently as an ecotourism guide, but some of his cousins are employed at the hotel. I ask him if they like their jobs. He laughs as he answers, 'I don't know if they like their jobs, but I know I like mine! That's why I'm speaking out.'

'The first sawfish I ever saw was on the west side of the North Sound in North Bimini. That place is now part of [Bimini Bay's] marina where all the big boats are docked. That habitat, the very place where I first saw a sawfish, no longer exists,' says Dr Dean Grubbs, who helped to establish the Bimini Biological Field Station and is one of the world's leading sawfish experts. That place is also where Denver learnt to be a bonefish guide.

'The unique thing about Bimini is that if you look behind me, you find the Gulf Stream,' says Professor Samuel 'Doc' Gruber, gesturing over his shoulder. He is the founder of the Bimini Biological Field Station, also known as the Shark Lab, which he established in 1990. He is sitting in a large wooden chair on the patio of Coconut Cove, a house on South Bimini. Every now and again he raises a hand to swat at a mosquito or sand fly.

The Gulf Stream is a warm conveyor belt of nutrient-rich water that brings life to Bimini and much of the North Atlantic. The current is loaded with larvae picked up as it flows along the coast of Central America. The larvae develop in the current and every day the tide brings these pristine waters to Bimini where, if they are lucky, the tiny organisms will find a home. 'All of the reef fish, all of the conch, all of the lobster, all of the invertebrates, they mostly come from the plankton and they come in here and settle. And you know why? Because if you go all the way from here down to Cuba, you will find basically no mangroves. Bimini is the only spot in the north-western corner of the Great Bahamas Bank that has mangroves,' explains Doc. 'It just so happens that Bimini is big enough to support mangroves and that is why it is such a paradise for sharks and why it used to be called the world's greatest sport-fishing capital. It's not that any more. Now it's a gambling casino or something,' he concludes with a sardonic smile.

For years, as a permanent member of the Bahamas National Trust (BNT), Doc worked to create a marine protected area that would encompass the North Sound and stretch eastwards into East Wells. Despite numerous promises and announcements, the North Bimini Protected Area was never established. Doc resigned from the BNT and watched in dismay as mangroves were dug out and a massive channel was dredged up the inside of the lagoon so that big boats could reach the Bimini Bay Marina. The major problem with dredging is siltation and the destruction of sea grasses that need light to photosynthesise. According to Dean, 'Sea-grass beds are a major nursery for animals that are of commercial importance, like blue crab, lobster and conch. And, of course, the higher trophic animals, the sharks, the stingrays and things like that, they rely on these things for food and so it's a boom up effect that can have a huge impact on the ecosystem.'

Another threat is nitrification. When the seabed is dredged up, it releases nutrients into the water that lead to algal blooms. The waste created by a growing population exacerbates this problem. Dean describes seeing for the first time 'big mats of bacteria' in the North Sound. Doc is concerned that this degradation could

Drainage pipes and an excavator are the new inhabitants of what used to be the mangrove forest on the western side of North Sound. The resort project has continued to expand for two decades; now plans to build a golf course could spell disaster for the remaining intact mangrove system at Bimini.

be severely amplified by the construction of a golf course. 'Right now, the entire east side of Bimini is preserved and there is no golf course. Once there is a golf course, you get a tremendous need for water. You get tremendous need for manicuring the golf course and you get fertiliser run-off,' he explains.

A short ferry ride from South Bimini lies Alice Town, the southernmost settlement on North Bimini, the most populous of the islands. A few tourists are wandering in and out of air-conditioned shops and a steady stream of golf carts passes by, mostly filled with young Americans sporting selfie sticks in one hand and a beer in the other. Drunk driving seems to be tolerated, but it is clearly a problem; earlier in the week, two golf carts found floating in the lagoon had been driven straight off the end of the island.

I turn right off the main road into the Sea Crest Marina, one of Bimini's older establishments. In the background, a stream of million-dollar boats motor up towards Bimini Bay. Sea Crest, owned by the Sweeting family, is not as busy as it used to be. Since the development of the resort, business has shifted northwards. A couple of game fishermen have paused in gutting their catch, distracted by something in the water below the pier. I follow their gaze and am surprised to see two large bull sharks cruising below us. Bimini truly is a real-life theme park for shark lovers. Where else can you wake up to watch juvenile lemon sharks weave their way through mangroves and then catch a quick snorkel with nurse sharks and eagle rays, followed by a lunch-time picnic down at Honeymoon Harbour to hand-feed southern stingrays and then spend your evening watching bull sharks from a marina?

The fishermen return to cleaning their fish and I remember a conversation I had with a family after its tour of the Shark Lab a few days earlier. Keen fishermen, brothers Robert and Adrian Otero have been coming to Bimini for 20 years. They stay on South Bimini, having crossed by boat from Florida. It's only a two-hour ride and they generally stay for a week to 10 days at a time. 'It's a piece of paradise and a piece of quiet. We like it because it's quaint and primitive,' explained Robert. Over the years, the Oteros' visits to Bimini have coincided with the growth of Bimini Bay. 'We watched them construct the resort through the pines. We used to spend the whole day at the beach. There was nobody there,' remembered Adrian. 'It doesn't do the islanders any good. It's changing their lifestyle. They need the income. But they are paying a huge price. They're losing their paradise.'

On my way out of Sea Crest I meet Alfred Sweeting Senior. His property is next door to Bimini Bay and there is something that he would like to show me. North Bimini is only 11 kilometres (six miles) long so it's a quick ride up to Al's house. We drive down to the edge of his lawn and look out at paradise. To my right our view is interrupted by a massive concrete pier that stretches hundreds of metres into the sea. The dock was completed in 2014 so that the resort could bring its casino ship in from Florida. The cruises ran for just over a year before being abandoned, although a new company has recently resumed operations.

The Sweetings' bright green lawn stretches from the road all the way down to the sea. In fact, it is literally crumbling into the sea. This is what Al wants me to see. Since the ocean floor was dredged to

Snorkellers stand on the wreckage of a Curtiss C-46 aircraft that crashed in 1986 during a smuggling operation off South Bimini. Despite its historical notoriety for smuggling and piracy, The Bahamas has developed into a world-class travel destination, attracting more than four million tourists each year.

build the pier, the west side of North Bimini has experienced massive land erosion. In just one hurricane season the entire beach disappeared. Al is fortunate that his house is about 100 metres (330 feet) back from the ocean, but his neighbours have had to build retaining walls – and even they are crumbling too. A little way down the road in the Bailey Town graveyard, I had watched contractors trying to build up the land to prevent tombstones from tumbling into the ocean. As we drive back towards the road, Al points up to the balcony that wraps around the second floor of his house. 'The view I get really turns me on. They didn't have this over there [Florida] and the ones that liked it always came back,' he says sadly.

Al and his home belong to a forgotten era. Less than 100 metres up the road beats the corporate heart of modern Bimini. A freakishly out-of-place concrete archway marks the entrance to Bimini Bay Resort and uniformed guards wave at me as I walk through it. The large fountains, paved footpaths and bright green lawns are a far cry from the potholed roads, colourful wooden houses and narrow pavements that I had seen throughout the rest of North Bimini. A few hundred metres from the gate a brand-new building glistens in the oppressive heat. The Hilton Hotel opened in June this year and boasts more than 300 rooms, multiple bars, pools and a casino. I gasp as I walk into the foyer. The air-conditioning has been cranked so high that my body is struggling to make sense of it. I look over at a group of semi-sober men in their late twenties who are juggling for space at the bar. 'There's a really nice pool on the fifth floor,' one slurs to his friends. This is a good place for tourists who want to go on holiday without feeling like they ever left home.

It's easy for nature lovers with foreign passports to lament the loss of paradise, but the resort has undoubtedly brought prosperity to some Biminites. The local population has grown from about 1,300 to closer to 2,500 and although locals have mourned the demise of their tight-knit community and the inevitable problems this has brought, businesses have grown and there are more opportunities on the island. The golf cart rental business, for example, is thriving and the general demand for supplies has grown as well. Percy Duncombe's family owns a fleet of carts and two supply stores on the island. He has a more balanced view on the resort. 'It's got its good points and its bad points. Being a small community, we needed something other than fishing to depend on. We needed to broaden our horizons. Right now we have grown from one small freight boat per week to about three freight boats a week. Before, you didn't have as much opportunity, you know? There were so many kids that would go to school in the States and not come back home. Now, with these opportunities, more of them are able to come back home and live back home,' he explains. However, despite his interests in the golf cart business, when it comes to the golf course, Percy is resolute. 'I don't think it's necessary to have a golf course. I think the resort is already big enough to satisfy the average tourist that comes to Bimini.'

These sentiments are echoed by Cardinal Bain, one of the activists mounting a campaign against the Hilton. 'We want to embarrass them. For hundreds of years we lived here and fished here. We don't need the resort if it costs us our ecosystem,' he tells me. 'Money changing hands makes a

A southern stingray *Dasyatis americana* swims over the head of a visitor during a ray feeding session at Honeymoon Harbour, a secluded beach on an island a few kilometres from Bimini. Unique marine life encounters like this have nourished the ecotourism industry on these islands.

A juvenile lemon shark *Negaprion brevirostris* is put into tonic immobility to be observed by high-school girls during an educational programme organised by Sharks4Kids. The Bimini Biological Field Station Foundation offers numerous outreach activities, from tours like this to working with documentary film-makers.

Charlotte Sams, a staff member at the Shark Lab, swims a tiger shark against the current to revive it after it had been put into tonic immobility while data were being collected.

Professor Samuel 'Doc' Gruber speeds away from the wreckage of *SS Sapona*. In addition to having studied sharks for more than 50 years and contributed numerous articles to scientific publications, Doc is the founder of Bimini Biological Field Station, more commonly known as the Shark Lab. Many leading shark researchers cut their teeth in the field at this world-renowned research station.

'Doc' Gruber throws bait to an approaching Caribbean reef shark *Carcharhinus perezi* while a group of snorkellers observes the feeding. The Shark Lab has been playing an active role in education by running tours for visitors and offering field research experiences to the public.


MERCURY

A Caribbean reef shark *Carcharhinus perezi* with its nictitating membrane half-closed bumps the camera at Triangle Rock, a popular spot for shark diving at Bimini. Sharks are protected throughout The Bahamas and their populations remain abundant, making the country one of the top destinations for shark diving in the world.

↑ Newspaper cuttings about the ongoing large-scale – and controversial – resort development at Bimini have been collected by a member from a local environmental group. Although the project has created more than 1,000 jobs for Bahamians, many Biminites fear that its impact on the environment will jeopardise their local economy and livelihoods, which have historically relied on a tourism industry based on the ecological richness of the island.

→ Bahamian boys play pool at the Bimini Big Game Fishing Club on North Bimini. Hailed as the sport fishing capital of the world, Bimini has long attracted game fishermen, including Ernest Hemingway. The author visited the island regularly and wrote the novel *The Old Man and the Sea* here in 1951.

strange creature of people,' he adds. Like most of the locals I have spoken to, he only hints at foul play between the government, developers and associated business owners. At present he works at a locally owned bar. His greatest fear is that if the development destroys East Wells, local businesses that have relied on it will fail and Biminites will be forced to find work at the hotel for minimum wage. Two hundred kilometres (125 miles) south-east of Bimini lies Nassau, the home of Baha Mar, a US$3.6-billion development that went bankrupt before it even opened its doors. If developers press on with their plans, the nursery habitat might never recover, destroying the remaining fish stocks and sending Bimini's longstanding client base to seek other, more tranquil getaways, perhaps in nearby Cuba, which is once again open to Americans. What if Bimini Bay fails? With neither a resort nor a functioning ecosystem, what will be left for Denver and his generation of Biminites?

A couple of kilometres north of the Hilton, I walk along a white sandy track that stretches northward. To my right, I watch in amazement as two manta rays glide over the reef and back out towards the horizon. To my left is a scarified wasteland. What would have been a mangrove forest is now hard beige land dotted with broken construction vehicles and half-built villas. After about 15 minutes of walking, I reach a hand-painted sign that reads 'Road to East Wells' in black block letters. Further along, I climb to the top of a man-made hill and look out. Beyond the box-shaped skeletons that will become exclusive homes, a large mass of flat land is being extended into the lagoon. Eventually the landfill will spread all the way across the North Sound to East Wells Island, where the last remaining expanse of mangroves not only is 'God's own nursery', but has also protected Biminites from hurricanes for centuries. I continue along the road until I reach a barrier that marks its end-point. Another sign reads 'End of Phase 1'. For two decades, the Biminites' protests have gone unheard while the development crept eastwards and they watched it happen like frogs in a pot, adjusting to the slowly warming water and mutely hoping for the best. But, as phase two moves in, life on Bimini is set to reach boiling point.

A few days before leaving the island, I find myself on a small boat watching a glowing wake stream out behind us. It's 2.30 in the morning, the ocean is dead calm and the bioluminescence is on display. We are out on a long-line check for a tiger shark research project. Félicie Dhellemmes, a PhD student from France, is driving the boat; at 25, she is the oldest of the all-woman crew of Shark Labbers. I have been amazed at the competence and autonomy exhibited by the lab's team of young adults. Now we move slowly as a crew member shines a spotlight onto the line of equally spaced hooks, exhaling in unison at the sight of a huge shadow resting near one of the buoys. Félicie takes hold of the line and tries to pull the shark up to the side of the boat. The huge animal has only just been hooked and immediately starts to thrash, pulling the boat in a circle. My heart is bashing around in my chest and it dawns on me that I have not been this excited for a very long time. With almost no fuss, the Shark Labbers work up the 2.8-metre female tiger shark and we all watch her swim off into the darkness.

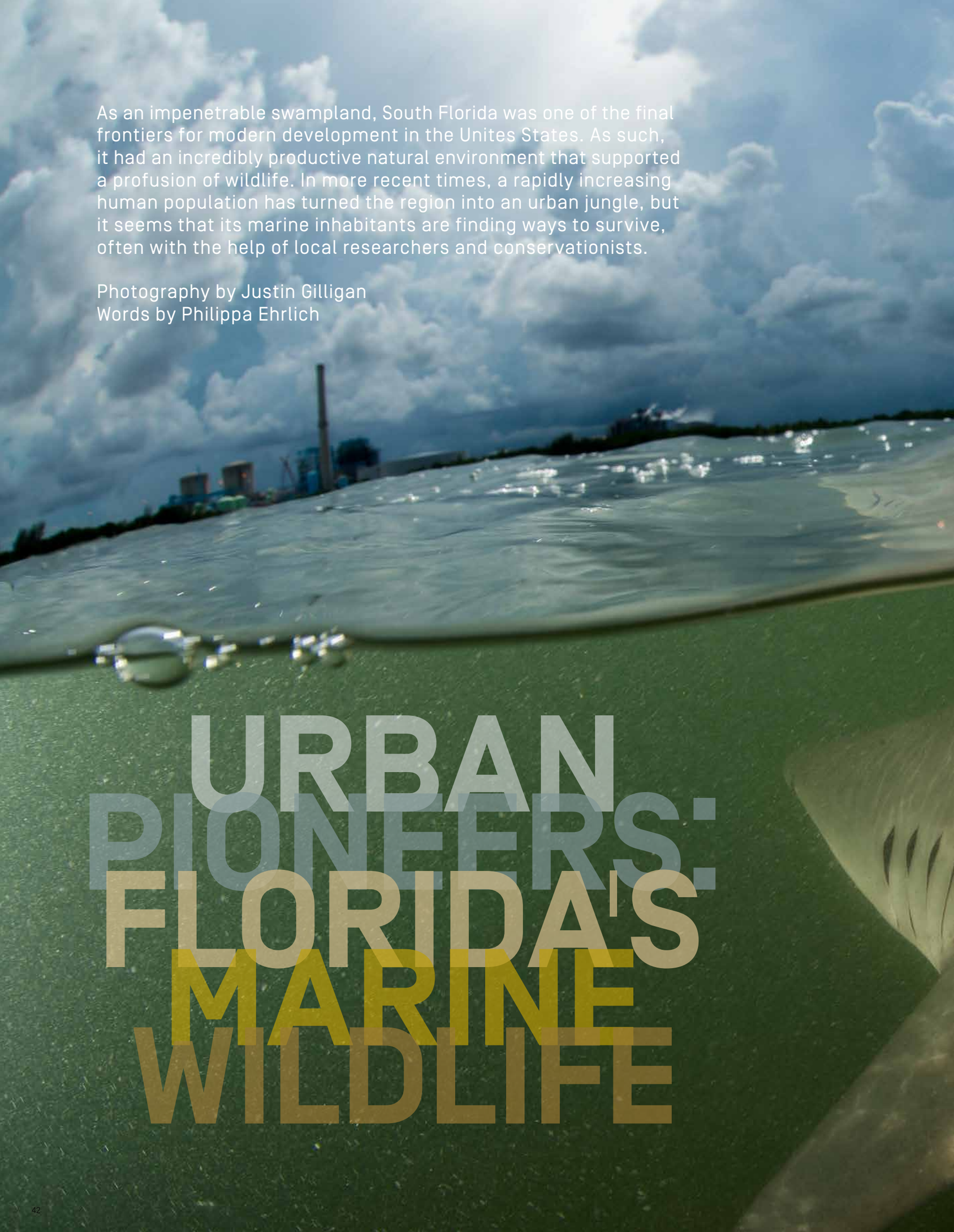
As we head back towards the Shark Lab, the sky is a shade lighter and I am torn by a strange juxtaposition of emotions. I feel elated by what I have just experienced: to have come that close to such a visceral force of nature and shared the experience with the Shark Labbers. At the same time I feel a deep sense of sadness as I look back at the lights over North Bimini. As tenants in The Bahamas, the Shark Lab community cannot get involved in the fight to save East Wells, but they will continue to study here and document the changes as they happen. They and Denver Stuart may come from different worlds, but they are all driven by a similar force: to understand and immerse themselves in the natural wonders of Bimini. Perhaps by continuing to do and share what he loves, Denver will move other Biminites to call for a more sensible approach to these little 'islands in the stream'.


IYW

On a humid weekend evening, a crowd enjoys live music at Stuart's Conch Shack, a popular spot frequented by both locals and tourists. Being so close to Miami, Bimini is an easy getaway for tourists and there are ongoing developments on the island to accommodate larger-scale tourism.

A behavioural researcher from the Shark Lab works inside a shark pen housing a large number of juvenile lemon sharks *Negaprion brevirostris*. The lab's scientific research has provided critical information to support elasmobranch conservation and has led to the establishment of a shark sanctuary in The Bahamas and lemon shark protection in Florida, among many other successes.

A visitor pets a juvenile lemon shark *Negaprion brevirostris*. The young sharks are being reared in captive pens as part of behavioural experiments by researchers at the Shark Lab.



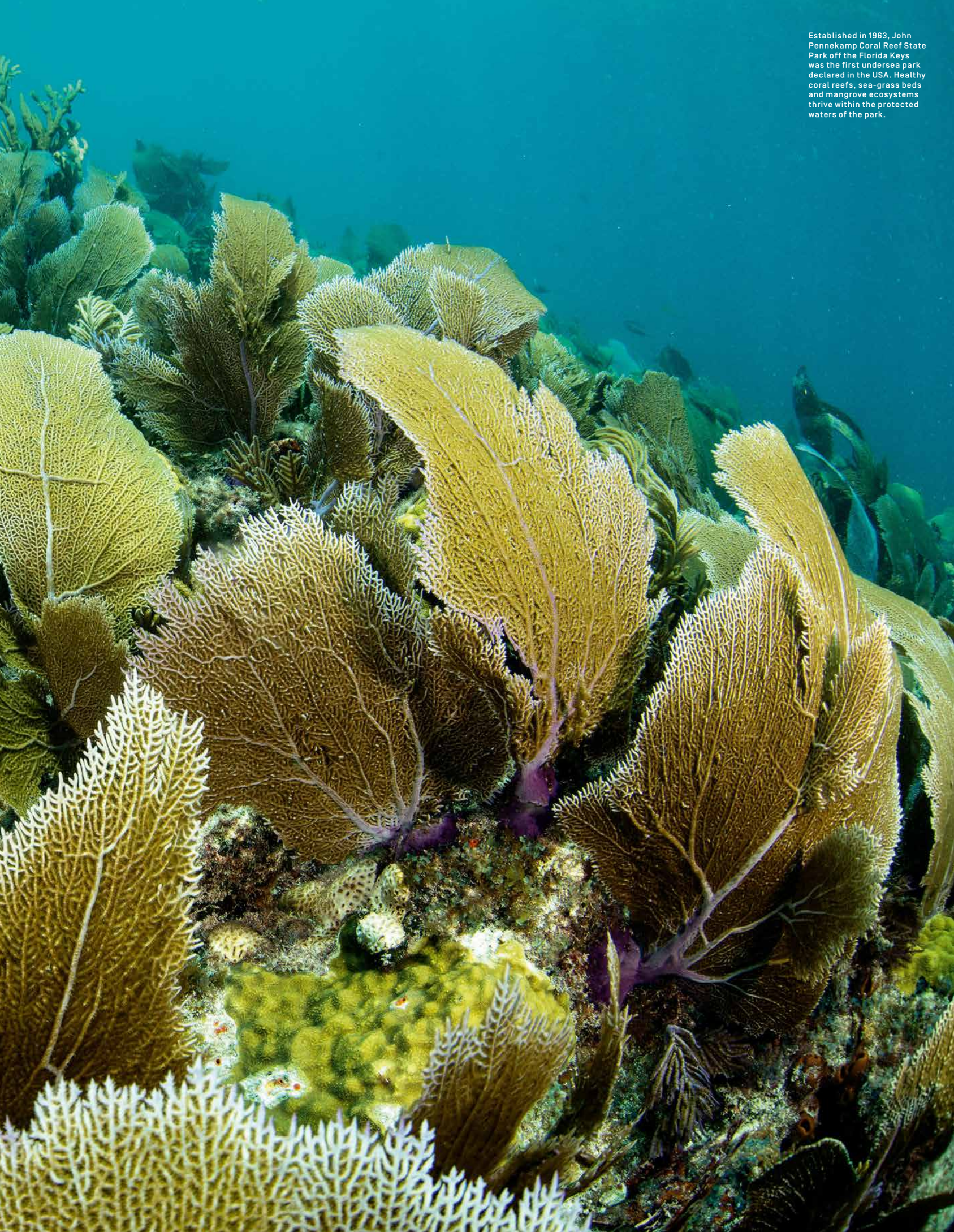
As an impenetrable swampland, South Florida was one of the final frontiers for modern development in the Unites States. As such, it had an incredibly productive natural environment that supported a profusion of wildlife. In more recent times, a rapidly increasing human population has turned the region into an urban jungle, but it seems that its marine inhabitants are finding ways to survive, often with the help of local researchers and conservationists.

Photography by Justin Gilligan
Words by Philippa Ehrlich

URBAN PIONEERS: FLORIDA'S MARINE WILDLIFE

Following investigation by the University of Miami's shark-tagging team, a blacktip shark *Carcharhinus limbatus* is released back into Biscayne Bay opposite the Turkey Point Nuclear Generating Station.

Hundreds of party-goers flock to the Haulover Sandbar on the Intracoastal Waterway north of Miami during the Fourth of July Independence Day holiday.



Established in 1963, John Pennekamp Coral Reef State Park off the Florida Keys was the first undersea park declared in the USA. Healthy coral reefs, sea-grass beds and mangrove ecosystems thrive within the protected waters of the park.

As sea levels rise, they are threatening premium stretches of beachfront in front of multi-million-dollar condominiums. Beach restoration is a common preventative measure on beaches in South Florida. Many of these sites overlap with turtle nesting habitat.

Just before midnight on a South Florida beach, a massive sea turtle comes to land on hard, wet sand at the edge of the surf. She hesitates. All her senses strain to pick up any imminent threat. This is the third time she has come up onto this beach tonight; twice she has U-turned, disturbed by voices or unfamiliar vibrations. By now she is frantic. It has been two years since she last came to nest and she will come ashore between three and five times before the end of the season. Eventually, satisfied that she is safe, she uses her powerful flippers to force her body up the sand. In the water she can move like lightning, but on land it feels like she's trying to propel herself through treacle syrup.

About 100 metres away, two colleagues and I sit in silence, watching the heavy black shape push herself up the sand. Behind us is a wall of high-rise buildings, as there is along most of the coastline of south-eastern Florida – although Jupiter is positively parochial when compared to the urban jungle of Miami further south. It is a perfect mild evening and, apart from a few red lights in the distance, the beach is completely dark. My companions are photographer Justin Gilligan and Dr Jeanette Wyneken, a leading turtle expert and professor at Florida Atlantic University. Jeanette has been working in South Florida since 1984 and has been based at Jupiter since 1990. Both Jeanette and Justin are anxious to get what they need from this turtle and we have already seen a number of U-turns tonight. The trick is to wait for her to start laying, when she will go into a kind of trance and allow us to get up close.

After some time, Jeanette signals that we can approach. We walk along the shoreline until we find the end of the turtle's track. From the interlocking strokes in the sand, Jeanette can tell that this is a loggerhead, a widespread and highly migratory species that is known to cross the Atlantic and Pacific oceans. We approach the turtle carefully from behind and Jeanette squats down next to her nest, pulling from it what looks like a soft white ping-pong ball. Loggerheads lay roughly 100 eggs at a time and it will take about two months for the young to hatch. 'The hatchlings find their way to the water by fleeing tall, dark silhouettes. If there is a bright light, they are attracted to or disoriented by it, so instead of finding the sea, they are trapped by the light,' she explains.

Finding a way to deal with light trapping was one of Jeanette's first challenges when she arrived in Florida. At that time, it was not unusual for her to get phone calls from Floridians saying 'We've got sea turtles in our swimming pool', 'We've got sea turtles in our parking garage' or 'There are sea turtles crawling onto the highway'. Much of the local human population is made up of retirees, so adequate lighting of beaches and buildings at night is a legitimate concern. Jeanette and her colleagues had to find a way to balance people's needs and those of the turtles.

'A lot of this has been an exercise in learning from people who do lighting,' she says. 'There have been several approaches and one of them was to understand what the turtles see. They don't see red light, or at least not very well. When we found that out, we thought, "Okay, the turtles don't see this spectrum of light very well, but people do." That gave us a tool that would enable people to see without disturbing the turtles.' Having found a way to avoid disrupting the turtles' breeding attempts, she and her team then had to embark on a long-term education programme to inform Florida's local municipalities and building managers and get them on board. With new people constantly trickling into the state, public education about lighting is an ongoing challenge.

As the turtle's nest fills with eggs, Jeanette reaches over to touch her shell and I watch in amazement as a glowing zigzag follows her finger down the length of the carapace. The turtle

Dr Jeanette Wyneken of Florida Atlantic University examines a green turtle *Chelonia mydas* that is returning to the sea after nesting on Juno Beach. A major focus of Dr Wyneken's research is to study the adaptations of the turtles to urban threats. This individual was photographed using red torchlight, in accordance with research permit MTP16-073.

has carried a thin layer of bioluminescence up the beach with her.

'Florida is producing virtually all the turtles in the North Atlantic – probably about 85%. So what happens to these animals in the Atlantic is driven by what happens here,' explains Jeanette. Last year more than 15,000 loggerhead nests were recorded in the region, as well as 700 green turtle and 160 leatherback nests. For these animals, lighting is not the only challenge. 'If you were to go back and look at what was happening in the late 1990s and early 2000s, the numbers then were declining and declining,' she continues. 'Now we are seeing a big increase in loggerheads and that coincides with the implementation of the turtle excluder devices (TEDs).' The deployment of TEDs in Florida was a major conservation success and meant that this population of loggerheads is still classed as Vulnerable rather than Endangered.

Although TEDs may mitigate some anthropogenic threats, there are others that are harder to deal with. Turtles cannot outrun temperature increases and with cyclical as well as general global warming, this is a growing concern. Eggs and embryos are particularly vulnerable. Typically the hatching success rate is between 70 and 75%, but with last year's El Niño it dropped to between 23 and 28%. Most of the embryos did not even develop and others died in the nest. Temperature also impacts gender ratios. There are always more females born than males, but last year all the hatchlings were female.

Another problem is Florida's growing population of enthusiastic boaters. 'When a turtle floats up dead, the most common thing is we don't know what happened. The second most common thing is that it's been hit by a boat,' says Jeanette. Turtles did not evolve with ocean traffic and educating boaters about how to avoid turtles that are coming up to the surface to breathe is the latest frontier of turtle conservation in Florida.

It's now about 2 am on the beach and the loggerhead has covered up her nest and is starting her painfully slow return to the sea. It takes her many minutes to reach the surf, but as soon as she is immersed in water deep enough to float her huge body, she seems to dissolve into the dark Atlantic.

Loggerheads grow to more than a metre (three feet) in length and there are records of adults weighing over 200 kilograms (440 pounds). Scientists are not sure how old these turtles get, but they only become sexually mature at about 35 years. An adult this size could be twice as old as that and when she hatched sometime around the 1950s, Florida – or 'the Sunshine State' – would have been a very different place. Jeff Trotta grew up in North Miami Beach in the years just after World War II. 'In one lifetime we went from being a fairly low-density population to being one of the highest in America,' he says. 'There was an enormous influx of people from the 1940s into the mid-1950s. The population just kept on growing and eventually Miami became a large city. Florida was still regarded as an exotic location and housing prices were cheap because agricultural land was being used for building.' With a current population of more than 20 million, Florida is now the third most populous state in the USA and, after California, attracts the second highest number of tourists.

The state's unique ecosystem is one that has been most impacted by human-induced change. The Everglades was a vast swampland created by brackish waters in the south merging with fresh water flowing out of Lake Okechobee in the north to form a very wide, shallow and intermittent river. But the draining of this enormous wetland has turned it into the largest water drainage district on the planet. 'There's only one of this type of system in the world and we're it,' explains Jeff. 'But it's been channelised and dyked and ditched and reclaimed and built on, so now we have a much smaller area and it is under pressure

The Gulf Stream pushes nutrient-rich waters along the east coast of Florida, providing a buffet for this rich ecosystem. Shark diving and game fishing are the major tourism activities in these waters and often sharks, such as this silky shark *Carcharinus falciformis*, bear evidence of encounters with humans during the latter pursuit.

because the water isn't going where it would naturally flow. If they didn't keep pumping it out, the Everglades would return.' Although now no more than a fraction of its original size, the Everglades is still a critical wildlife habitat for numerous species, including the smalltooth sawfish, and continues to play a critical role in shaping the marine environment of southern Florida.

The secret behind the Sunshine State's enduringly abundant and diverse ecosystem is the waters that feed it. There's the Gulf Stream, a flow of warm, clear water pumping a few kilometres offshore that is loaded with plankton. And combining with this, a nutrient-rich outflow of sediment and silt pours out of Florida Bay, while what remains of the Everglades provides a rich smorgasbord for the entire marine food web.

The effect of this bounty can be most clearly observed in the Florida Keys, a chain of limestone islands that formed between the Gulf of Mexico and the wider Atlantic Ocean. 'If you look at the morphology of the keys, you see an opening in the chain of islands, a major pass where water flows into and out of Florida Bay and bathes the edge of the shelf. That is where there are really high concentrations of sharks and sawfish because that is where the productivity is,' explains Dr Dean Grubbs, the current president of the American Elasmobranch Society and associate director of research at Florida State University. He has been studying the habitat use of sawfishes in the Everglades since 2010. 'Most of the nursery grounds occur in the 10 000 islands of the Everglades National Park region and then the adult habitat occurs from the southern part of the Everglades throughout the Florida Keys,' he adds. The Florida Keys National Marine Sanctuary protects 2,900 square nautical miles of water and includes the world's third largest barrier reef, extensive sea-grass beds and mangroves, as well as more than 6,000 marine species.

It's mid-afternoon on the overseas highway. Beyond the narrow bridge Justin and I are driving along, the view stretches across overwhelming spaciousness to distant horizons in all directions. Belying the general perception of 'overseas' as an exotic, faraway destination, the overseas highway is a 182-kilometre-long concrete snake built literally over the sea to link the islands of the Florida Keys from Miami in the north to Key West in the southwest. We are currently travelling between Islamorado and Upper Matecumbe Key. At the end of the bridge we take a sharp right into Robbie's Marina, a famous spot where visitors can get a taste of what this part of Florida is all about. I hear shrieks of excitement long before we reach the large pier that juts out just to the left of a busy restaurant. People are queuing to buy buckets of bait and out on the jetty parents dare their children to lean out over the water and tempt the monstrously large fish below. I watch as a little girl recoils in shock as a huge tarpon, black mouth agape, smashes through the surface and relieves her of her offering. With wide eyes and a pale face, she quickly hands her bait bucket to an older sibling. There is a lot of commotion on the other side of the pier where visitors are jostling to get a glimpse of a blimp-shaped grey creature that has just surfaced. The somewhat mangy-looking manatee is much smarter than it appears. Almost on cue, one of the well-trained visitors picks up a hosepipe to spray fresh water onto the animal, which happily twitches its whiskery face in thanks. Its shower is interrupted by a woman who scolds the onlookers for encouraging the manatee; with so many boats moving in and out of the marina, this is a dangerous place for it to be.

This may be far from a pristine wilderness, but when it comes to meeting some of Florida's wild inhabitants, Robbie's Marina is guaranteed to deliver. You can see manatees, brown pelicans and tarpon within half an hour and if you get here at the right time, you will be treated to the feeding of conditioned nurse and

Dr Kim Bassos-Hull of the Mote Marine Laboratory & Aquarium investigates the life history, reproduction and population status of the spotted eagle ray *Aetobatus narinari*, a species that is protected in Florida but vulnerable in the rest of its range.

lemon sharks as well. Despite having one of the largest shark fisheries in the USA, Florida has followed the global trend in adopting a more understanding attitude to sharks in recent decades. 'I think opinions have changed dramatically in the past 20 years. Twenty years ago, if you brought a great hammerhead into a dock in the Florida Keys, everyone would want to come and see it. They would want to take photos with it and that kind of thing. If you were to do that now, you had better get security, because people are going to be after you. Folks just don't tolerate that sort of thing any more,' reflects Dean.

It is fortunate that residents of the Sunshine State have learnt to tolerate sharks because as Florida's urban jungle has evolved, the previously separate realms of people and elasmobranchs are becoming increasingly enmeshed. This is perhaps most apparent from January to March, when phenomenal numbers of blacktip sharks migrate up the coast of south-eastern Florida towards the Carolinas. Remarkably, there are very few negative incidents between sharks and people during this time. In 2015 there were only two cases of people being bitten and neither was life-threatening. 'It is a steep continental shelf and you get animals concentrated along that shoreline because it gets deep so quickly,' Dean explains. 'There are aerial images of just thousands and thousands of blacktips migrating right off the beach and all along it there are skyscrapers and hotels and condos.'

It was this view from the air that motivated Neil Hammerschlag of the University of Miami to initiate a research project that hopes to understand how sharks are faring in Florida's increasingly urbanised seascape. 'We were on a plane looking over Miami and I was just amazed at how built up it is. Everywhere, even in the water, was just built up and there were skyscrapers and boats everywhere. I just thought, where can you go if you are an animal? Where can you seek refuge? It's got to be a tough life,' remembers Neil. 'We have a lot of data from all over the world, but really what we know about sharks is coming from less impacted areas. What about the animals that are living among people in urban environments? There are probably going to be winners and losers when it comes to living an urban lifestyle.'

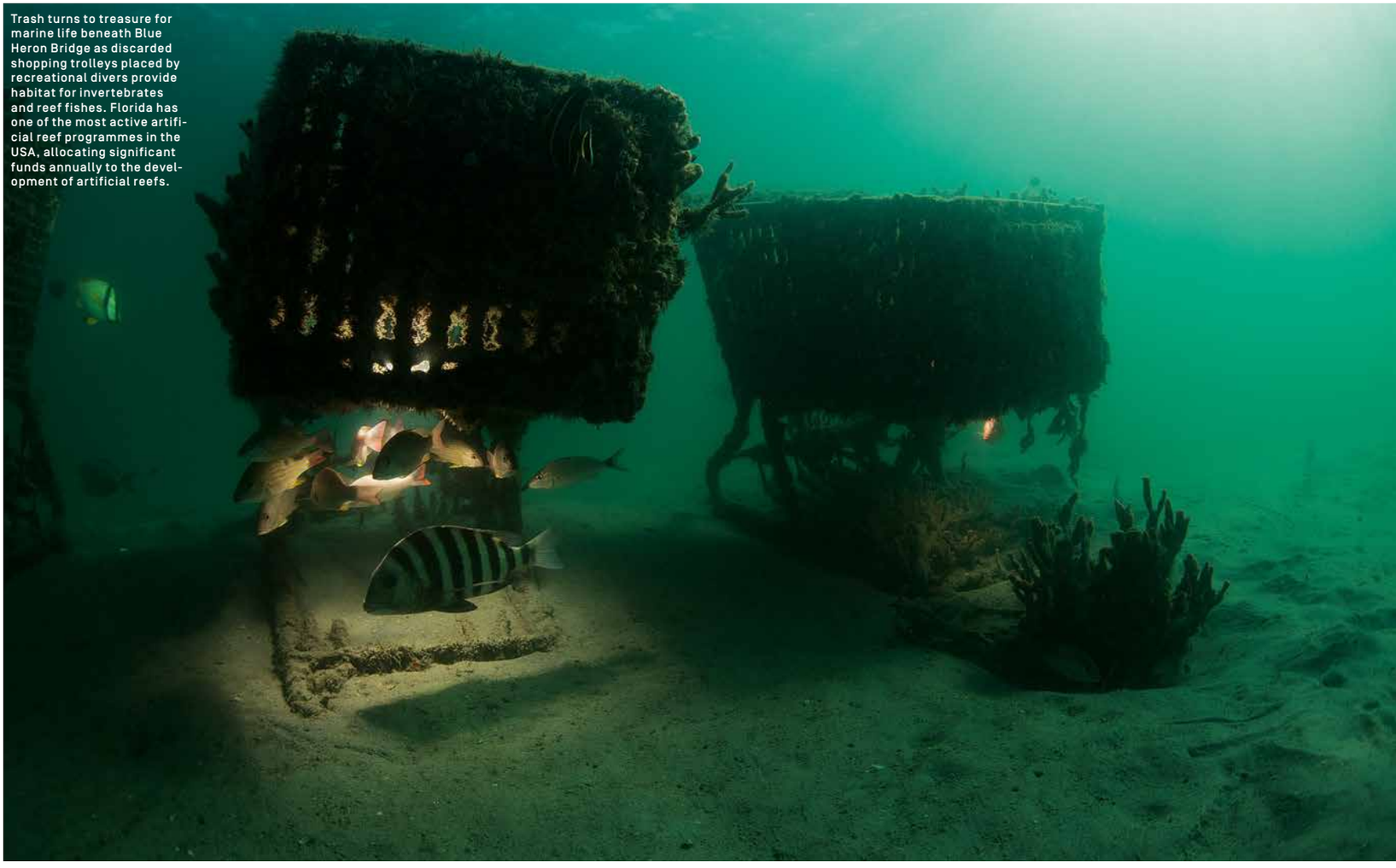
Working between Biscayne Bay in the north and the Everglades in the south, Neil is using tracking technology as well as physiological data to investigate who these winners and losers might be. The species he and his team encounter most are bull sharks, blacktips, nurse sharks and hammerheads. In addition to tagging the animals, they are looking at hormones like serotonin and trying to understand the sharks' nutritional condition by testing triglycerides and the amount of fatty acids. Much of this research is fundamental, as we will have to learn what a hormone like serotonin means for sharks before this knowledge can be applied specifically to an urban environment.

In addition to the more obvious threats like habitat loss and decreasing food stocks due to fishing pressure, the sharks face a number of water-related stresses such as pollution, higher temperatures and changes in salinity. The project is still in its infancy, but Neil has already seen some interesting results. 'On the first download we seem to be picking up the animals moving north to south across our different arrays, but they weren't being detected in front of canal mouths. This is surprising, but it also kind of makes sense because this is where there are outflows and they are really not nice environments. I think the sharks can detect the increase in nutrients and salinity because we are not picking them up in front of those spots, which suggests to me that they must be moving beyond the detection range,' he explains. Boat traffic is also a serious concern, above and below the surface. 'One of the issues we have is how much noise we


Bud n' Mar
Press

Historically the Florida Keys was a celebrated destination for big game fishermen, with large sharks being prized catch. Today there has been a shift in public attitudes towards sharks, with Floridians being more tolerant, respectful and conservation minded.

Tourists flock to Robbie's Marina on Islamorada to feed tarpon *Megalops atlanticus*. Before casting off they have the opportunity to see various representatives of the local wildlife, including tarpon, lemon sharks and manatees.

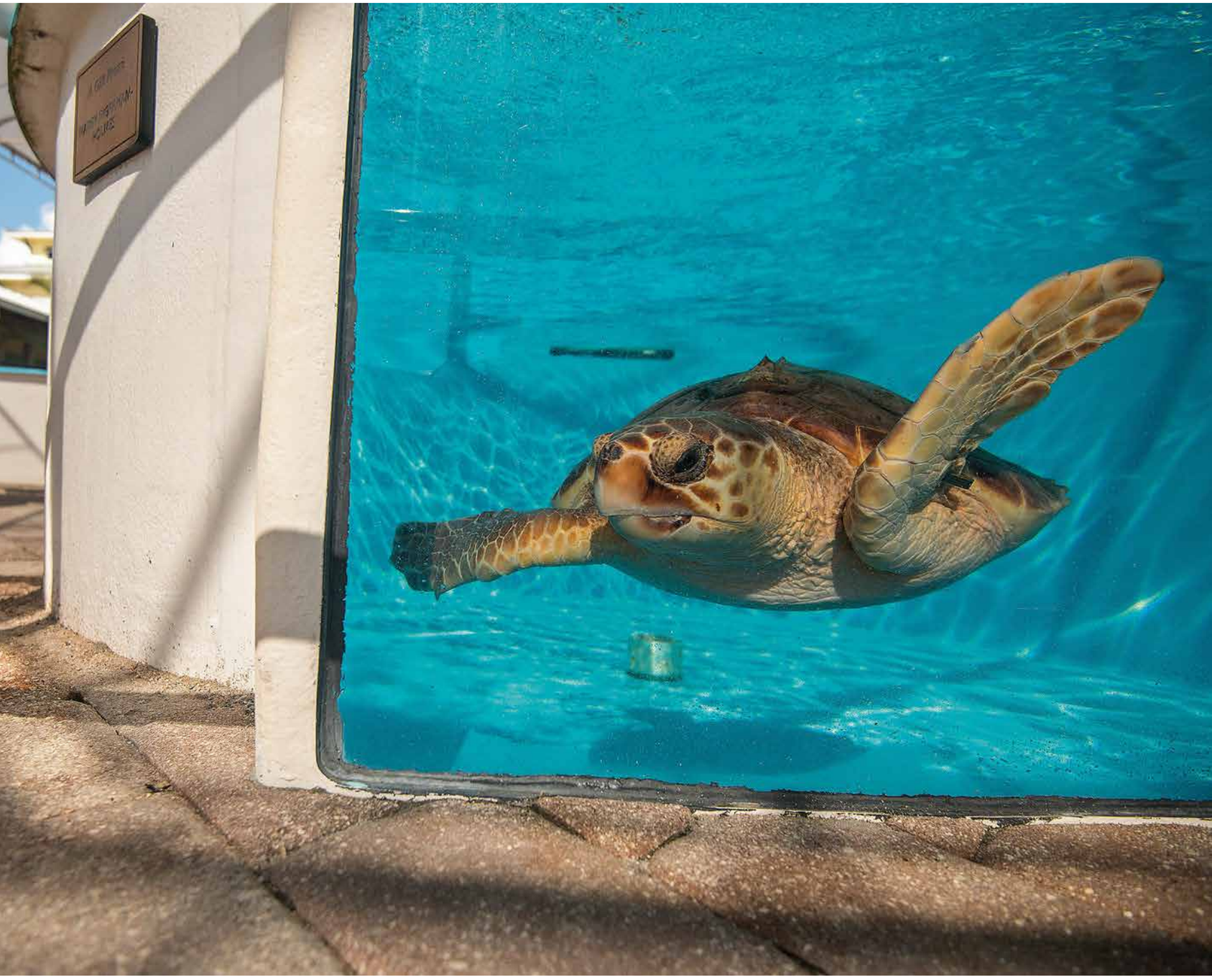


Trash turns to treasure for marine life beneath Blue Heron Bridge as discarded shopping trolleys placed by recreational divers provide habitat for invertebrates and reef fishes. Florida has one of the most active artificial reef programmes in the USA, allocating significant funds annually to the development of artificial reefs.

A nurse shark *Ginglymostoma cirratum* is secured alongside a University of Miami research vessel near downtown Miami. The research is part of a project investigating shark movements and habitat use in urban environments.

Leila AtallahBenson, a Masters student with the University of Miami's Shark Research & Conservation Program, says that tiger sharks represent everything she aspires to be: a strong, healing, independent soul driven by the will to survive and embodied by pure grace, elegance, beauty and power. Here she prepares a set line in front of the downtown Miami skyline for the urban shark-tagging project.

A juvenile brown pelican *Pelecanus occidentalis* watches the passing crowd at Robbie's Marina on Islamorada. Robbie's is a gateway for tourists to explore the Florida Keys on charter vessels that offer kayaking, snorkelling, diving, fishing and partying.



Loggerhead Marinelife Center at Juno Beach is committed to the rehabilitation of sick and injured sea turtles. Its prime goal is to return each rehabilitated turtle, including this loggerhead *Caretta caretta*, to the ocean as quickly as possible.

pick up on receivers. I have never seen that before. The amount of disturbance from noise is mind-blowing,' he adds. 'You have to remember, as humans we have a lot of choices. When we are dealing with our day we are thinking about things like dinner and what we would like to eat. Every single day, life for these animals is "just survive".'

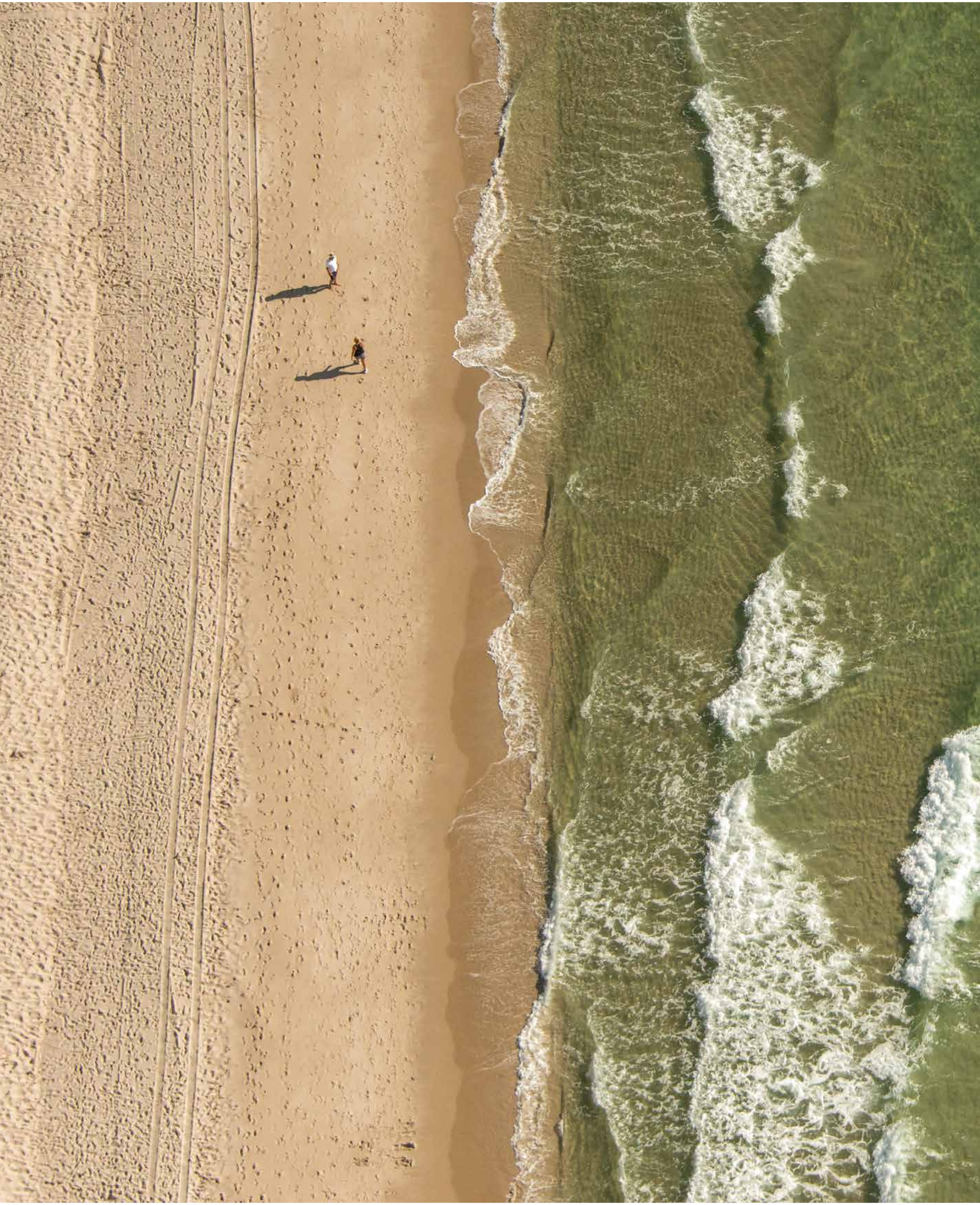
Fortunately for the survival of some species, Floridians offer a helping hand. On my last day in Florida I find myself on a large dive boat heading away from the shore of Jupiter Beach and out towards the mighty Gulf Stream. This trip has been organised by the Loggerhead Marinelife Center (LMC), in collaboration with a local dive company. In addition to running an impressive public education programme, the centre plays a critical role in conserving the local turtle population by monitoring nests and rehabilitating about 100 injured sea turtles every year. Today we are making the trip to release a green turtle named Susan. She is on the deck, strapped to a turtle-shaped stretcher, and has been at the centre for almost a year after colliding with a boat. Next to her are two large, flat Tupperware containers writhing with turtle hatchlings that did not make it to the sea on their own. Once we reach the open ocean, the boat slows and the LMC team lifts Susan to the end of the boat and releases her into the water. For a turtle that has been in captivity for so long, she moves pretty quickly and barely gives us enough time to get a photo before she is gone.

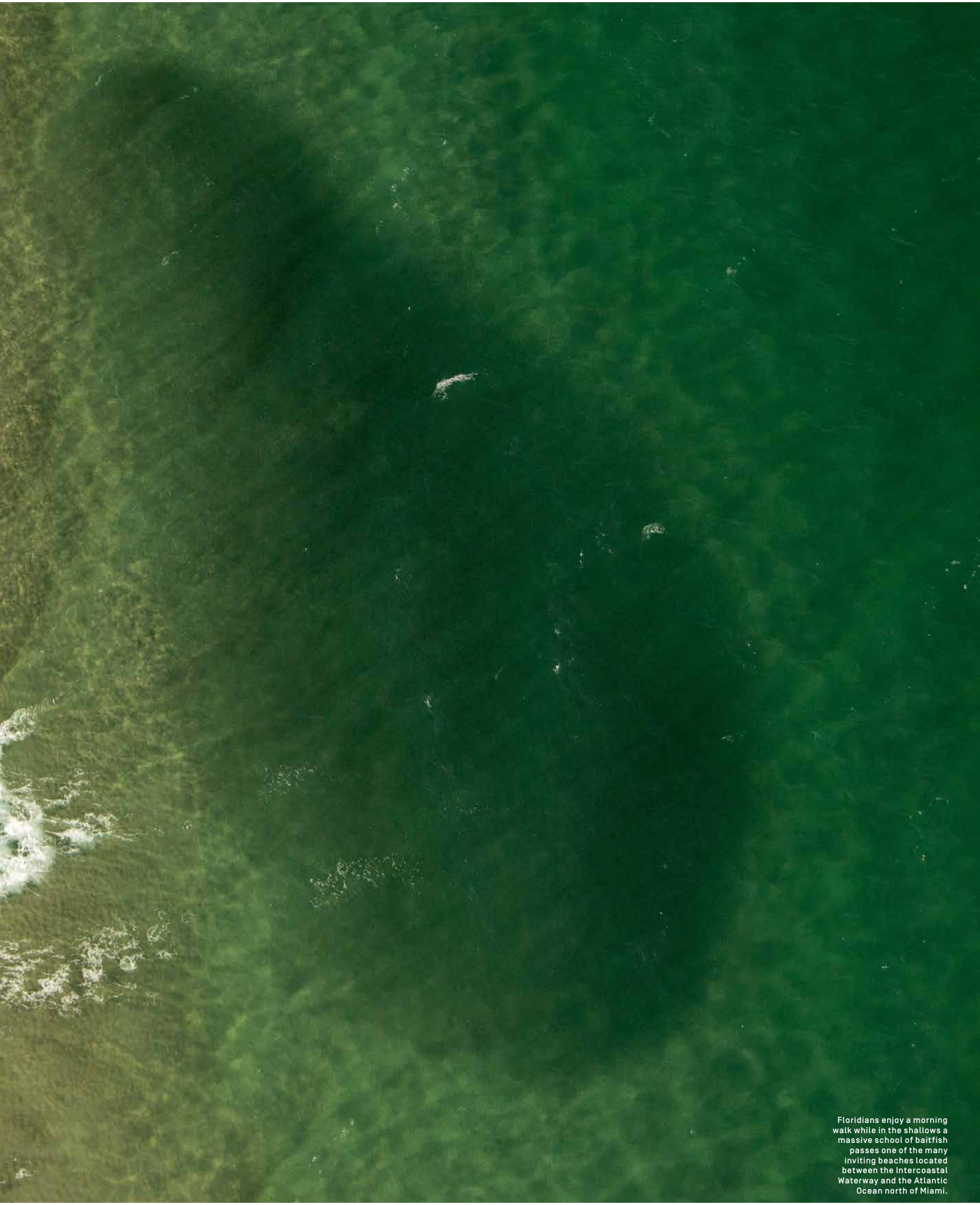
Releasing the hatchlings is a more complicated procedure as we need to find a decent-sized mat of sargassum. These floating islands of seaweed provide a critical space for the young turtles to hide in and find food. Being about as big as a quarter, the little animals need as much protection as they can get. After more than an hour of searching, we eventually find what we are looking for and I drop into the deep, clean waters of the Gulf Stream to follow the procession of tiny turtles that are being released one by one. I have never seen a young animal with a survival instinct as frantic as that of a newly hatched turtle. From the second it is born, its 'swimming frenzy' will last for up to a few days, until it reaches the open ocean. Even inside their container,

the little creatures were desperately 'swimming' over one another. Now in the water, I watch in amazement as they nestle into the sargassum, pull in their flippers and float like a motionless army of marine Mars bars.

It is humbling to see these tiny parcels of life begin their journey within the immensity of the Atlantic and I am reminded of a thought I have had over and over during my time in Florida. As humans, we have spent thousands of years learning how to pioneer our way into natural places and we have been extremely successful. Yet nature is designed to continue and somehow in Florida our fellow species are finding ways to forge their futures in the environments that we create. 'Sometimes I am aghast, you know? I have dived in some of the most remote places in the world. And yet you can go to Palm Beach County, Florida, and jump into the water and anything can happen – and it does. It's still pretty good, you know?' Jeff Trotta had said during our interview a few days earlier. Looking back at the busy city skyline while surrounded by an army of tiny loggerheads, I have to agree with him.

Veterinarians at the Loggerhead Marinelife Center do regular check-ups of the turtles in their care to monitor their rehabilitation. The centre is equipped with a surgical suite, X-ray room, blood work lab, endoscope and ultrasound to carry out a stringent treatment protocol from rescue to release.





Floridians enjoy a morning walk while in the shallows a massive school of baitfish passes one of the many inviting beaches located between the Intercoastal Waterway and the Atlantic Ocean north of Miami.

Paul Verian of Finn-Atic Fish Co. bags a speared lionfish *Pterois volitans* off Fort Lauderdale. Commercially exploited to supply restaurants throughout the USA, this invasive species is thought to have been introduced through the aquarium trade. In the absence of predators, it has thrived off Florida and in the Caribbean.


NSU
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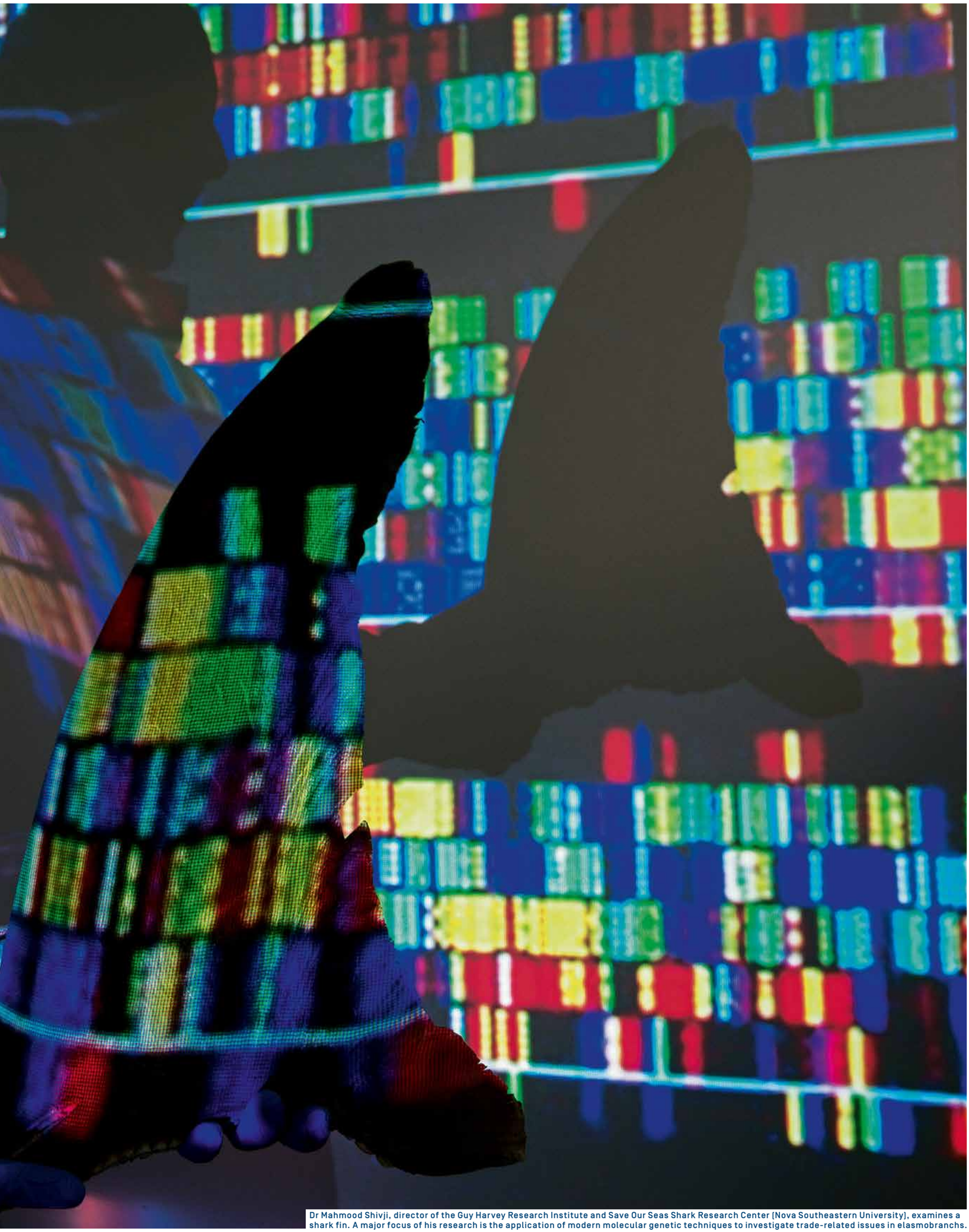
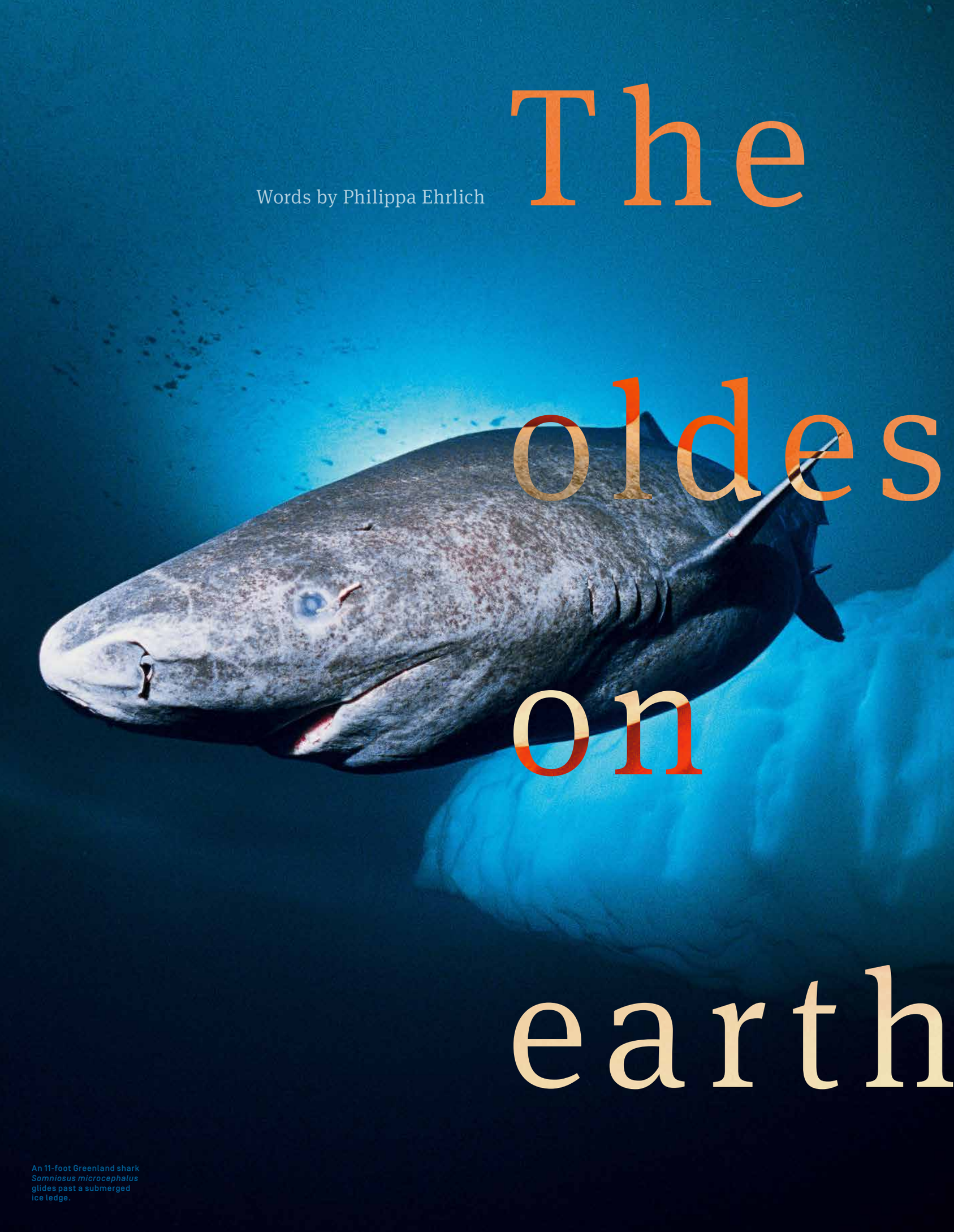


Dr Mahmood Shivji, director of the Guy Harvey Research Institute and Save Our Seas Shark Research Center (Nova Southeastern University), examines a shark fin. A major focus of his research is the application of modern molecular genetic techniques to investigate trade-related issues in elasmobranchs.

The oldest on earth

Words by Philippa Ehrlich



An 11-foot Greenland shark *Somniosus microcephalus* glides past a submerged ice ledge.

We don't know much about what Greenland sharks do, but we do know that whatever they do, they do it painfully slowly – and this results in an astonishingly long lifespan. Peter Bushnell and his colleagues recently published a landmark study in Science that reveals just how long these enigmatic sharks live.

For societies of hunters and fishermen in the Arctic Circle, the Greenland shark that was once a critical resource has become a source of great irritation. For centuries, these First Nations hunted the mysterious, deep-dwelling carnivores for oil for their lamps and food to power their all-important sled dogs. But in more recent years, Greenland sharks have become a nuisance – to the extent that in some places a bounty is paid for their hearts. And according to a recent article published in *Science*, these hearts are among the oldest vital organs on our planet.

Greenland sharks are notorious for getting themselves entangled in the long-lines and gill nets that fishermen depend upon to make a living from catching halibut. In 2009 it was reported that the sharks made up more than half of the waste disposed of by residents of Uummannaq, a small town on the western coast of Greenland. At the time, technology experts were suggesting that Greenland shark remains be turned into biofuel and that shark by-catch could supply the town of 1,300 people with 13% of its energy needs.

This assessment caught the interest of Dr Peter Bushnell, a biologist at Indiana University South Bend, and Dr John Steffensen at the University of Copenhagen, who realised that the Greenland shark could be the subject of a case study for research that Bushnell was carrying out with Dr Richard Brill of the Virginia Institute of Marine Science. Bushnell and Brill's studies in Virginia examined the potential of electropositive metals to reduce shark by-catch. After six months of experimenting in Greenland, the shark repellent proved to be ineffective, but the shark with the coldest and most northerly distribution in the world had captured Bushnell's and Steffensen's curiosity. 'The more we delved into it, the more interesting and odd it got to be,' explains Bushnell. 'These are incredibly large, slow-growing, mysterious animals and we know very little about them.'

The Greenland shark is the largest elasmobranch native to polar waters and can be found all along the Arctic Circle from eastern Canada to north-western Russia. Between 1770 and 1963, thousands of Greenland sharks were harvested for their livers, which provided oil for lamps. Trade reports suggest that every year from 1890 to 1940 more than 30,000 animals were killed in Greenland's waters alone. This brief period of commercial importance gave rise to studies by Danish and Norwegian researchers, but for the most part the Greenland shark has remained what Bushnell describes as 'an enigma wrapped in a conundrum'. And the more he tried to unwrap it, the more interesting and bizarre it became.

Growing to more than five metres (16 feet) in length and weighing more than 1,000 kilograms (2,205 pounds), the Greenland shark is one of the largest predatory shark species in the world. But when Bushnell first encountered these giants, it was not just their size that struck him. 'I was amazed at how large they were – and even more amazed at how lethargic they were. They just lay there. When we caught them on a long-line, it was sometimes difficult to tell a live one from a dead one.' It is not hard to imagine why scientists named the shark *Somniosus microcephalus*, meaning 'sleepy little brain'.

Their lack of speed notwithstanding, most Greenland sharks have hitchhikers that dangle from the surface of their eyeballs: parasitic copepods that attach themselves to the cornea. Scientists suspect that the presence of these seven-centimetre (three-inch) hangers-on may render the sharks partially blind, but as they exist in such a deep, dark world, it is doubtful that they have much use for sight anyway. Greenland sharks are usually found between 300 and 600 metres (1,000 and 2,000 feet) deep but have been tracked to beyond 1,800 metres (6,000 feet). The frigid water temperature at such depths ranges between -1 °C and 6 °C (30 °F and 43 °F) , which makes it possible for the species' metabolic rate to be very low. This, in turn, leads to one of the most startling of all this enigmatic shark's mysteries: its incredible lifespan.

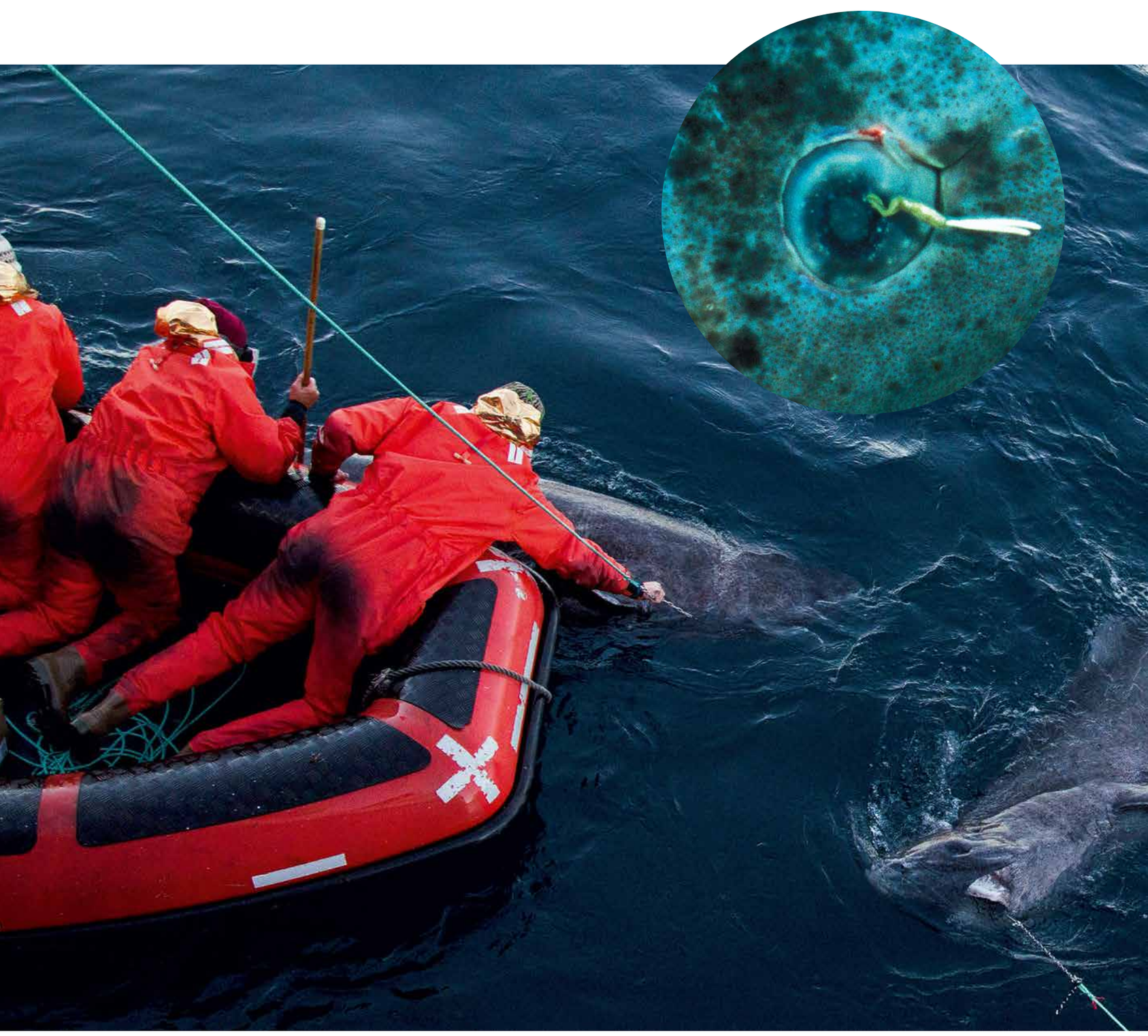
Ironically, the key to this secret lies in the lens of the Greenland shark's parasite-infected eyeballs. With the help of a group of international collaborators, Bushnell, Steffensen and Julius Nielsen (a PhD student from the University of Copenhagen) applied a radiocarbon dating technique to the shark's eyeballs that has never been used with animals before. In doing so, they have dragged the Greenland shark from relative obscurity to the heights of biological fame as the oldest known vertebrate species on the planet.

A crucial element of Bushnell's study is the atmospheric bomb pulse – a radical injection of carbon-14 (a kind of radioactive carbon) into the atmosphere – that resulted from the testing of hydrogen bombs in the mid-1960s. This sudden and dramatic increase in carbon-14 (bomb-carbon) was quickly incorporated into both terrestrial and marine environments, making all creatures living at the time part of the world's largest chemical-tagging experiment. The higher levels of carbon were incorporated into the marine food web over the next decade, and the fact that they can still be identified in organic tissue enables scientists to determine the age of that tissue.

Radiocarbon ageing techniques, such as the use of bomb-carbon, have been proven to work when tested against simpler ageing techniques, such as counting the growth layers in the otoliths (tiny ear bones) of bony fishes or in the spines of some shark species. However, the simpler method cannot be applied to the Greenland shark because it is cartilaginous and has no calcified structures. This is why Bushnell and his team had to find an alternative technique: carbon-dating tissue from the lens of the shark's eye. 'The fundamental assumption is that the nucleus of the eye lens is more or less inert,' explains Bushnell. 'This means that whatever the isotopic carbon ratio is in the nucleus, it is a reflection of what the environment was like when the animal was conceived.' The basic principle is that if the eye lens of an individual shark has been imprinted with the bomb pulse, the animal was born later than the early 1960s.

To prove their theory, the researchers needed eyeballs. Most of these were obtained through collaborating with commercial trawlers and the Greenland Nature Institute, which provided them with samples from sharks caught as by-catch, but the team also needed to collect samples of their own. Working in one of the coldest and most remote places on earth is a logistical and financial challenge. 'It's the remoteness of the field site that affects the expense. To work in eastern Greenland, for instance, you pretty much need to have a large, 60-metre (200-foot) research vessel,' he explains. After five years, four expeditions and funding from numerous organisations, the team managed to collect the data they needed.

Photo by Nick Caloyianis | National Geographic Creative



Greenland sharks at the surface on a recovered long-line. The sharks were caught at the bottom of the 500-metre-deep (1,640-foot) Ammasalik Fjord during field work in 2012.

Since 2011, the researchers have been travelling to the frigid, iceberg-studded regions of the Arctic every summer – when it's perpetually daylight – to conduct their field work.

During field trips, the team spends weeks on research vessels off the coast of Greenland setting long-lines to catch sharks. 'There's nothing like bouncing about in a small rubber boat, hands numb from the cold water, feeling dwarfed by icebergs as they float by, and with an extremely sulky, large and powerful shark 20 centimetres (eight inches) from your face to remind you that this is its world and you are nothing more than an unwelcome intruder,' reflects Bushnell.

'Our biggest challenges are icebergs and cold. You put your hands in the water and you lose feeling after 15 seconds, so it's difficult to do anything. I'm not scared of the sharks themselves, although their skin is incredibly rough and can tear you up like a wood rasp. What I am concerned about is that they get hopelessly tangled in the gear and while I'm untangling them I might get caught up in the line and that will drag me down. Death would be a very slow and unpleasant process.'

In order to estimate the ages of individual sharks, the team has examined the eyeballs of 28 Greenland sharks caught in fjords and offshore waters. The animals ranged from 80 centimetres (32 inches) to 5.02 metres (16.5 feet) long. After testing the nucleus of each eye lens, the researchers discovered that only three sharks, all smaller than 2.2 metres (seven feet), displayed signs of the bomb pulse. This meant that the 25 larger animals had to be more than 50 years old. To age the other sharks, the researchers needed to use carbon dating in another way that would enable them to see further into the past.

The level of radiocarbon in food webs has always fluctuated slightly over time. To determine the age of their sharks, the team plotted the carbon measurement of each sample against Marine13, a radiocarbon calibration curve that has already been established. This enabled them to go back in time hundreds of years and determine an average age for Greenland sharks based on the relationship between size and age.

Their results, which suggest that Greenland sharks are not only some of the most ancient vertebrate species on the planet but also the longest-lived, have rocked the biological community. Radiocarbon dating

Photo by Julius Nielsen

does not provide exact measurements, but in conjunction with statistical models it enabled the scientists to estimate an age range. The largest shark in the study was just over five metres long. According to the scientists' models, this means it could be between 272 and 512 years old – a seriously old fish and easily longer-lived than the bowhead whale that previously held the record at an estimated 211 years.

When the story about these ancient creatures of the ocean broke, it garnered sensational public interest and was widely published by mass media. For shark researchers, however, the findings are more than just fascinating; they are important because they point to serious issues concerning vulnerability and conservation.

Despite numerous expeditions to Greenland and having caught and tagged more than 60 sharks in the past five years, Bushnell and his team have never captured a pregnant female. In fact, there is only one scientific report of a pregnant female; her pups were near term and measured 40 centimetres (16 inches) long. Tag-and-recapture experiments performed between 1936 and 1952 suggested that Greenland sharks only grow 5–10 millimetres (0.2–0.4 inch) per year and female Greenland sharks only become sexually mature when they are 4–4.5 metres (13–15 feet) long. The research indicates that at this size they would be about 150 years old; a very long time to wait before being able to reproduce. This means that although the sharks may seem common throughout the Arctic – at least common enough to be considered a source of biofuel – very few of them are actually big enough to breed. And with such slow growth rates, it will be decades before the younger generation, in turn, is ready to procreate.

Moreover, although the largest shark on record only measured 5.5 metres (18 feet), Bushnell has heard stories of animals as long as 6–7 metres (20–23 feet). Perhaps the liver oil fishery took its toll on these enormous and very old sharks or perhaps, as he points out, the tales of seven-metre giants are just 'fishing stories'.

The study published in *Science* is really just the first step in learning how to age such long-lived elasmobranchs. With more samples, especially from very big and very small sharks, researchers may be able to narrow down their estimates and achieve more accurate age measurements. In the meantime, though, it seems safe to say that some of the individual Greenland sharks that are

still swimming through the waters of the icy north were born long before Charles Darwin. These sharks are such masters of evolution that some of them have been alive longer than the theory itself.

Greenland's First Nations have their own theory about the origin of these very old fishes. Legend has it that at the dawn of time a woman washed her hair in urine and dried it with a cloth that was subsequently blown into the sea and became the world's first Greenland shark, *skalugsuak*. An unappealing tale perhaps, but it gives us great insight into the disagreeable relationship between the sharks and the people that share their home. Moreover, the fresh meat of the Greenland shark has a very high urea content that makes it toxic. Sled dogs have been seen lurching around unsteadily after eating it, giving rise to the local phrases 'drunk as a dog' and 'shark drunk'.

Given the story of the Greenland shark's origin and its nuisance value to fishermen, it is not hard to imagine why this is a 'wanted' species. Yet this attitude seems a little short-sighted considering what Bushnell and his team have shown. Hopefully, this new knowledge will transform the image of the Greenland shark from ugly nuisance to the living ancestor of the Arctic seascape.

The team's research in Greenland was funded by the Save Our Seas Foundation, the Danish Research Council, the Danish Centre for Marine Research, the Greenland Institute of Natural Resources, the Carlsberg Foundation, National Geographic, the University of Tromsø and the Blue Planet Danish National Aquarium.

Photo by Julius Nielsen

RV *Sanna* from the Greenland Institute of Natural Resources near a glacier front close to Upernavik, northern Greenland.

Photo by Lucas Santucci | Under the Pole

Peter Bushnell leans out of the research vessel to unhook an upside-down Greenland shark.

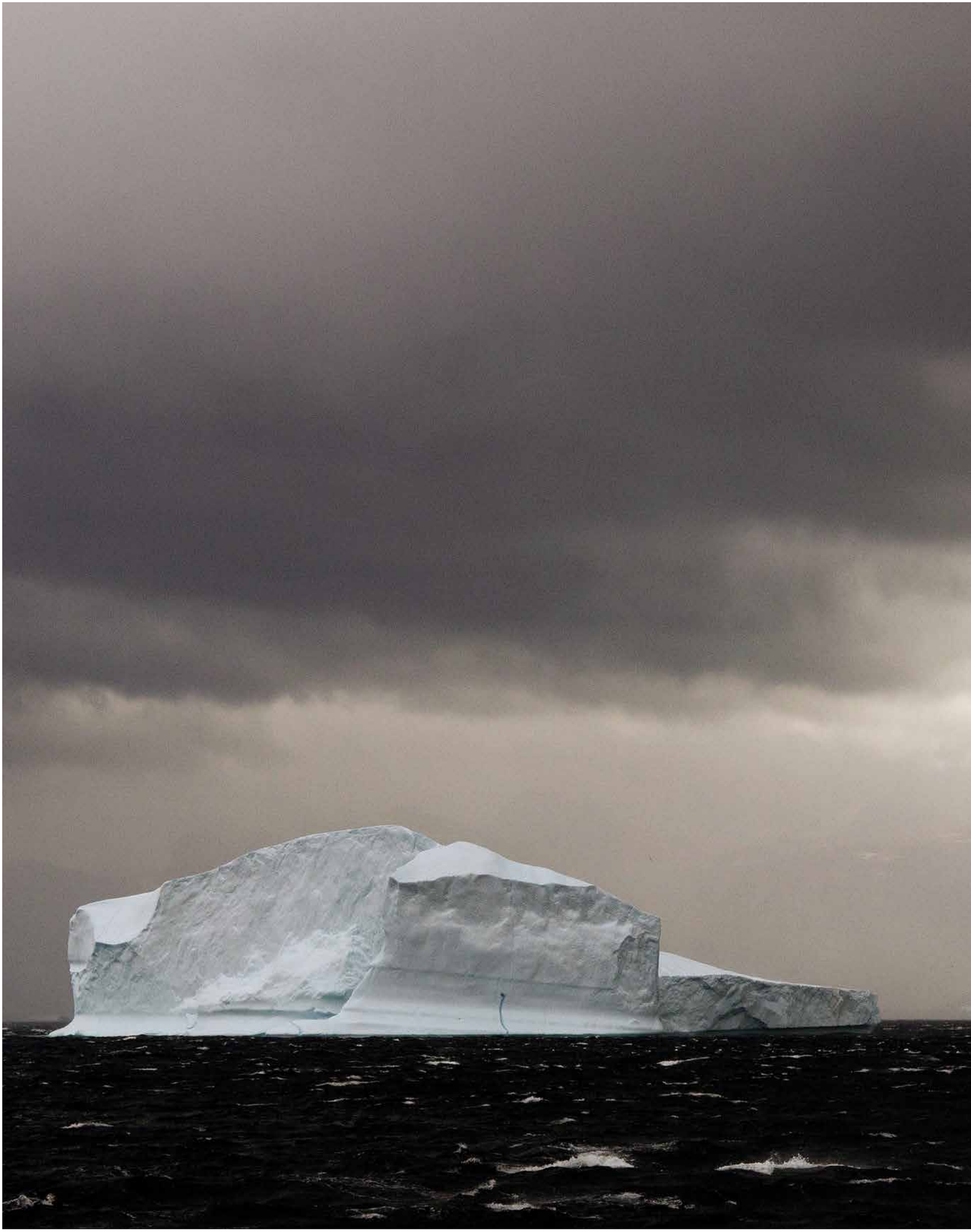


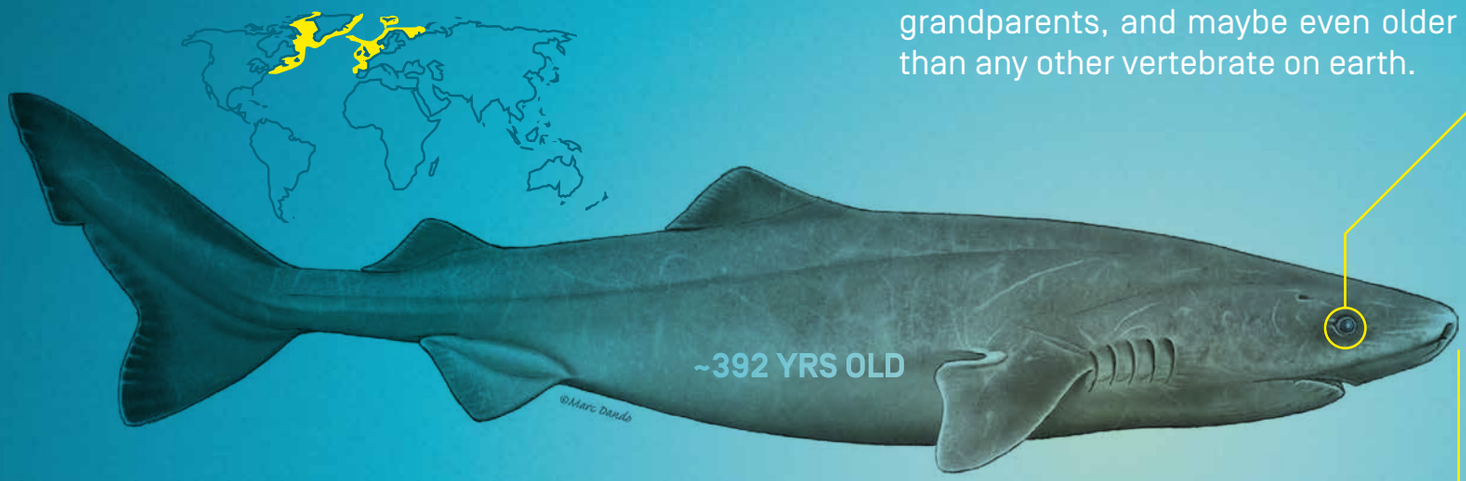
Photo by Julius Nielsen

A northern fulmar *Fulmarus glacialis* flies between the enormous icebergs that are produced from the glaciers in the Uummannaq Fjord.

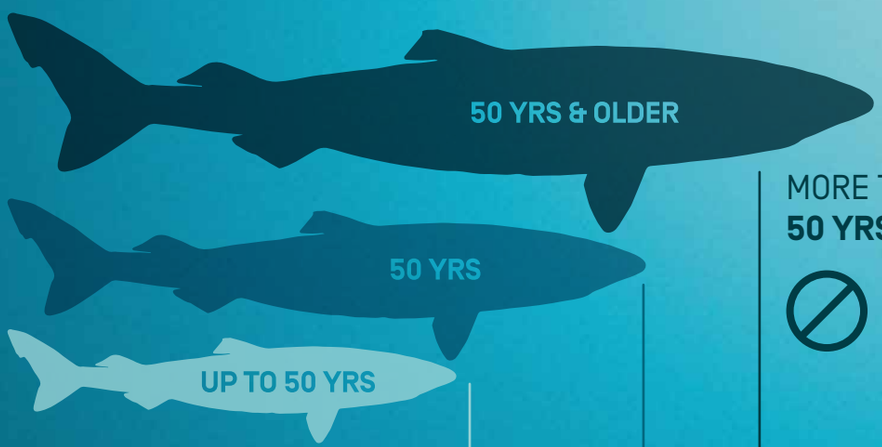
GREENLAND SHARKS

EYES ON AGE

Scientists have used a novel way of ageing sharks (that involves eyeballs) to figure out just how old Greenland sharks get, and the results are in: they can get older than your grandparents, and maybe even older than any other vertebrate on earth.



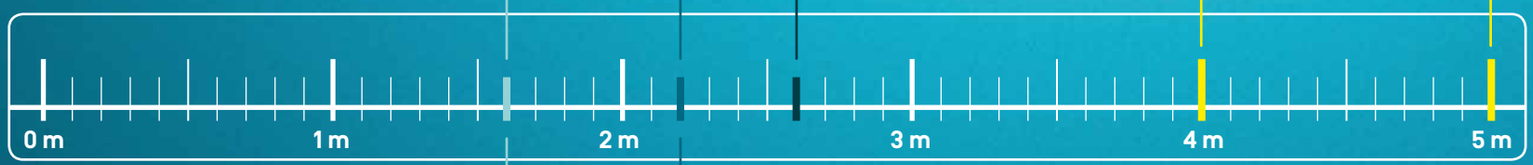
A team of scientists has gone through the steps of ageing 28 Greenland sharks between 0.8 and 5 metres long:



Greenland sharks reach maturity at >4 m, making them around 156 years old, according to the study.

MORE THAN 2.6 M
50 YRS & OLDER

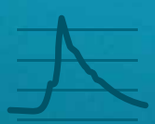
The remaining 25 larger sharks had no bomb pulse imprint, therefore they were born earlier than the 1960s.



1.6 M & SMALLER
UP TO 50 YRS OLD

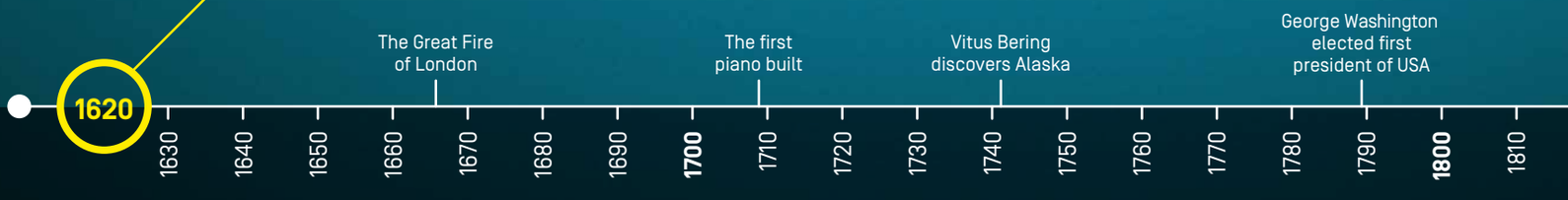
The two smallest sharks were imprinted with the bomb pulse, meaning that they were born since the atomic bomb testing of the early 1960s.

2.2 M
~50 YRS OLD



One shark, the third smallest, was imprinted with intermediate levels of radiocarbon, meaning it was born close to the onset of the atomic bomb testing.

But we also know Greenland sharks grow 5–10 millimetres a year, probably for the duration of their lives. Thus, using statistical models and established radioactive carbon curves, the scientists estimate that a five-metre shark could be 392 years old. A shark born in 1620 could still be alive today!



CARBON DATING EYEBALLS

Ageing of most fish has been refined to a science much like counting the rings in a tree trunk. Scientists assess a cross-section of the inner bones of a fish's ear and count the rings of calcium that are laid down on a yearly basis.

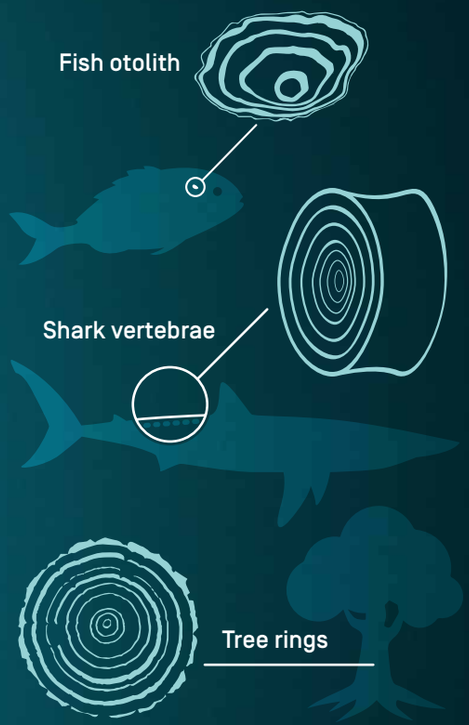
The problem with sharks is that they don't have bones; their skeletons are made of cartilage. So to age them, scientists use their vertebrae, or sometimes spines, which usually also have growth rings.

But the enigmatic Greenland shark does not have spines and its vertebrae lack growth rings. What it does have though – even though it is nearly blind – are eyes, and more specifically, corneas.

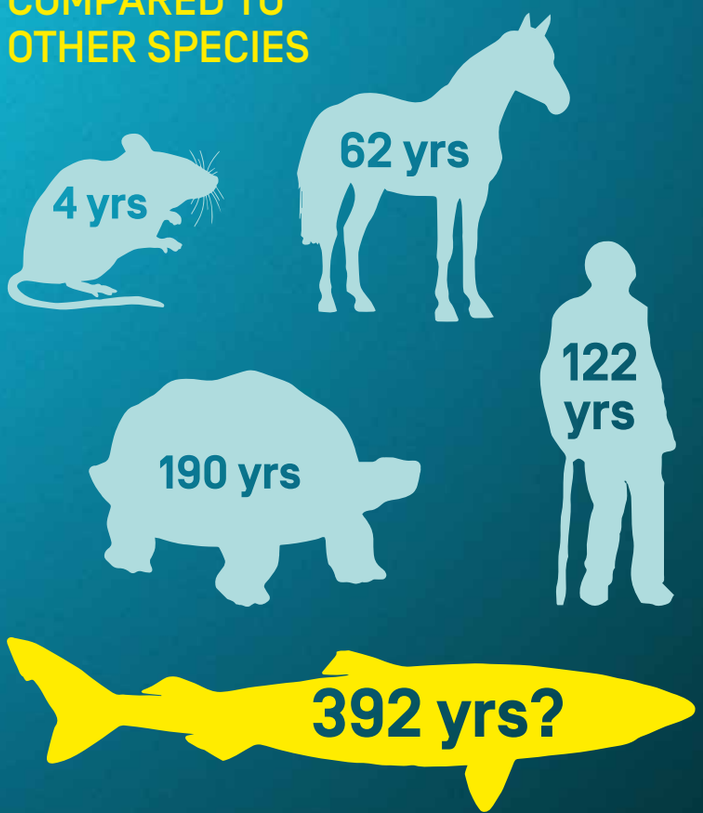
Corneas develop in the womb and are more or less inert, so scientists assume that they reflect the environmental conditions at the time of the shark's conception.

If there was more or less of a particular chemical in the environment when the shark was conceived, this concentration will be mirrored in the makeup of its cornea – even many years, or decades, after the shark was born.

Scientists are able to align the timing of the shark's conception with historic events that altered the chemical makeup of the environment – and thus the shark's cornea.



COMPARED TO OTHER SPECIES

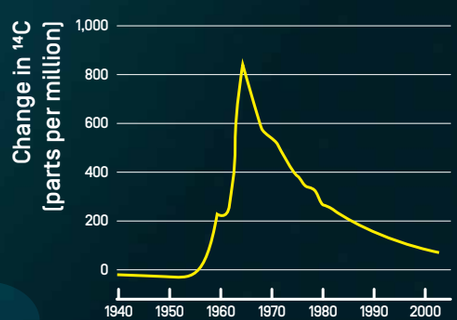


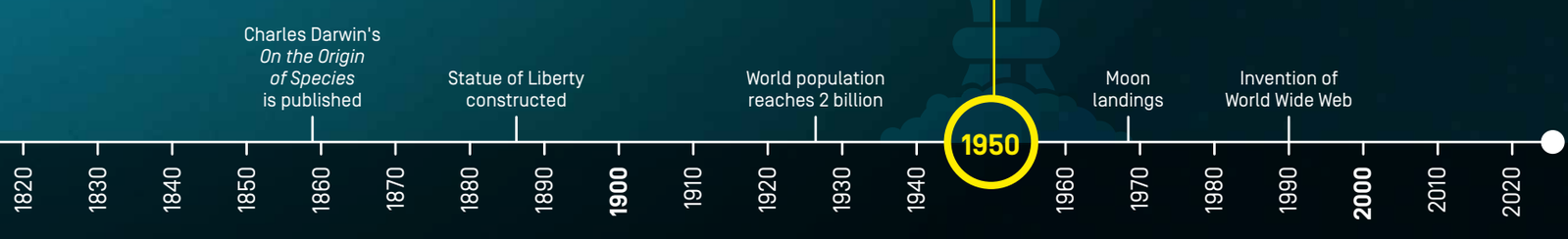
THE BOMB PULSE

1950–1963

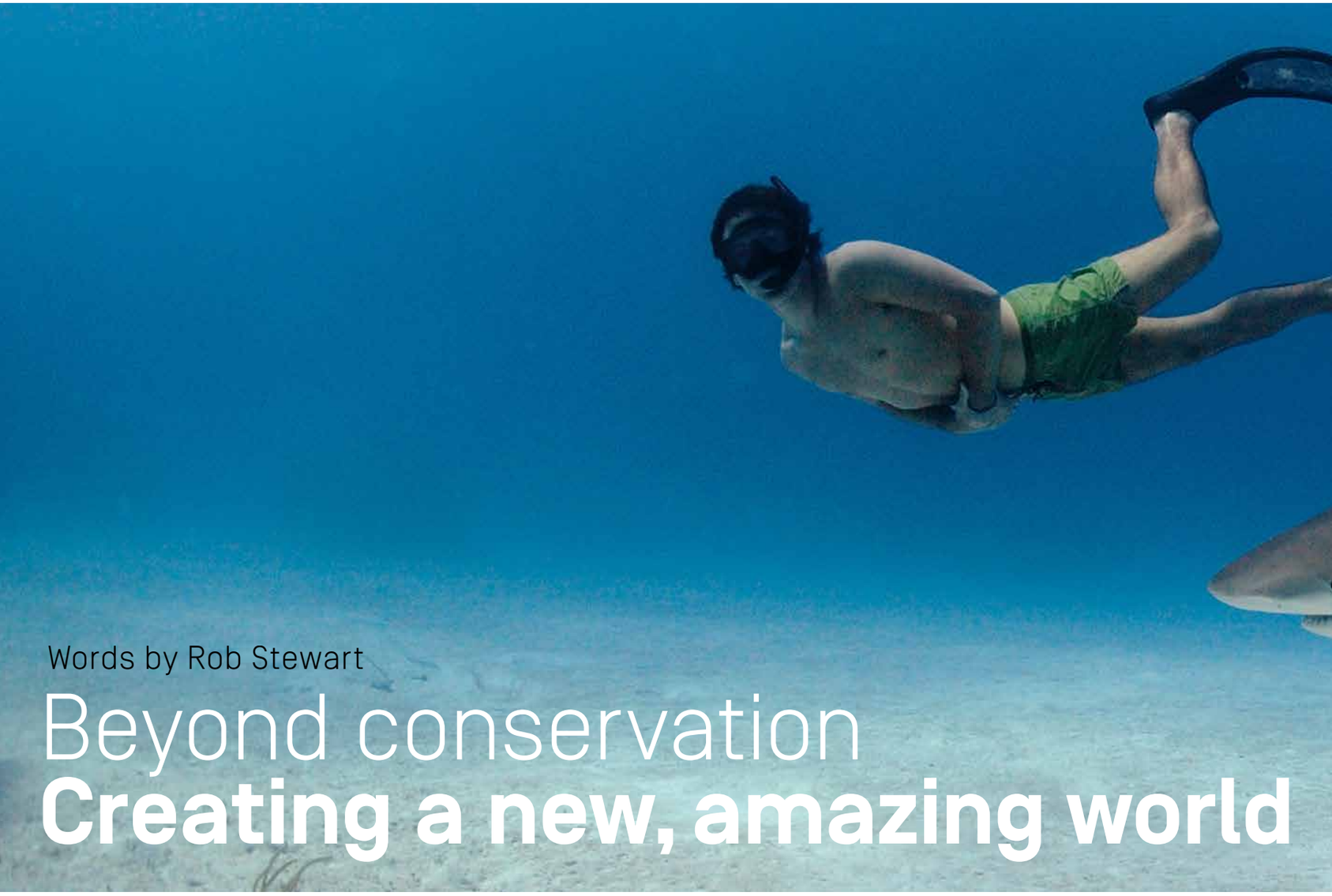
Widespread above-ground testing of atomic bombs from around 1950 to 1963 (when atmospheric nuclear testing was banned) resulted in a doubling of the amount of radioactive carbon (^{14}C) in the atmosphere. This ^{14}C was quickly incorporated into the environment – including the world's oceans. The effect was to chemically time-stamp all the animals living during this period or in the years following, as their bodies incorporated the radioactive carbon into their tissues.

→ Greenland sharks with higher than normal levels of ^{14}C in their corneas are likely to have been born after the nuclear testing of the 1950s and 1960s, and are less than 65 years old.





Infographic design by Daniel Smith | Content interpretation by Lisa Boonzaier | Species illustration by Marc Dando



Words by Rob Stewart

Beyond conservation
Creating a new, amazing world

Have I failed in my bid to save sharks? I've been involved in ocean conservation for 16 years and it seems the situation is only getting worse!

In 2002 I set out to make a film that would bring the plight of sharks to the attention of the public in the hope that if people could see sharks through my eyes and understand how magnificent and important they are, they would fight for their protection. It took four years, entailed travelling to 12 countries and nearly killed me – but *Sharkwater* brought the issue of shark finning into the spotlight and inspired people to get involved.

Yet in the 10 years since the film's release we've killed more than a billion sharks, contributing to the greatest wildlife massacre in history. Sure there are some successes to be celebrated: shark finning is banned in most parts of the world, sharks are on endangered species lists, conservation groups have sprung up to fight for sharks' protection. But today we are still slaughtering the world's greatest predator not just for its fins, but also for cosmetics, vaccines, pet food, livestock feed, fertiliser and fast food, to name only a few end products. As we set out to make our third film – my second to save sharks – the question why we haven't solved the shark issue, or any other environmental issue threatening humanity, becomes important. And I think I know the answer.

We have focused too much on slowing down our destructive tendencies instead of charting a path towards where we want to be – as a species and a planet – in the future. Even if we achieve our current goals, we will still be living in a degraded world where extinctions, poverty and conflict are rife.

When you imagine the future – 50, 100 years from now – what do you see? A technology-driven world? Flying cars? Hopefully! But what about our environment? What has happened to life on earth? If you're like most people, you'll see a world in which wildlife is relegated to reserves and parks, tiny vestiges of nature fenced off to protect it from – and for – people. In this future, most of our planet has been converted into a factory that provides for the most populous of the species: humans.

From where we are now, even that vision could be considered optimistic. We are, after all, careering towards a world that has no fisheries, no reefs, no rainforests – but it will have 10 billion hungry and thirsty people. It is easy to imagine a world in conflict for food, water, air and space. Rarely do we imagine what our world would look like if we got it right and made this planet amazing, a world that is beautiful for all species. I think that is our problem. When we look to the future we are merely aiming to slow down our destructive juggernauts and scrape by as a species – and in doing so all that we can achieve is a world impoverished for 99% of its people and species.

Let's face it: oil, agriculture, development, capitalism, extraction – the big destructive juggernauts that the conservation movement is fighting to slow down – have created the world we live in and a better quality of life for many. They bring daily benefits. By setting ourselves up against them, 'activists' such as myself become radicals and underdogs pitted against society and the most powerful organisations in the world. We are forced to tout pitiful solutions so as to avoid being squashed by the juggernauts we oppose.

We are living in an age when we have lost 90% of the big fish, 75% of the forests, 40% of the phytoplankton, 50% of the biodiversity and 90% of the food species; an age when we have built a civi-

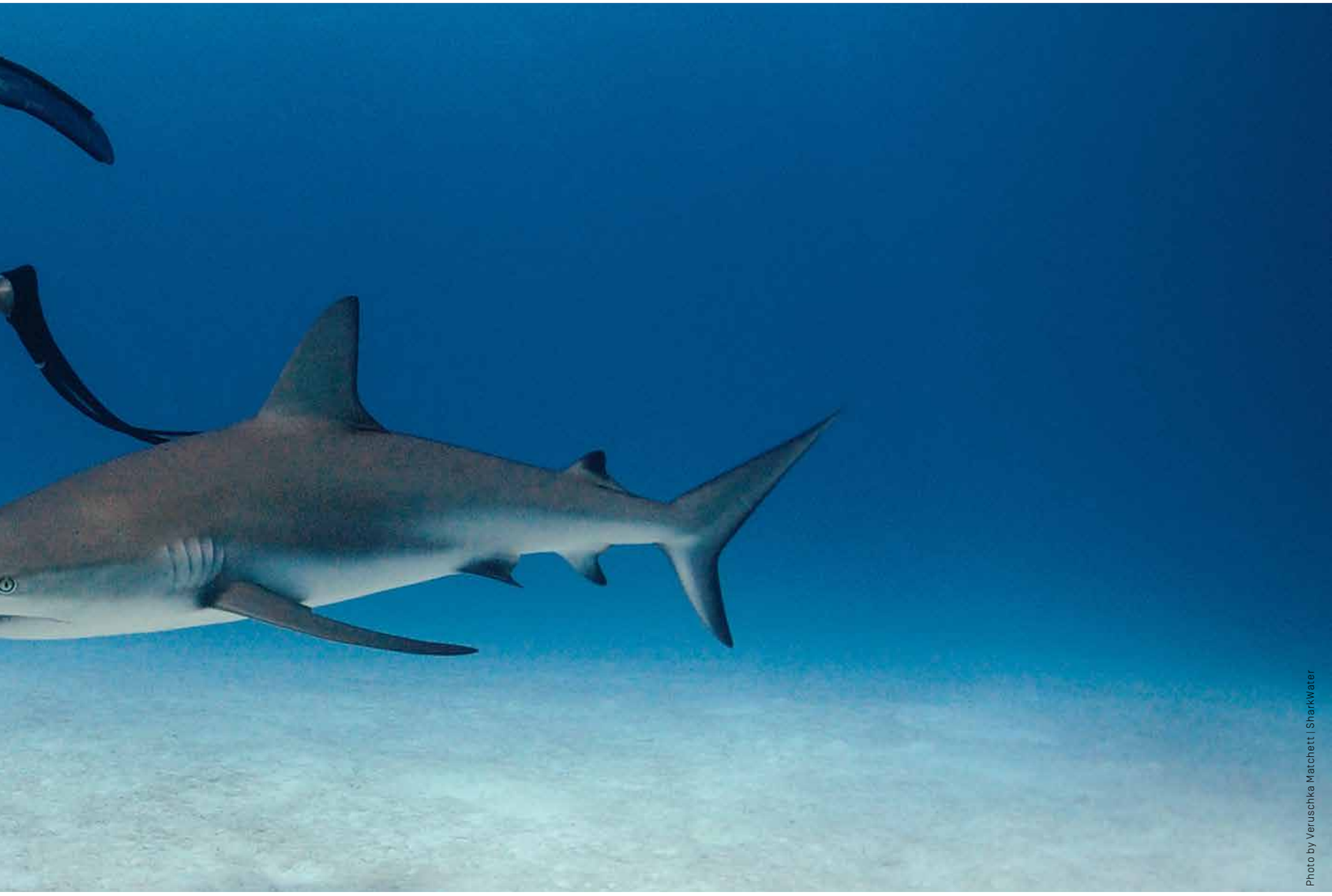


Photo by Veruschka Matchett | SharkWater

lisation by releasing a quadrillion pounds of carbon dioxide into the atmosphere and made the oceans 30% more acidic. At a time like this, solutions such as '20% reduction in emissions', 'Let's pollute less!', 'Let's slow down fishing and deforestation and development!' just won't cut it.

Consider our efforts for sustainability. A fishery that is 'sustainable' today would be achieved in a radically damaged ocean that has already lost 90% of its mega fauna. We need more than a fishery that is sustainable; only one that is beneficial or regenerative will do.

The unfortunate reality – and one that seems hopelessly apparent to the youth of today – is that the 'solutions' being touted are too little, too late. All they can do is slow humanity's arrival at a toxic and impoverished world of deficiencies, extinctions and conflict.

But what if we set a higher standard for ourselves and our devices: industry, capitalism and civilisation? What if we imagined a world that is beautiful for all species and fought for it instead of fighting against juggernauts? Could we unleash humanity's genius and leapfrog over our environmental battles in the process?

We are smart enough, ambitious enough, powerful enough and – for the first time in our history – connected enough to not just settle for a degraded world in which the vast majority of humans scrape by, but to create a world that's incredible. We can bring nature back, we can re-wild the planet – and we can do it through a project I call Wildify.

What is the best carbon sequestration device ever invented? What processes pollution, filters and stores toxins, regulates our climate, provides food for everyone and everything? What creates fresh water, topsoil? Life!

Life would pull vast amounts of carbon from the atmosphere and oceans to build itself and in doing so would address the crises of ocean acidification and climate change. Life creates ecosystems and they regulate climate, process water and waste and provide food for us and other life. In a Wildified world there should be enough plants and food growing everywhere to make hunger a foreign concept.

Can you imagine if we put the forests back? What if we restored life to the oceans and waterways and invited it into our cities? Could humanity shift from destroying this planet to regenerating it? I have enough faith in humanity to know that we don't need to live like a cancer on earth, but can figure out how our existence on it can make it a better place.

Only when we can imagine this better world can we chart a path towards it. Until then, I believe we're heading towards a technologically advanced but ecologically impoverished world of rats and 'roaches, and 10 billion-plus people fighting over who gets to eat them. But a world that is amazing for all species is exciting enough to motivate the best in us to achieve it. It is inspiring enough to dedicate my life to – and I think would be for many more people who fail to be inspired by the 'conservation' paradigm.

Now as we make our third film, currently titled *Sharkwater Extinction*, I am a different person, no longer a conservationist. Instead, I believe people need to know that they have been smearing shark on their faces, feeding shark to their pets and are eating shark without knowing it. They need to know because information changes the world, engages our morals and our humanity. With information, we as a species make better decisions. I hope that this film will not only launch a campaign called *#sharkfree* – to rid our daily lives of shark products – but will also put forward a view of the future that's so exciting that it will invoke genius to help achieve it. And that's going to take some imagination.

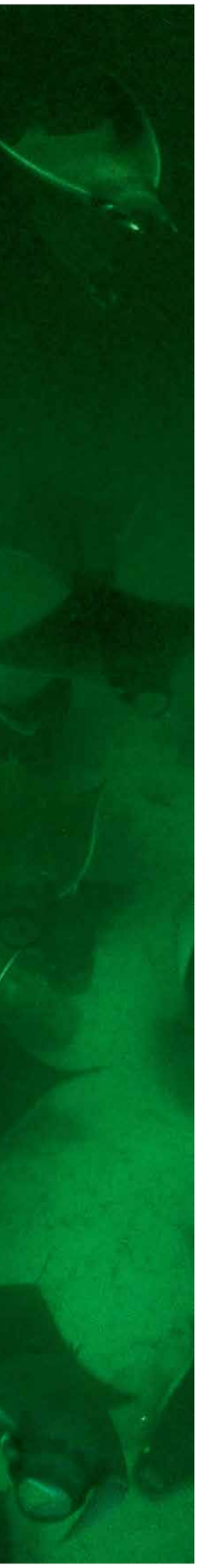
Wins for sharks and ‘mini mantas’ at CITES

Words by Sarah Fowler

Having attended the 17th Conference of Parties (CoP17) of CITES as a technical adviser to some of the countries proposing listings for sharks and rays, Sarah Fowler reports on outstanding successes for some sharks and rays.

‘The commitment shown by CITES Parties across the world to list thresher sharks, silky sharks and mobula rays on Appendix II is highly encouraging. These actions will help ensure the sustainability of shark fisheries, which are vital for the livelihoods and food security of coastal communities around the world. Sri Lanka looks forward to working with neighbouring countries and the Indian Ocean Tuna Commission to develop regional NDFs for these species to continue sustainable trade from the Indian Ocean.’

Daniel Fernando,
adviser on the Sri Lankan
delegation to CoP17



Smashing records

CoP17 broke several records for shark and ray conservation and management. The first, achieved long before delegates even met in Johannesburg, was the exceptionally large number of CITES Parties that co-sponsored each of the proposals for listing silky and thresher sharks and mobula rays in Appendix II. Supporters included close to half of all countries where these species occur (including some of the world's largest shark-fishing nations), the 28 EU member states and many small island developing states, whose waters include a substantial area of the world's oceans.

Silky shark:
49 Parties proposed, led by the Maldives
Thresher sharks: 51 Parties proposed, led by Sri Lanka
Mobula rays: 50 Parties proposed, led by Fiji

The second record was the landslide vote in favour of these proposals following the debate on them. The first shark vote was particularly striking because the silky shark is one of the world's most heavily fished and commercially important sharks, even though catches have fallen steeply in recent years. The second shark vote concerned all three species of thresher shark. They belong to a family identified as one of the most seriously threatened in the world and are traded for their meat as well as fins. Both proposals were passed with 79% of the vote (a huge margin above the two-thirds majority needed). Finally, the whole family (nine species) of devil rays was added to Appendix II, joining the closely related manta rays listed at the previous CoP, with 85% of the votes cast. This brings the total number of sharks and rays listed in the CITES Appendices to 30 (sharp-eyed readers will notice that there are only 28 species illustrated on pages 82–83. That's because a taxonomic reclassification of sawfishes has recently reduced their number from seven to five).

The vote counts were so overwhelmingly in favour of these listings that no attempt was made to reopen the debate on the sharks and rays with a view to overturning the results in the final Plenary. This probably contributed to a third record: CoP17 finished its business and closed one day earlier than scheduled – certainly a first for me.

Silky shark

This formerly very common pelagic shark, named for its sleek skin, has been caught in huge numbers by oceanic long-line and tuna purse-seine fisheries. During the 1980s, the fins of silky sharks made up at least 3.5% of the global shark-fin trade, a figure that rose to 4.4% in the 1990s. Today they are the second-most abundant fins (after those of the blue shark) in Hong Kong markets. Yet estimated numbers of silky sharks caught for the fin trade (500,000 to 1.5 million annually) pale into insignificance beside estimates of millions of juveniles ghost-fished and killed in the entangling nets that hang beneath many artificial fish aggregating devices (FADs). These FADs are used to attract shoals of tuna and make it easier for purse-seiners to catch the fish, but they are lethal to silky sharks. It's no wonder that silky shark populations are declining.

The association between silky sharks and tuna lay behind the decision of the government of the Republic of the Maldives to propose the silky shark for listing in CITES Appendix II. Tourism and fishing are the two most important economic activities in this island nation and healthy shark populations contribute to both. That's why, in 2010, the Maldives declared its entire Economic Exclusion Zone a shark sanctuary and prohibited all trade in shark products. It's well known that many tourists visit the Maldives to see reef and whale sharks, but not many people realise that pole-and-line tuna fishermen believe that healthy populations of silky sharks are essential to make tuna form shoals, in which they are easier to catch. Unfortunately, a sanctuary is of limited use when sharks swim outside it and are caught in unsustainable fisheries in adjacent waters. Maldivian tuna fishermen say that silky shark numbers have fallen by 90% in the past two decades.

Concern over the vulnerability of the silky shark to oceanic fisheries and its declining stocks has already caused the regional tuna fisheries management bodies in the Western Central Pacific and Atlantic oceans to prohibit the retention and landing of the species. However, these prohibitions are very poorly monitored and enforced. It will be very difficult to tell whether these measures are leading to a recovery in silky shark populations when no one is watching!

An alternative is to regulate silky shark fisheries, allowing a limited catch that supports livelihoods and also helps with the collection of scientific data and other information that can be used to monitor the health of the stocks. This is the approach promoted by Sri Lanka, the country that has reported 46% of the world's silky shark landings during the past decade. Sri Lanka was a very strong supporter of the Maldives' proposal to list the silky shark in Appendix II because it recognises the importance of the tools that CITES provides to ensure the sustainability of international trade and of the fisheries that supply it. It is also only too well aware of the need to use an international agreement to regulate international fisheries.

What is CITES?

The Convention on International Trade in Endangered Species of Wild Fauna and Flora, known as CITES, was established in the 1970s to prevent international trade from contributing to the extinction of exploited plant and animal species. It is the only multilateral environmental agreement (MEA) whose measures can be legally enforced, for example by setting quotas for exports of products from listed species. It is also one of the largest MEAs, with 183 of the world's 193 United Nations member states signed up.

CITES is often associated with elephant ivory and rhino horn; the African elephant and rhinos were among more than 1,000 species of plants and animals listed by consensus in the original Appendices. Today, however, the three Appendices to the Convention list about 30,000 plant species (about half of which are orchids) and some 5,600 animal species, ranging from whales and gorillas to insects and snails.

Appendix I lists fewer than 1,000 species that are threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances.

Appendix II lists almost 35,000 species. They are not necessarily threatened with extinction, but trade in them must be controlled in order to avoid utilisation incompatible with their survival. The Appendix ensures that trade is legal and sustainable.

Appendix III contains about 150 species that are protected in at least one country that has asked other CITES Parties for assistance in controlling trade.

The triennial meetings of the Conference of Parties (CoP) are where CITES Parties review progress and make decisions on international wildlife trade matters, including the addition of new species to Appendix I and Appendix II. CoP17, held in Johannesburg, South Africa, in September and October 2016, was the largest ever convened.

Thresher sharks

Thresher sharks – common, pelagic and bigeye – have become known as 'Indiana Jones sharks' by the media because of their long, whip-like tails, which they use to stun small fishes. They also have the unfortunate distinction of belonging to one of the most threatened shark families – all three thresher species have undergone serious population declines.

Threshers are fished for their meat and their fins. In the early 2000s, they comprised about 2.3% of shark fins identified in Hong Kong markets, representing some 350,000 to 3.9 million sharks per annum. A recent study of the fin trade, albeit using different methods, found that only 0.1% of fins sampled in 2014 were from thresher sharks. The meat, particularly that of the common thresher shark, is also highly valued, and threshers are popular game fishes for sea anglers.

On the other hand, the value of thresher sharks for non-consumptive dive tourism can be huge. The community of Malapascua Island in the Philippines made a desperate plea to Parties in Johannesburg, begging them to list threshers in CITES because this would help them protect their single greatest asset: the pelagic threshers that visit a local fish cleaning station, which is now one of the world's most famous shark dives. These sharks, through the support of visiting divers, enabled the island to rebuild its economy after the devastation of Typhoon Haiyan. This community must now be one of the world's most fervent advocates for thresher shark conservation.

The bigeye thresher was proposed for listing in Appendix II by Sri Lanka, supported by a record-breaking 50 other CITES Parties. The proposal was developed because the species is widely recognised as being so vulnerable biologically, and so susceptible to capture in pelagic fisheries, that it is now a prohibited species in the Mediterranean Sea and the Atlantic and Indian oceans. Sri Lanka has also enacted domestic legislation to protect the species, which can no longer be landed by Sri Lankan fishers. Regional fisheries prohibitions are very difficult to enforce without complementary trade controls to ensure that products entering trade were legally obtained and from sustainable fisheries. Because the fins of all three threshers are very similar, the other two species (common and pelagic threshers) also had to be listed in CITES Appendix II under 'lookalike' provisions so that trade in the bigeye can be regulated.

Devil rays

The nine species of mobula rays received a public relations makeover in Johannesburg when the description 'mini mantas' was chosen to replace the less cuddly 'devil rays'. In 2013 at CoP16 in Bangkok, their larger relatives, the huge, plankton-feeding manta rays, had been listed on Appendix II because they were being fished unsustainably for their gill plates, which are used in traditional Asian medicine. It soon became clear that mobula rays were under similar pressure for exactly the same reason and that some populations had declined very rapidly in the past few years.

While the mantas have been a particular focus of the Save Our Seas Foundation (SOSF) for many years, more recently our efforts have shifted to the devil rays in recognition of the serious problems that they also face. The SOSF has funded research into life histories, genetic studies and fisheries and markets, as well as the preparation of visual identification guides for all species and for their gill plates. The identification guides were particularly important in supporting the efforts of the Manta Trust to secure the CITES listing because they demonstrated that it is easy to train customs officers to identify manta and devil ray gill plates, if not to distinguish between all nine mobula species.

Fiji had successfully proposed the mobulas for listing in the Appendices of the Convention on the Conservation of Migratory Species in 2014. Now, two years later, it spearheaded the successful proposal to add two of the largest species, for which declines had been reported, to Appendix II of CITES. All the smaller species were included in the proposal for 'lookalike' reasons. This proposal was passed with an astonishing 80% of the vote – only 20 Parties voted to reject the listing.

Making Appendix II listings work

The overwhelming vote in favour of the shark and ray proposals confirmed that CITES is indeed ready to contribute to the sustainability of important commercial fisheries that supply the shark-fin trade. So what happens next?

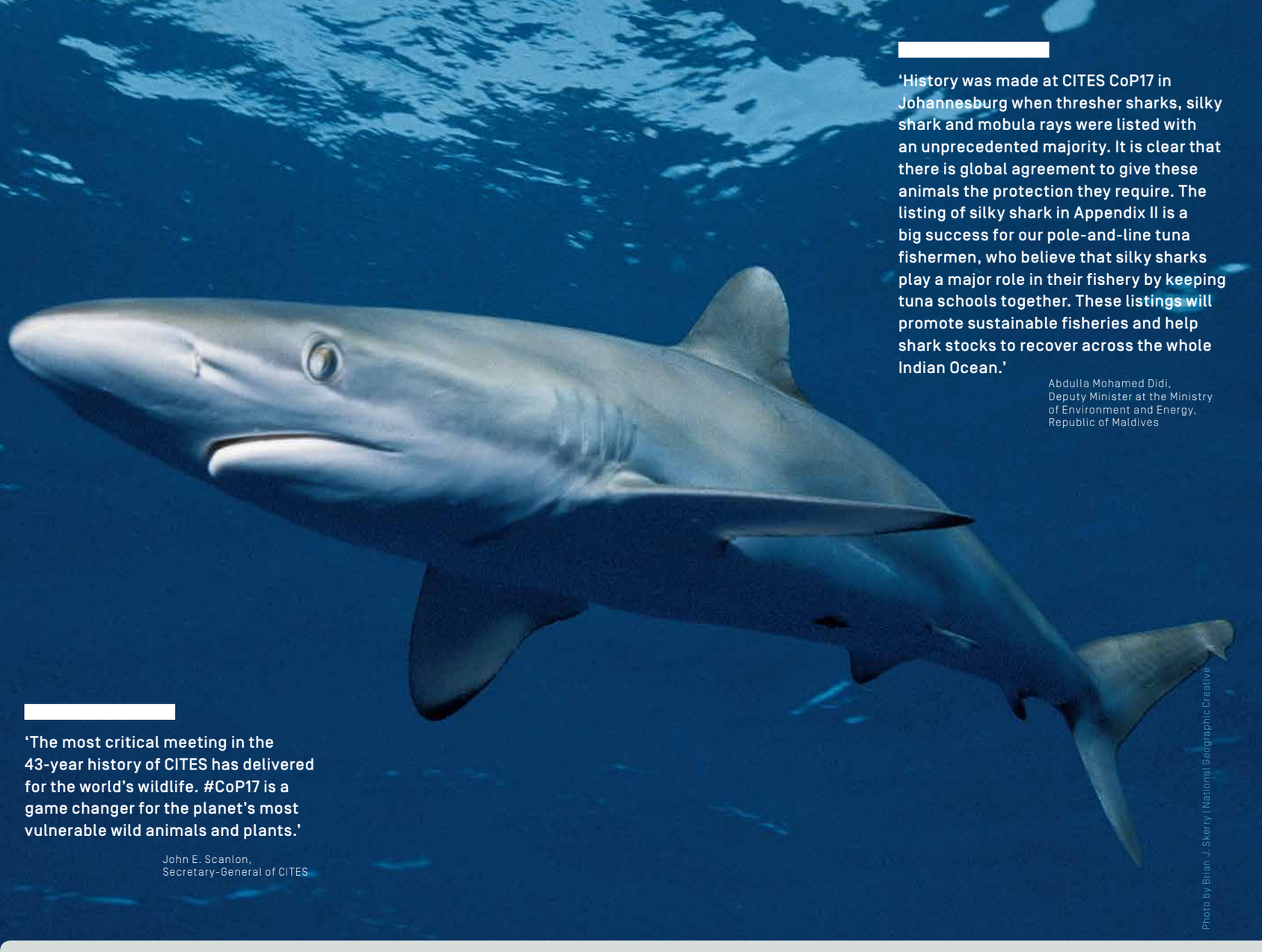
The two shark proposals were adopted with a 12-month delayed implementation period and the ray proposals with a six-month delay (the listings would otherwise have come into force three months after the CoP). This gives countries extra time to work out how to implement them, for example by ensuring that the species and their products can be identified by national fisheries and customs staff and that sustainable levels of capture have been defined.

Appendix II requires that trade be legal and sustainable. Countries where the sharks and rays are fished must first issue a Legal Acquisition Finding. This confirms that the products being traded did not, for example, come from protected species or protected areas, or from prohibited fishing gears, or in contravention of other laws. Once that's done, a Non-Detriment Finding (NDF) must be issued to confirm that the export will not be detrimental to the wild populations. This is a form of sustainability certificate. For transboundary stocks, it makes sense to develop shared or regional NDFs. These might set out what needs to be done to make the fishery sustainable and/or set a Total Allowable Catch for the whole stock and split this up into quotas for each country.

The shark listing proposals were helped through the debate at CoP17 by the fact that Germany had already commissioned and circulated draft regional NDFs for thresher sharks in the North Atlantic and for silky sharks in the Indian Ocean. These drafts are intended to be developed further by fishing countries, to agree conservation and sustainability actions in each region and to decide what levels of fishing and trade are safe for species listed in Appendix II. This is just the beginning of an extensive programme of work that needs to be undertaken over the next three years to implement the shark and ray listings adopted last month, as well as those from CoP16 in Bangkok in 2013. There will be close scrutiny of implementation efforts over the next few years, when countries report back to CoP18 in Colombo, Sri Lanka.

CoP17 by numbers

- The largest ever CITES CoP.
- More than 3,500 people from 158 nations attended, including 152 governments and thousands of observers from UN bodies, non-governmental organisations and the media.
- More than 200 documents were considered, including 62 species listing proposals submitted by 64 countries.
- The highest number of side events at any CoP were held, including several on the conservation and management of marine species.
- The international wildlife trade is estimated to be worth billions of dollars a year. It includes hundreds of millions of plant and animal specimens, from live animals to food, medicines, tourist souvenirs, fish and timber products. Only a small proportion of this trade comes from threatened species.



'History was made at CITES CoP17 in Johannesburg when thresher sharks, silky shark and mobula rays were listed with an unprecedented majority. It is clear that there is global agreement to give these animals the protection they require. The listing of silky shark in Appendix II is a big success for our pole-and-line tuna fishermen, who believe that silky sharks play a major role in their fishery by keeping tuna schools together. These listings will promote sustainable fisheries and help shark stocks to recover across the whole Indian Ocean.'

Abdulla Mohamed Didi,
Deputy Minister at the Ministry of Environment and Energy, Republic of Maldives

'The most critical meeting in the 43-year history of CITES has delivered for the world's wildlife. #CoP17 is a game changer for the planet's most vulnerable wild animals and plants.'

John E. Scanlon,
Secretary-General of CITES

Photo by Brian J. Skerry | National Geographic Creative

CoP17 also loved

Chambered nautilus

These colourful living fossils, distant relatives of squid and octopus, have hovered along the deep slopes of Asia–Pacific reefs and islands for many millions of years. They take 10–17 years to reach maturity and lay only one egg at a time, which incubates for up to a year – in other words, populations increase very slowly indeed. Many populations are isolated by deep water, which nautilus cannot cross. Local fisheries that trap nautilus for their shells and meat have caused huge population declines. The shells enter trade in huge numbers. The listing proposal easily obtained the necessary two-thirds majority to approve adding nautilus to Appendix II.

Pangolins

No, not marine animals, but very cute and among the species that most urgently required CITES attention. All eight species of Asian and African pangolins were already listed in Appendix II, but were under serious threat because of huge illegal trade in their scales, which are used in traditional Asian medicine. There was virtually unanimous agreement at CoP17 that these species, which are the world's most heavily trafficked mammals, should be transferred from Appendix II to the protection of Appendix I.

Big grey animals

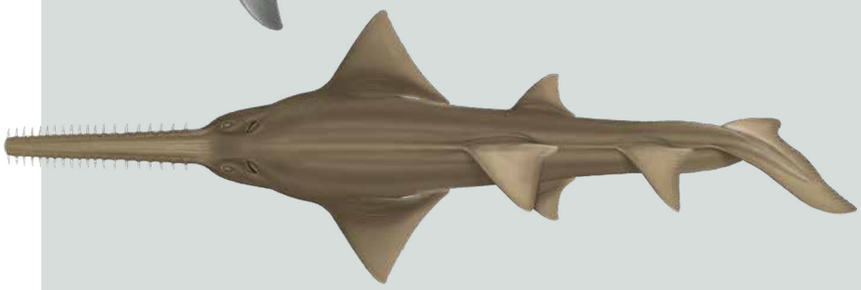
Year after year, elephants (ivory) and rhinos (horn) dominate discussions at CITES meetings. This year was no different, but why mention this in an article that focuses on marine species?

The reason is that there are important parallels between these large mammals, listed in the CITES Appendices during the first meeting in 1976, and sharks and rays, which have been such a struggle to add in recent years. All these species are being killed at unsustainable rates in substantial parts of their range, depleting many wild populations. They are being overexploited primarily to provide high-value luxury goods that are traded internationally, particularly to meet consumer demand in East Asia. In all cases, it is therefore necessary not only to control the supply end of the chain (poaching and fisheries), but also to reduce consumer demand.

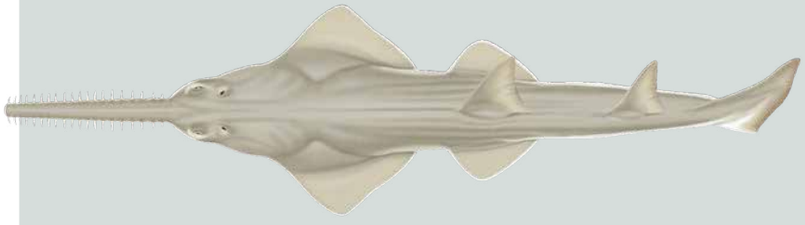
While these species can be even more valuable alive than dead for the relatively few communities able to engage in ecotourism, not all communities have this opportunity. An additional problem is that some of these animals are potentially dangerous alive, at least in some situations, and undeniably very valuable when dead if their products enter trade (legal or illegal).

So there is a cautionary tale here: it has definitely not been easy to implement CITES listings for charismatic species like elephants and rhinos, which confront many of the same problems faced by sharks and rays. We should not automatically assume that progress will be any smoother for sharks and rays. However, the management of marine species through CITES will benefit significantly from the long history of various countries' experience of managing their elephants, rhinos, sturgeons and even commercial timber species. Sharks and rays have another important factor in their favour: the combination of fisheries management at national and regional levels, with newly available CITES trade controls, may yield benefits not available to many large grey land animals.

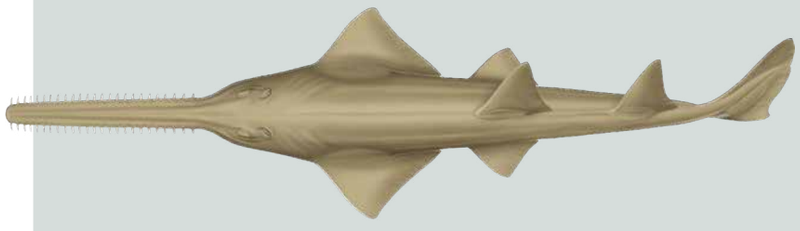
CoP13: 2004 Appendix II
White shark *Carcharodon carcharias*



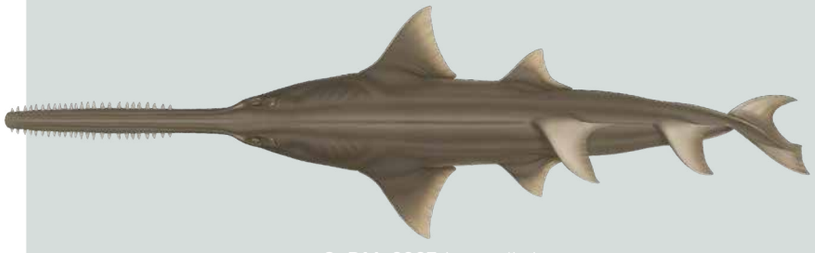
CoP14: 2007 Appendix I
Common sawfish *Pristis pristis*



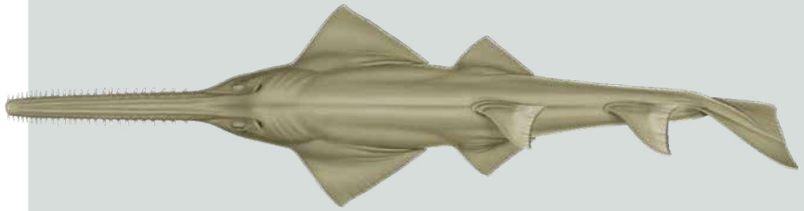
CoP14: 2007 Appendix I
Queensland sawfish *Pristis clavata*



CoP14: 2007 Appendix I
Smalltooth sawfish *Pristis pectinata*



CoP14: 2007 Appendix I
Knifetooth sawfish *Anoxypristis cuspidata*



CoP14: 2007 Appendix I
Narrowsnout sawfish *Pristis zijsron*

CoP16: 2013 Appendix II
Porbeagle shark *Lamna nasus*

CoP16: 2013 Appendix II
Oceanic whitetip *Carcharhinus longimanus*

CoP16: 2013 Appendix II
Smooth hammerhead *Sphyrna zygaena*

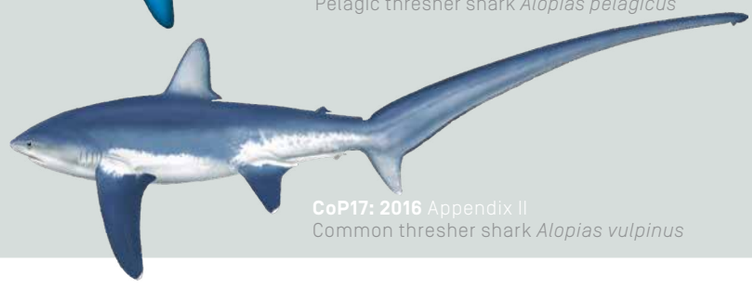
CoP16: 2013 Appendix II
Great hammerhead *Sphyrna mokarran*

CoP16: 2013 Appendix II
Scalloped hammerhead *Sphyrna lewini*

CoP17: 2016 Appendix II
Silky shark *Carcharhinus falciformis*

CoP17: 2016 Appendix II
Bigeye thresher shark *Alopias superciliosus*

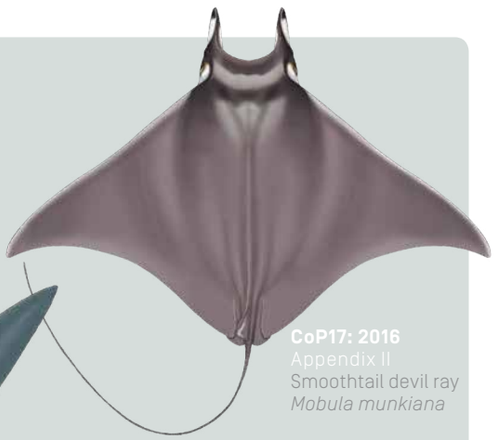
CoP17: 2016 Appendix II
Pelagic thresher shark *Alopias pelagicus*



CoP17: 2016 Appendix II
Common thresher shark *Alopias vulpinus*

CoP12: 2002 Appendix II
Basking shark *Cetorhinus maximus*

CoP12: 2002 Appendix II
Whale shark *Rhincodon typus*



CoP17: 2016
Appendix II
Smoothtail devil ray
Mobula munkiana

CoP17: 2016
Appendix II
Lesser Guinean
devil ray *Mobula*
rochebrunei

CoP17: 2016
Appendix II
Spinetail devil ray
Mobula japanica

CoP16: 2013
Appendix II
Oceanic manta ray
Manta birostris

CoP17: 2016
Appendix II
Sicklefin devil ray
Mobula tarapacana

CoP16: 2013
Appendix II
Reef manta ray
Manta alfredi

CoP17: 2016
Appendix II
Bentfin devil ray
Mobula thurstoni

CoP17: 2016
Appendix II
Giant devil ray
Mobula mobular

CoP17: 2016
Appendix II
Shortfin devil ray
Mobula kuhlii

CoP17: 2016
Appendix II
Atlantic devil ray
Mobula hypostoma

CoP17: 2016
Appendix II
Pygmy devil ray
Mobula
eregoodootenkee

Pristis microdon and *P. perotteti* are listed in Appendix I, but not illustrated here because taxonomists believe that they are synonyms of *P. pristis*.

Words by Dean Grubbs

Hidden mortality: the effects of by-c

Fisheries come in a number of different guises, but tagging along with virtually all of them is a simple word with portentous significance: by-catch. Dr Dean Grubbs weighs up the world's fisheries and explains why some are better for elasmobranchs than others.

What is by-catch?

atch

A fisherman's hands show only a few shrimp caught after an hour of towing his net, but many kilos of by-catch.

Photo by Brian J. Skerry | National Geographic Creative

By-catch is one of the most difficult issues to overcome in fisheries management. In simple terms, it is the capture of animals that are not part of the targeted or desired catch. Often these animals are not marketed but are discarded at sea, either alive or dead. In many fisheries, by-catch at some level is unavoidable and sometimes it may even be sustainable: for example, if the by-catch rate is negligible, if the by-catch species reproduce and replace themselves at a faster rate than the targeted catch, or if most of the by-catch is released alive and subsequently survives.

A simple metric often used to evaluate how 'clean' a fishery is in terms of by-catch is the ratio of discards to landings. In a perfectly clean fishery, only targeted species of marketable size would be captured and this ratio would be 0 since there are no discards. Purse-seine fisheries that target small schooling fishes such as anchovies and menhaden tend to be the cleanest fisheries. Targeted species often make up about 99% of the catch (a discard-to-landings ratio of 0.01) because they are found in massive single-species schools. However, it is important to realise that these are among the largest fisheries in the world, so even a small proportion of by-catch can add up to millions of metric tons of discards on a global scale. It is also important to recognise that purse-seine fisheries may have other ecological consequences, since they target the forage base (the food species for other species) for larger fishes, including sharks.

At the other end of the by-catch spectrum, bottom trawls for shrimp and demersal (bottom-associated) fishes are typically the 'dirtiest' fisheries. For example, the dead discards in shrimp trawl fisheries are usually larger, sometimes much larger, than the targeted catch. It has been estimated that in the Gulf of Mexico between five and 10 kilograms (11 and 22 pounds) of by-caught fish, crabs and other animals are discarded for every single kilogram (2.2 pounds) of shrimp.

By-catch is especially problematic when the incidentally caught species has a life history that is much more conservative than that of the targeted catch; in other words, it matures later and reproduces more slowly. If the targeted species matures quickly and can double its population in one or two years, even a small by-catch of a long-lived species that requires more than a decade to double its population may be unsustainable.

An endangered or charismatic species, such as a marine mammal or sea turtle, being taken as by-catch often elicits an emotional response from the general public. Of greater concern, though, is the fact that these species are often long-lived and reproduce slowly, so their populations do not rebound quickly after they have been depleted. For example, sawfishes (Pristidae) are considered to be the most imperilled of all chondrichthyans (sharks, rays and chimaeras). All five sawfish species are Endangered or Critically Endangered on the IUCN Red List of Threatened Species; in the USA, the smalltooth sawfish was the first native marine fish to be listed as Endangered under the US Endangered Species Act. Yet even though this species is thus fully protected in US waters, it is caught incidentally in shrimp trawls – and this fishery is believed to be the main reason for smalltooth sawfish mortality. Whereas the targeted shrimp mature in less than a year and produce hundreds of thousands of offspring – thus replacing themselves many times in one year – the smalltooth sawfish takes about 10 years to mature and produces about 10 offspring probably every other year, which means that only 10–15% of the population is replaced each year. Such disparate life histories of targeted and by-catch species within a fishery are a recipe for trouble.

The equipment fisheries use to catch fish can be divided into two broad categories: active gear, which physically moves through the marine environment and is capable of catching animals regardless of their behaviour; and passive gear, which requires the quarry to come to it. Active gear includes purse- and haul-seine nets that encircle schools of fish; mid-water trawl nets that are dragged through the water column and essentially filter out the animals in it; and bottom-trawl nets and dredges that scrape animals off the sea floor, often causing significant damage to the habitat.

Passive gear may either attract fish, often with bait, or simply catch fish that pass by. In the first category are included a baited hook on a line and baited pelagic and bottom long-lines, as well as traps that

attract fish by providing food or refuge. Nets are the other form of passive gear and they include gill, pound and fyke nets. Gill nets may be set on the bottom or in mid-water and may be anchored or drifting.

On a global scale, purse-seine and trawl fisheries yield far more marine produce than all other types of fishing gear combined. Rates of by-catch, which includes sharks and other elasmobranchs, vary dramatically between these fisheries; even small operations can be of concern in some circumstances. There are four major fishery types – trawling, gill-netting, long-lining and purse-seining – and each involves elasmobranch by-catch in different ways.

Trawl fisheries

Trawls are large, funnel-shaped nets that are towed behind one or two fishing vessels. A combination of large 'doors' on bridles at the sides of the net, weights on the bottom and floats at the top keeps the net open. Caught animals are filtered down to a cod-end that is dumped when the net is hauled aboard. Pelagic, or mid-water, trawl nets target the likes of squid, herring and pollock and typically have low by-catch rates because these species often travel in single-species schools. In addition, the nets make no contact with the sea floor so there is little damage to marine habitats. Fisheries such as mid-water trawling for Alaskan pollock are therefore considered to be among the cleanest in the world.

By-catch can become a concern, however, if the fishery also catches predators with vulnerable life histories that are feeding on the target species. For example, pelagic trawl fisheries for herring occasionally catch the marine mammals eating the small, silvery fish. Similarly, fisheries targeting pelagic squid may inadvertently take the molluscs' predators, such as crocodile sharks or sharpnose sevengill sharks.

In contrast to the pelagic type, bottom-trawl fisheries are among the dirtiest and most damaging. The net either drags or rolls along the sea floor, scraping up any animals that can't out-swim it or squeeze underneath it. It often causes significant damage to marine habitats, from sea-grass beds in coastal zones to deep-sea corals. In most, perhaps all, bottom-trawl fisheries the by-catch exceeds the targeted catch; in some cases its biomass is more than 10 times that of the targeted catch. In the USA it has been estimated that nearly three-quarters of all fishery discards come from bottom-trawl fisheries.

In general terms, these fisheries come in three categories, depending on their target: crustaceans such as penaeid and rock shrimp; ground fish such as flounder, cod and pollock; and deep-sea species such as grenadiers, scorpionfishes and beryciformes like orange roughy, alfonsino and redfish. By-catch of sharks and rays can be significant in all these categories and since the trawls can last from one to many hours, mortality is often nearly 100%. As an example, shrimp trawl fisheries in the USA have the highest discard-to-landings ratios and by some estimates are responsible for nearly 50% of all US fishery discards. The discards include a wide array of species, from small fishes and crustaceans to sharks and sea turtles. Recent stock assessments for small coastal sharks such as bonnethead, Atlantic sharpnose and blacknose show that total fishing mortality is dominated by by-catch discards in shrimp trawl fisheries.

Bottom-trawl fisheries targeting ground fish often include significant by-catch of skates and demersal sharks, whose local and regional populations can be quickly depleted. Angel sharks (Squatinidae) and guitarfishes (Rhinobatidae) are among the most threatened of all elasmobranch families and in many regions, such as the north-eastern Atlantic and the Mediterranean, by-catch in bottom-trawl fisheries is the main reason for the decline in their populations. Other bottom-trawl fisheries specifically target certain elasmobranch species and may inadvertently catch others. In the north-eastern USA, for example, two species of skate are targeted by a large fishery for their 'wings' and for bait, while five other species are taken as by-catch. These seven species vary in their abundance and life history and their capture can lead to declines in the ones that are more vulnerable. The population of at least one species, the thorny skate, has become severely depleted by this fishery.

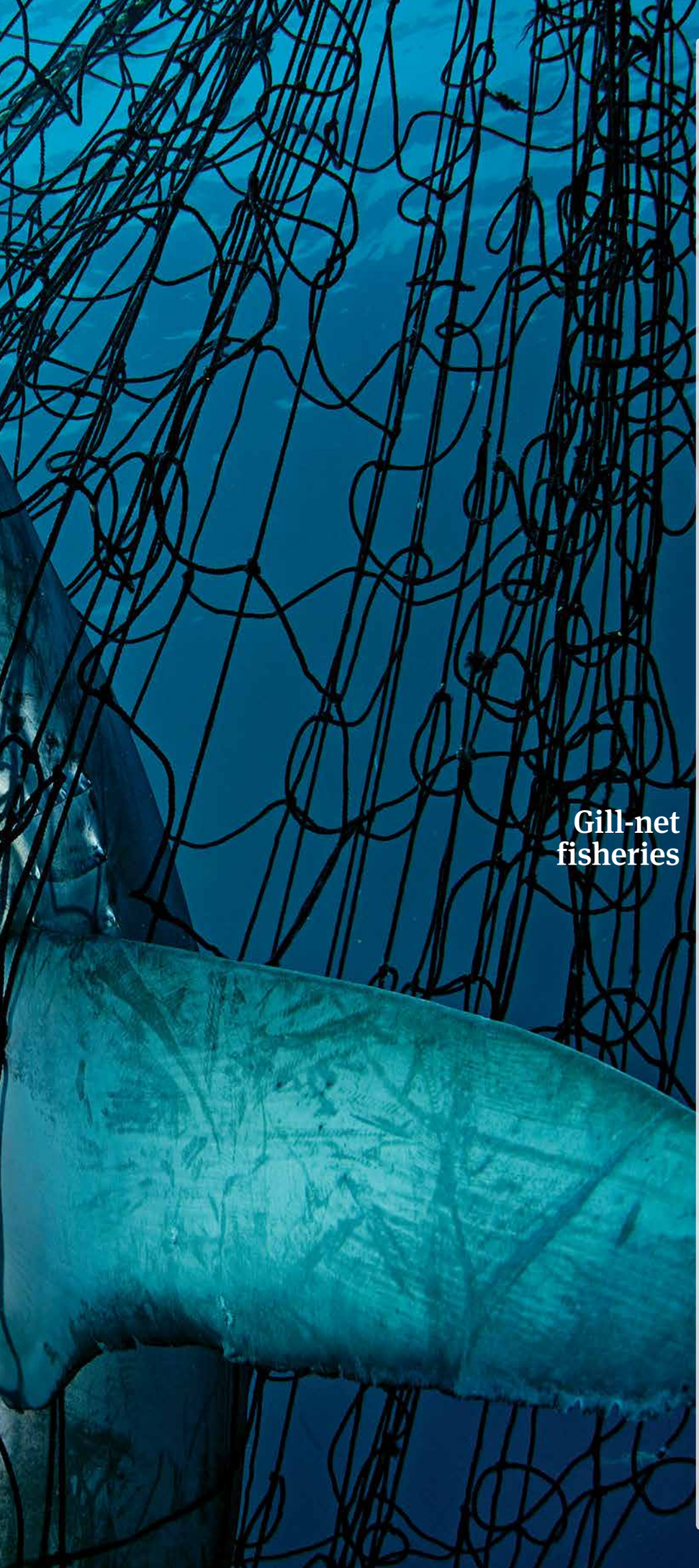
Deep-sea bottom-trawl fisheries can also take significant numbers of elasmobranchs, particularly squaliform sharks and catsharks

Photo by Flip Nicklin | Minden Pictures | National Geographic Creative

Purse-seine fishing for salmon in Clayoquot Sound, Vancouver Island, British Columbia, Canada.

Photo by Brian J. Skerry | National Geographic Creative

A thresher shark is fatally caught in a fishing net.



Gill-net fisheries

(Scyliorhinidae), as by-catch. Squaliform sharks are often not discarded but kept for their meat and oil-rich livers, and regional populations can quickly be depleted. Off the coast of New South Wales, Australia, deep-sea fisheries were reported to have caused severe population reductions in a suite of gulper sharks and dogfishes, as well as sawsharks, angel sharks and sevengill sharks.

It is important to recognise that whereas some shark and ray species caught by trawl fisheries may be able to withstand high levels of by-catch mortality and rebound relatively quickly when by-catch levels decrease, other species are much more vulnerable and their populations may require decades to recover. At one end of the spectrum, although the Atlantic sharpnose shark suffers very high by-catch mortality in US trawl fisheries, the population remains stable because the species matures quickly (three years) and has a high reproduction rate. The barndoor skate in the north-western Atlantic has been shown to rebound in less than 10 years due to its high fecundity (approximately 50 eggs per year) in comparison to most elasmobranchs.

By contrast, deep-sea squaliform sharks have some of the most conservative and vulnerable life histories. The data suggest that some gulper sharks take more than 30 years to mature and produce very few offspring (generally 1–4) following a gestation period of two years or more. As a result, it takes at least 50 years for a population to double. These sharks therefore are extremely vulnerable to by-catch overfishing and will take many decades to rebound if their populations are depleted.

There has been little research into how the by-catch of sharks in trawl nets can be reduced. Although methods to reduce sea turtle by-catch have been developed successfully – and may also be moderately effective for large batoids such as stingrays – it is unlikely that they could be modified for small coastal and deep-sea sharks. In the case of the former, the effect of limiting tow time on post-release survival should be explored. However, restrictions on the type of trawling gear used and the closure of specific areas to trawling may be the only viable mechanisms for reducing elasmobranch by-catch.

Gill nets rely on fishes swimming into them and getting entangled and since they can catch anything larger than the size of the mesh, their rates of by-catch are very high. The size of the mesh varies depending on the size of the targeted catch, in theory allowing smaller fish to pass through it. By-catch rates therefore tend to be higher for nets with smaller mesh.

As in the case of bottom-trawl fisheries, the by-catch in gill nets comprises a wide variety of species; some researchers estimate that globally gill nets are responsible for more by-catch mortality of marine mammals, sea turtles and sharks than any other gear. High-seas drift gill-net fisheries such as those for flying squid and salmon in the North Pacific have been criticised for their extremely high rates of marine mammal and seabird by-catch, but their rates for shark by-catch are no less extreme. It has been estimated that approximately two million sharks, primarily blue and salmon sharks, were caught in the squid drift-net fishery in the North Pacific in 1990 alone.

Gill-net fisheries for coastal fishes such as drums (Sciaenidae) and mullets (Mugilidiae) and coastal pelagic species like mackerels (Scombridae) often also catch large numbers of stingrays and small coastal sharks such as sharpnose and smooth-hound, as well as juveniles of large coastal species like blacktip and bull sharks. A recent analysis of by-catch in the drift gill nets (targeting Spanish mackerel) and sink gill nets (targeting drums and Spanish mackerel) along the south-eastern coast of the USA found that more than 20 species of sharks and rays were caught, including prohibited species such as Atlantic angel, dusky and sandbar sharks and manta ray. Although most elasmobranchs taken as by-catch are reported as discarded alive, post-release survival is very variable. It may be quite high for some stingrays, but is very low for many sharks. Despite aggressive management of the targeted long-line fishery for sharks in this region, species such as sandbar and dusky sharks have failed to recover fully from overfishing, probably because juveniles are being taken as by-catch in gill-net fisheries.

A ban on the use of gill nets, particularly in locations where there

are vulnerable species or life stages, is clearly the most straightforward way to reduce by-catch. The mortality of juvenile smalltooth sawfishes in gill-net fisheries for mullet in Florida waters is thought to have been a major contributor to the decline in this population of the Critically Endangered species. Following the ban on gill-net fisheries in Florida more than 20 years ago, researchers are now reporting signs that the smalltooth sawfish population is beginning to recover. However, gill nets are used extensively by artisanal fishers in developing nations because they are easy to deploy and retrieve from small boats. This being so, it is not feasible to ban them outright. Yet by-catch even at an artisanal scale can have major conservation implications for species that are endemic or have small regional distributions, such as river sharks (*Glyphis* spp.) and freshwater rays. Research into the effects of soak time and the size and break strength of gill-net mesh on shark by-catch rates and post-release survival is therefore badly needed.

Long-line fisheries

Long-lines are an effective fishing gear that can be employed across various habitats from rivers (where gear such as catfish trotlines may be used) to shallow coastal waters, the open ocean and the deep sea. Unlike trawl and gill nets, long-lines are selective for species that can be lured to take a baited hook, which include most predatory fishes.

A long-line consists of a main line to which a series of branch lines (also called gangions or snoods) is attached. Each branch line terminates in a baited hook. The main line may be any length and contain any number of hooks, but generally it ranges from hundreds of metres long with only 20 or so hooks in some near-shore and deep-sea fisheries to more than 100 kilometres (60 miles) long with over 1,000 hooks in pelagic fisheries. The branch lines may be clipped to the main line during each deployment or sewn permanently into the main line.

Pelagic long-lines are not anchored, but are set adrift and marked with highfliers (floats with a radar reflector and possibly a radio transmitter) to locate the ends. They employ a combination of floats, weighted branch lines and varied branch line lengths to reach the depths of the targeted species. Bottom-set (demersal) long-lines are anchored at both ends and marked by a buoy at one or both ends. Whereas the branch lines for pelagic long-lines may be as much as 10–20 metres (32–64 feet) long, the branch lines for demersal long-lines generally range from only 20 centimetres (eight inches) to three metres (10 feet) long.

Pelagic long-line fisheries are often seen in a negative light by environmental groups because of their by-catch, although they are relatively clean when compared to bottom-trawl and gill-net fisheries in terms of their discard-to-catch ratio. In US pelagic long-line fisheries, for example, only 3–15% of the catch is discarded. However, as in trawl fisheries, the disparate life histories of target and by-catch species are a concern in long-line fisheries. Whereas targeted pelagic fishes such as tunas and mahi mahi mature early and produce many offspring, resulting in population doubling times in the order of two years, the by-catch often comprises charismatic species such as pelagic sharks and sea turtles that have conservative life histories and population doubling times that may be much greater than those of the targeted species.

Sharks are often the dominant by-catch in pelagic long-line fisheries. In the tuna fishery in the Western Tropical Pacific, shark by-catch has been shown to be relatively high – approximately one shark for every two tunas caught. However, a comparison of many pelagic long-line fisheries has suggested that shark by-catch rates were lowest in high-seas fisheries targeting tunas (such as those of Japan, Fiji and Hawaii) and highest in fisheries in shallower water and closer to shore (such as Chile's mahi mahi and Hawaii and Chile's swordfish fisheries).

Although the number of individual sharks caught may be very large, relatively few shark species are affected by pelagic in comparison to bottom-trawl fisheries. Globally, the blue shark is the dominant species caught in pelagic long-line fisheries, followed by the silky shark and the oceanic whitetip. The proportion of sharks taken as by-catch being kept and sold as opposed to being discarded at sea varies greatly from one fishery to the next, depending on regulations and the markets available. It has been shown that most of the sharks

Photo by Brian J. Skerry | National Geographic Creative

Guitarfish, rays and other by-catch are tossed from a shrimp boat.

A stingray is fatally caught in a gill net.

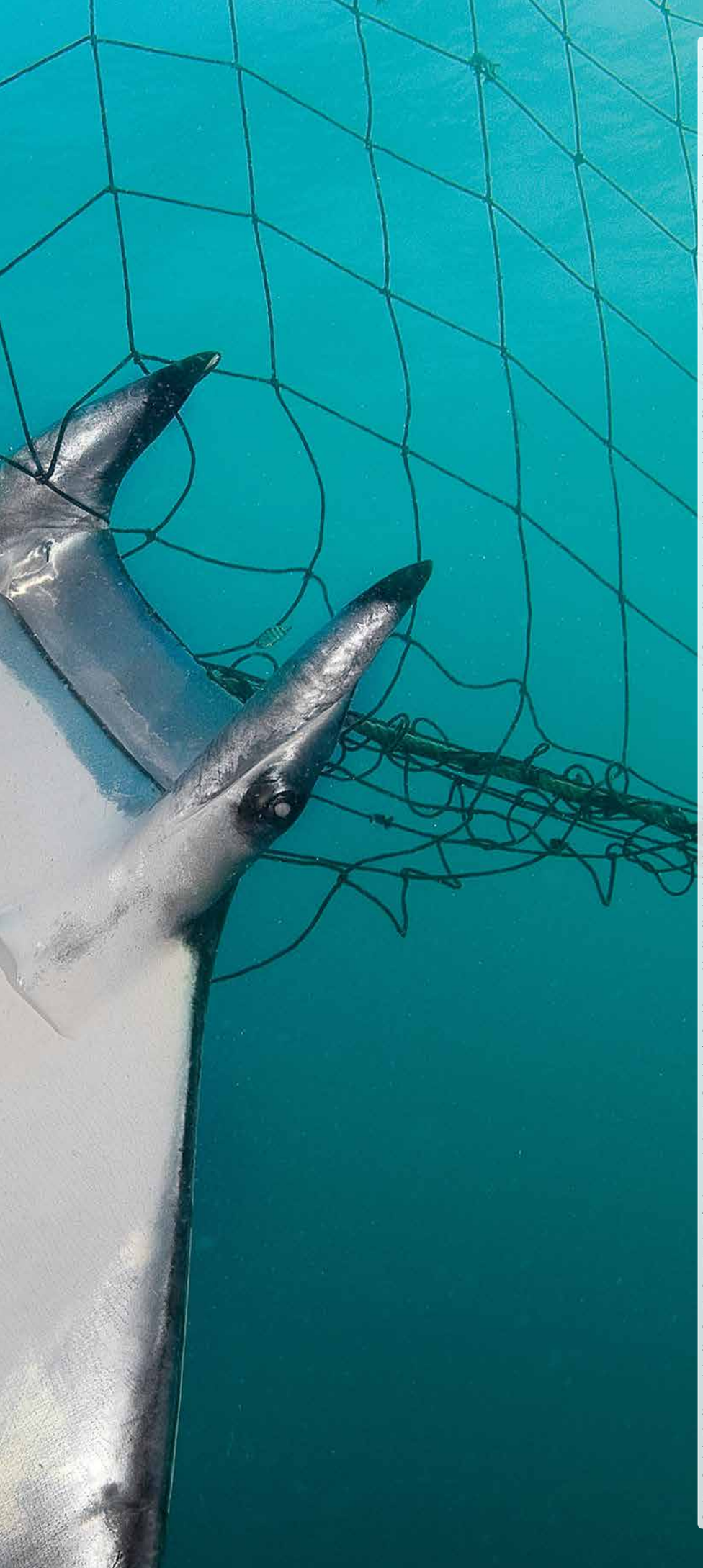


Photo by Brian J. Skerry | National Geographic Creative

that end up in the international fin trade are by-catch in pelagic long-line fisheries and there is concern that, while the targeted stocks of pelagic bony fishes are harvested sustainably, these shark species may become depleted.

In most pelagic long-line fisheries, the blue, silky and oceanic whitetip sharks are reported being discarded alive, but post-release mortality has not been estimated and may be high. Marketable species such as the shortfin mako and the three thresher sharks are typically kept to be sold and, given their conservative life histories, they are of great management concern. It is also important to recognise that some pelagic fisheries retain all the sharks taken as by-catch. For example, the swordfish fishery off Uruguay, which has an extremely high rate of shark by-catch, typically markets more than 95% of the blue sharks caught.

Several mitigation measures to reduce shark by-catch on pelagic long-lines have been assessed, though their effectiveness often depends on the species involved. The use of monofilament instead of steel leaders and of squid bait instead of fish bait has been shown to reduce the number of sharks caught, with relatively little – or even a positive – effect on the catch rate of the targeted tunas and swordfish.

The depth of the hooks is often an important consideration. The majority of pelagic sharks, such as silky and oceanic whitetip, spend most of their time in the upper mixed layer shallower than 100 metres (330 feet). Increasing the depth of hooks to 100 or 150 metres (500 feet) has been shown to reduce by-catch rates significantly for these and most other shark species. However, blue, bigeye thresher and shortfin mako sharks make daily excursions to depths of 400 metres (1,320 feet) and more. For them, factoring in both time of day and depth when deploying hooks may reduce by-catch. More research needs to be undertaken to determine what influences shark by-catch rates in pelagic long-line fisheries so that additional mitigation measures can be identified.

At-boat and post-release mortality rates for sharks caught on pelagic long-lines vary widely, depending on the species. Some sharks, such as the smooth, scalloped and great hammerheads and all the thresher sharks, often suffer at-boat mortality at a rate of at least 25% and sometimes more than 50%, and it is likely that most of the sharks released alive do not survive for long. In contrast, the at-boat mortality rate of blue, silky and oceanic whitetip sharks – the three species most often caught on pelagic long-lines – as well as of mako sharks, is only 5–20%, and the few data available suggest that post-release survival may be quite high. A large meta-analysis of tagged blue sharks caught on pelagic long-lines suggests that the species' total mortality rate (at-boat and post-release) is less than 15%.

Demersal, or bottom-set, long-lines are those whose hooks lie directly on the sea floor (as opposed to pelagic long-lines, whose hooks are suspended in the water column and the lines themselves drift with the current). Many targeted shark fisheries deploy demersal long-lines as their primary gear, but there are also a number of fisheries using the same gear for bony fishes that take significant shark by-catch. In fact, the by-catch on demersal long-lines can be 50% or more of the overall catch – a much higher overall by-catch rate than that of pelagic long-lines.

In terms of species, it is likely that demersal long-line fisheries take more shark species as by-catch than do all other fisheries combined. In the Gulf of Mexico, the two most common by-catch species taken by the US demersal fishery for groupers are Cuban dogfish and blacknose shark. It is reported that more than 95% of these sharks are released alive, but a recent study has shown that about half of them would have soon died, even if they were released in a healthy condition. In addition, on some vessels the hook is ripped from the shark's mouth, breaking the lower jaw, which probably increases the post-release mortality rate.

The deepest fisheries in the world are demersal long-lining ones, such as those targeting Patagonian toothfish (down to 3,000 metres, or 9,840 feet) and Greenland halibut, grenadiers, hake and ling (2,000 metres, or 6,560 feet). Shark by-catch in these fisheries can be very high for species like Portuguese dogfish, lanternsharks, gulper sharks and their relatives, as well as for numerous species of catshark. Some of these species are kept and sold for their livers

and meat, but most small sharks are discarded at sea. Mortality is probably 100% in these fisheries as not only are the sharks unable to survive being retrieved from great depth, but their jaws are broken on landing by the auto-line retrieval system that pulls the hooks through a set of steel rollers.

Similarly, demersal long-lining fisheries targeting cusk-eels off Chile and hake off the coasts of numerous European and African countries have relatively high by-catch rates of deep-water catsharks, gulper sharks and dogfishes. The species caught in these deep-sea fisheries have some of the most conservative life histories and are therefore extremely vulnerable to by-catch overfishing. Generation times are measured in decades and recovery time for a population may take centuries if depletion is severe.

Even in targeted shark fisheries that are reasonably well managed, by-catch is a major concern. The shark long-line fishery in US Atlantic waters targets large coastal sharks and is regarded as one of the best-managed fisheries of its kind in the world. However, more than half of its catch can be of small coastal sharks, such as the Atlantic sharpnose, that are not marketed – and most are discarded dead. Moreover, species that are prohibited because they are overfished (such as dusky or sandbar sharks) or endangered (smalltooth sawfish) are also taken as by-catch. Fortunately, many of these are quite resilient and probably survive capture.

Purse-seine fisheries

The largest fisheries in the world are purse-seine fisheries that target small pelagic fishes such as anchovies, herring and menhaden. Historically these fisheries have been relatively clean in terms of by-catch as they typically target dense single-species schools of fish. Industrialised fishing for larger pelagic fishes such as tunas has developed relatively recently – during the latter half of the 20th century – and now purse-seine nets are also responsible for catching more tunas than any other form of fishing.

Three types of fishing gear are primarily used for harvesting tunas: bait boats with hand lines, pelagic long-lines and purse-seine nets. Globally, the three types resulted in similar tuna landings until the early 1980s, but since then purse-seine landings have increased nearly 10-fold whereas long-line and hand-line landings have remained relatively stable. Purse-seine fisheries are now responsible for about 70% of all tuna landings worldwide, although the pattern differs from one species to another. Most albacore tuna are still landed in long-line, hand-line and troll fisheries, but 75–90% of global skipjack, yellowfin and bigeye tunas are caught in purse-seine nets, which are also the dominant gear type used to harvest Atlantic bluefin tuna.

Purse-seine nets are deployed in the open ocean over deep water. Those used for tunas are typically 1,000–2,000 metres (3,280–6,560 feet) long (about 300–650 metres, or 985–2,130 feet, in diameter) and usually at a depth of about 200 metres (650 feet). Very simply, the seine has a float line and a lead line and it is positioned to encircle a school of fish, with one or two boats pulling it from the larger harvest vessel. Once the float line circle is closed, the opening at the bottom of the net is closed, or pursed, by cinching the lead line and thus preventing any fish from escaping. The net volume is reduced and the catch is hauled aboard the harvest vessel, removed from the net and placed in the ship's hold.

Four methods are used to locate the tuna. Visual spotters on the vessels or in aircraft look for free schools of tuna feeding or swimming at the surface. This is the most challenging and least productive method, as free schools are constantly moving and difficult to locate and the tuna are more likely to be startled and dive deep before the net has been deployed. However, free schools tend to be dominated by the targeted tuna species and there is therefore very little by-catch.

Tunas are often not close enough to the surface to be spotted, but they are known to associate with other species – primarily dolphins, but also whales and whale sharks – that do spend more time at the surface. In the Eastern Pacific, if a large pod of feeding dolphins is located, there is often a substantial school of yellowfin tuna below it – an association that is far less common in other parts of the world. By-catch in dolphin-associated purse-seine fisheries is mainly silky sharks, but rates are quite low.

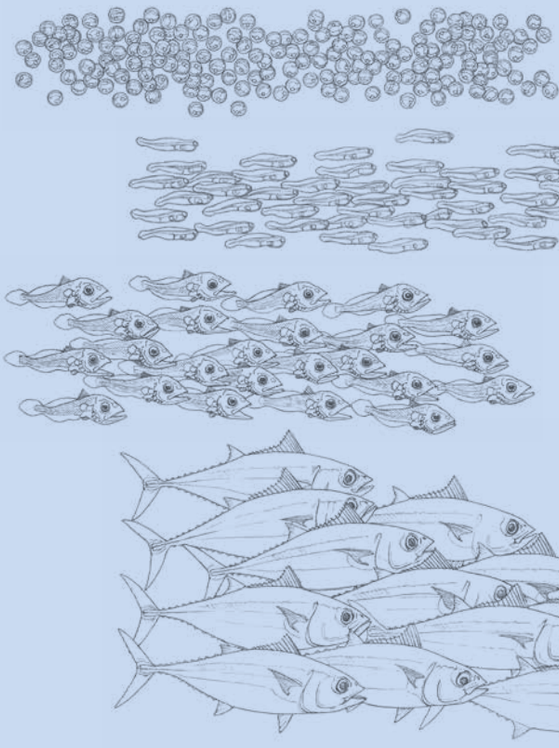
Photo by Brian J. Skerry | National Geographic Creative

A bottom trawler scrapes the ocean floor, destroying the habitat.

Photo by Brian J. Skerry | National Geographic Creative

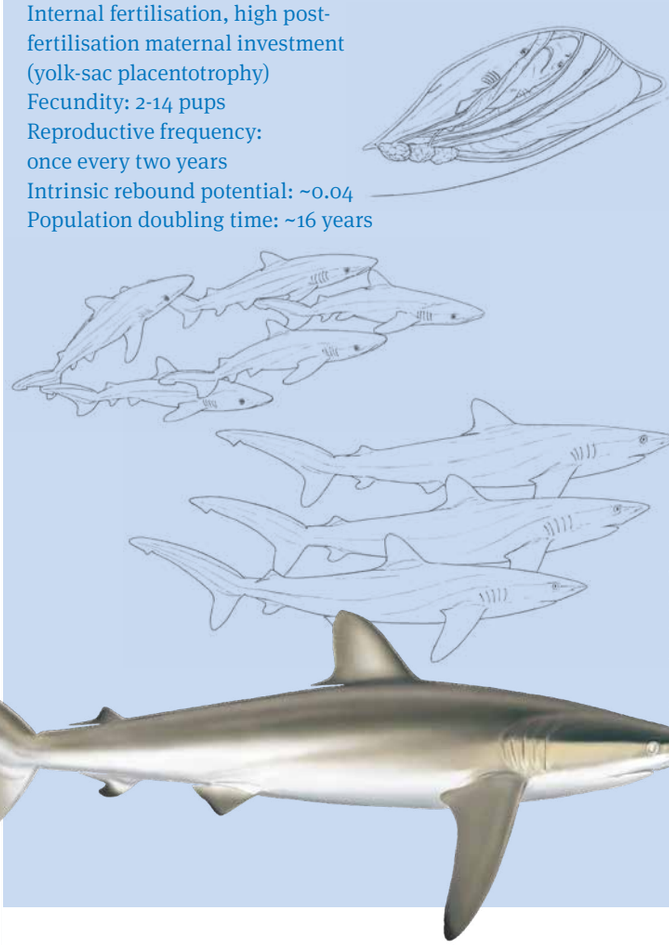
Yellowfin tuna

Maturity: ~2 years
External fertilisation, no post-fertilisation maternal investment
Fecundity: 2-10 million eggs per spawning
Spawning frequency: many times per year
Intrinsic rebound potential: >0.10
Population doubling time: ~4 years



Silky shark

Maturity: ~12 years
Internal fertilisation, high post-fertilisation maternal investment (yolk-sac placentotrophy)
Fecundity: 2-14 pups
Reproductive frequency: once every two years
Intrinsic rebound potential: ~0.04
Population doubling time: ~16 years



Illustrations by Marc Dando

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Floating objects that drift around oceanic gyres (sometimes for years) tend to attract and hold large communities of organisms that seek refuge in the dangerous open ocean. These objects may be natural, such as trees or logs that have been swept into the sea from rivers, or man-made, like lost fishing nets or pieces of wrecked vessels. According to one study, more than 300 fish species are associated with such refuges in the open ocean. Pelagic predators such as tunas and sharks in turn are attracted to these floating objects and the potential prey they harbour. Many tons of pelagic fishes may aggregate at a relatively small floating object and, not surprisingly, by-catch rates on floating-object sets are much higher than on free-school or dolphin-associated sets. The most vulnerable component of this by-catch is pelagic sharks.

The fourth method to locate tunas is a variation on the floating object theme. Fishers exploit the tendency for tunas to gather at floating objects by deploying purpose-built fish aggregating devices (FADs) to attract them. These FADs may be floating or anchored and as simple as palm fronds tied together or as complex as large structures with radio or satellite locator beacons and integrated sonars that enable fishers to estimate the biomass of aggregated fish. FADs attract diverse communities of animals and the by-catch rates of the associated fishery are therefore very high. Pelagic sharks, big and small pelagic fishes and large amounts of undersize tuna discards make up most of the by-catch.

The evolution of tuna purse-seine fisheries in the Eastern Tropical Pacific with their associated by-catch issues is an interesting case study in the complexities of fisheries management – and perhaps in the effects of well-meaning but misguided environmental activism. This was the subject of many years of research by Dr Martin Hall of the Inter-American Tropical Tuna Commission. The targeting of dolphin-associated tunas became an environmental issue in the late 1960s that generated significant controversy due to the high rate of dolphin mortality and estimates of rapidly declining dolphin populations. However, by the late 1980s dolphin mortality began to decrease dramatically after the fishery developed its own technique – called a 'backdown' – to reduce dolphin by-catch. After encircling a pod of dolphins and the associated tunas, the fishers would reverse their vessel and pull the back of the net, submerging the floats and allowing the dolphins to escape before being hauled into the net.

Although dolphin mortality was already in a steep decline, the 'dolphin-safe' tuna labelling campaign was launched by the Earth Island Institute. This led US canneries to adopt dolphin-safe policies in 1990, which required them to buy only tunas that had been caught by methods that did not involve encircling dolphins. The labelling campaign led to only a modest reduction in the number of dolphin sets made in the Eastern Pacific and by the late 1990s the amount of fishing effort associated with dolphin pods was back to pre-1990 levels and the tuna was being sold to countries other than the USA. Yet by 1993 dolphin mortality had decreased to almost zero, thanks to the procedures developed by the fishery prior to dolphin-safe labelling, and it has remained extremely low for more than 20 years.

In an unintended consequence, however, dolphin-safe labelling led the US purse-seine fleets to develop the use of FADs. In the Eastern Pacific, as recently as 1989 95% of the floating objects used by the purse-seine fishery were natural; by 1995 more than 80% were FADs and by 2009 the proportion had risen to 95%. By-catch in purse-seine fisheries in this region between 1993 and 2009 was estimated to be only 0.5% of the catch in dolphin sets but nearly 10% of the catch in FAD sets – a 20-fold difference. This annual by-catch was calculated to include nearly 3,500 sharks in dolphin sets but more than 35,000 sharks in FAD sets. It was estimated that the capture of one single dolphin in dolphin-associated purse-seine nets was equal to the by-catch of approximately 25 sharks and more than 900 fishes in FAD-associated purse seines. The success of using fisherman-deployed FADs to catch tunas in the Eastern Pacific in the early 1990s led to the rapid expansion of their use in all tropical oceanic regions. FAD-associated purse-seine fisheries now account for more than half the global landings of tuna.

It is widely recognised that of the diverse species that are taken as by-catch in FAD-associated tuna fisheries, sharks are the most

vulnerable because of their life histories. In some regions, more than 20 shark species are caught in purse-seine nets. And of these sharks, silky and oceanic whitetip sharks dominate worldwide, followed at some distance by scalloped and smooth hammerheads. The magnitude of the purse-seine fishing effort globally puts these species at risk and significant population decreases have been documented in some regions.

In most purse-seine tuna fisheries, it is required that any sharks caught have to be released alive. However, the sharks caught in these fisheries are mostly pelagic and, as obligate ram ventilators, they must swim constantly so that sufficient water passes over their gills to oxygenate them. These sharks therefore tend to be quite fragile and soon die if they aren't actively swimming. For this reason, whereas pelagic sharks caught on long-lines have a relatively high survival rate, the rate for sharks taken by purse-seine fisheries is likely to be very low. Two recent studies examined post-release mortality in silky sharks caught in tuna purse-seine nets set around FADs in the Pacific Ocean. In both studies it was found that most silky sharks were dead when landed and the majority of those released alive subsequently died. The total mortality for silky sharks caught in purse-seine nets was estimated to be 80–95% in one study and at least 84% in the other. One study also reported that 100% of scalloped hammerheads taken in purse-seine nets died after being released.

The problem of by-catch in purse-seine fisheries using drifting FADs is compounded by the fact that the structure of the device itself causes additional mortality. In many drifting FADs, old fishing net hangs down from the structure and marine life, including sea turtles and sharks, becomes entangled in it. These deaths are not included in fishery by-catch estimates, but they can be substantial. A recent study conducted in the Indian Ocean estimated that the mortality of silky sharks entangled in FADs may be five to 10 times the actual by-catch in the associated purse-seine fishery.

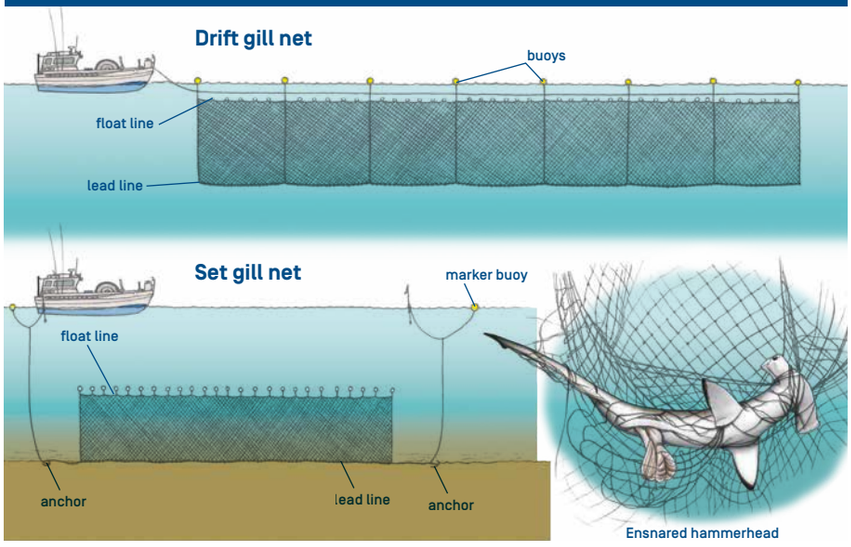
By-catch and how to reduce it is one of the most difficult and complex issues faced by fisheries managers. Relatively few fisheries exist where by-catch is not a major concern, and it is particularly troubling when it includes elasmobranchs whose life histories are more conservative than those of the targeted catch, making them more vulnerable to overfishing. To truly be sustainable, fisheries should be managed for the sustainability of the most vulnerable species caught, even if those species are by-catch with no economic value. This rarely happens, however, because fisheries are important to economies and the demand for seafood is high. It is important for consumers to understand that the real cost of seafood often goes well beyond the monetary cost of the product.

Shrimp fishing trawlers in dock in Guaymas, Mexico.

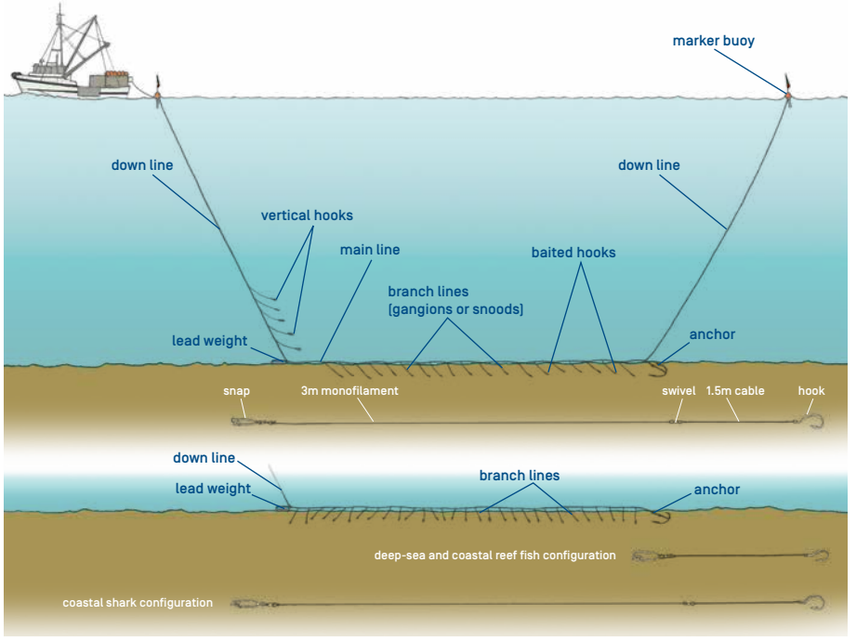
SOURCES OF SHARK AND RAY BY-CATCH

Globally, the number of sharks and other elasmobranchs captured as by-catch (species not targeted) is probably greater – perhaps by several times – than the number harvested in fisheries. The greatest biomass of sharks captured as by-catch occurs in pelagic fisheries using long-lines, purse seines and drift gill nets. By-catch in these fisheries is of great concern for the populations affected due to the magnitude of mortality. However, these fisheries affect relatively few species, with catches being dominated by a handful of pelagic sharks like blue sharks and silky sharks. In contrast, fisheries employing gill nets, bottom trawls and long-lines in the coastal zone often affect a great many species of sharks, skates and rays and the biomass of discard mortality is often grossly underestimated. The discard biomass in bottom-trawl fisheries in continental shelf waters is often many times the biomass of the targeted catch. Many deep-sea sharks have life histories that render them much more vulnerable to overfishing than their coastal counterparts, and deep-water trawl and long-line fisheries now operate to the maximum known depth at which sharks occur. Deep-sea edge habitats such as submarine canyons and sea mounts concentrate biomass and biodiversity and often have unique animal communities, including isolated shark populations that can be quickly depleted by relatively small fisheries.

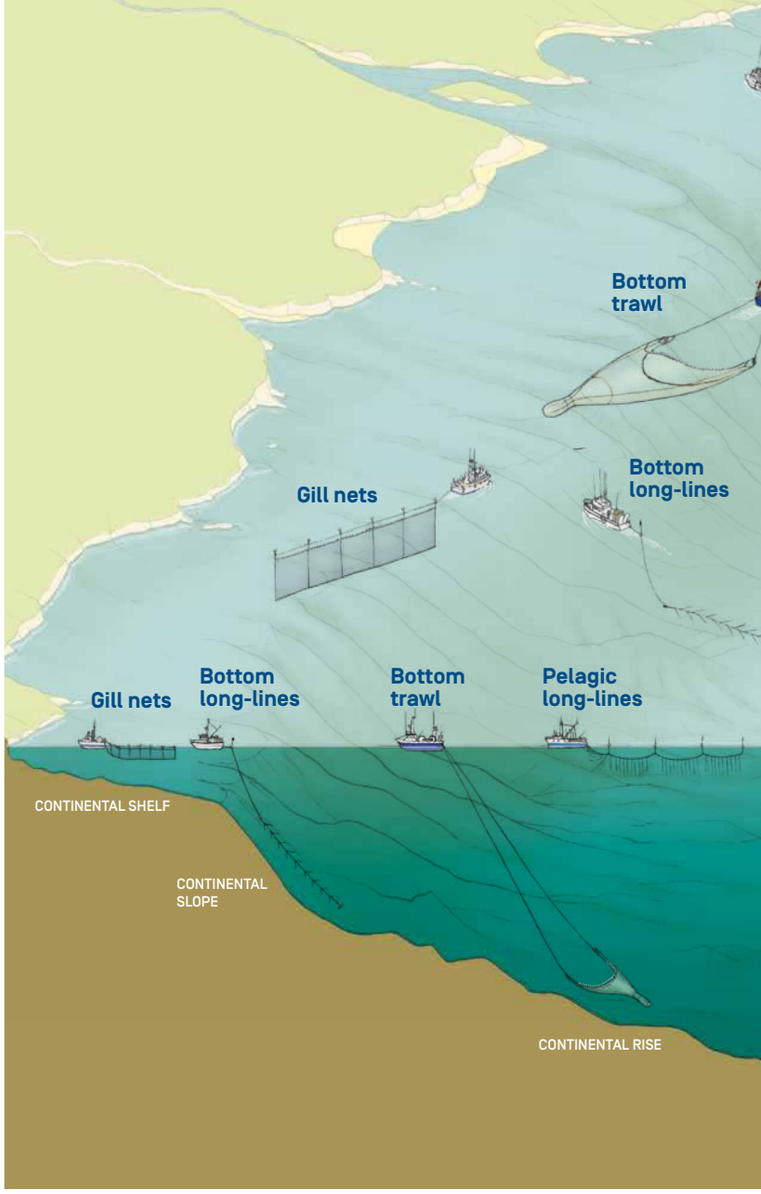
Gill nets



Bottom long-line



As the human population has grown and coastal marine resources have become fully exploited, and in some cases overfished, fisheries have spread farther from shore and into deeper regions of the world's oceans. Sharks and rays are now subject to harvest and by-catch by fisheries operating throughout their depth range from coastal rivers and estuaries to the deep continental slope more than 3,000 metres deep. The major fisheries responsible for shark and ray by-catch are illustrated and typical species that are exposed to each fishing gear are represented below.



Drift gill net

Prionace glauca

Lamna nasus

Sphyrna lewinii

Set gill net

Carcharhinus obscurus

Rhizoprionodon terraenovae

Squalus acanthias

Pristis pristis

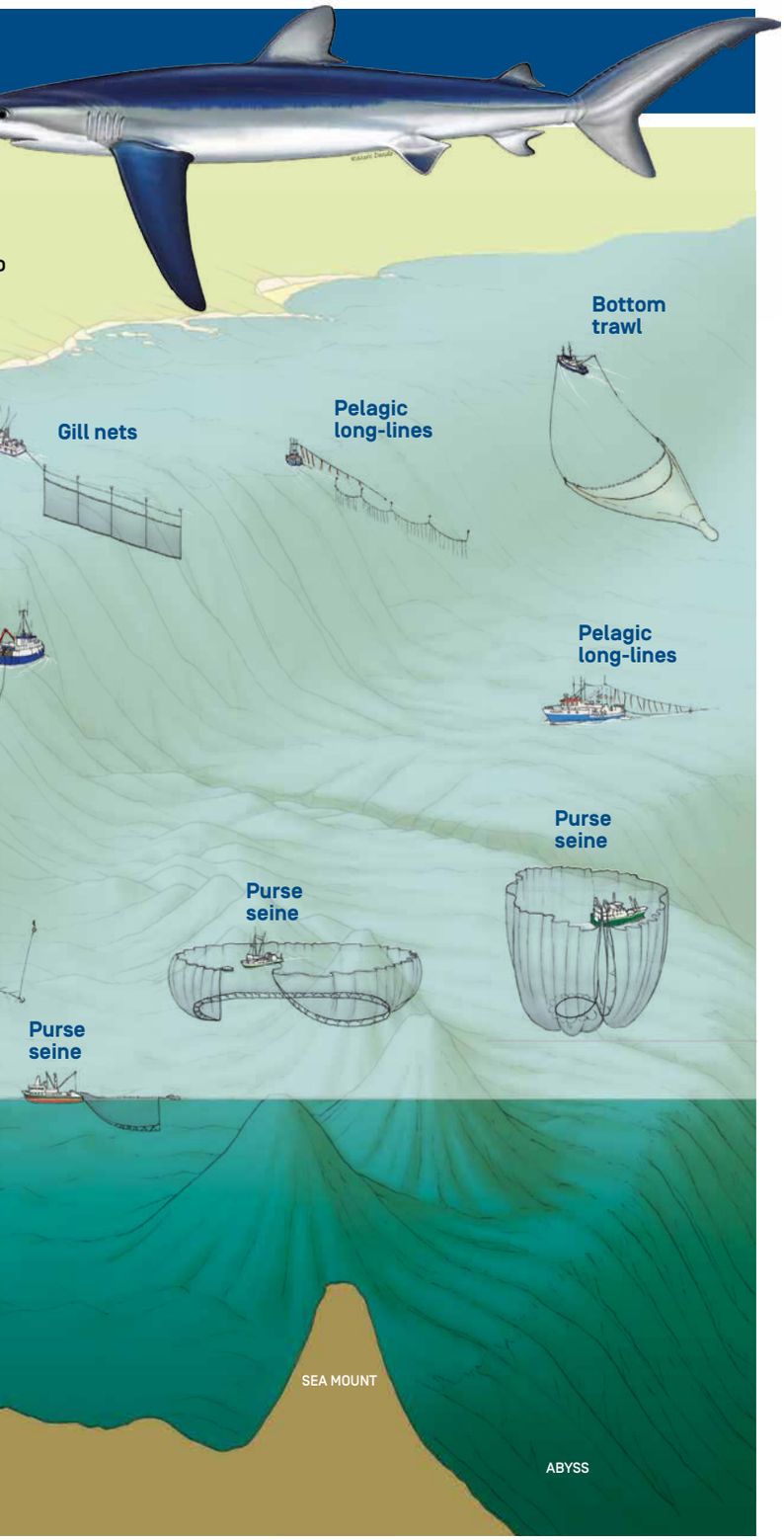
Bottom long-line

Carcharhinus plumbeus

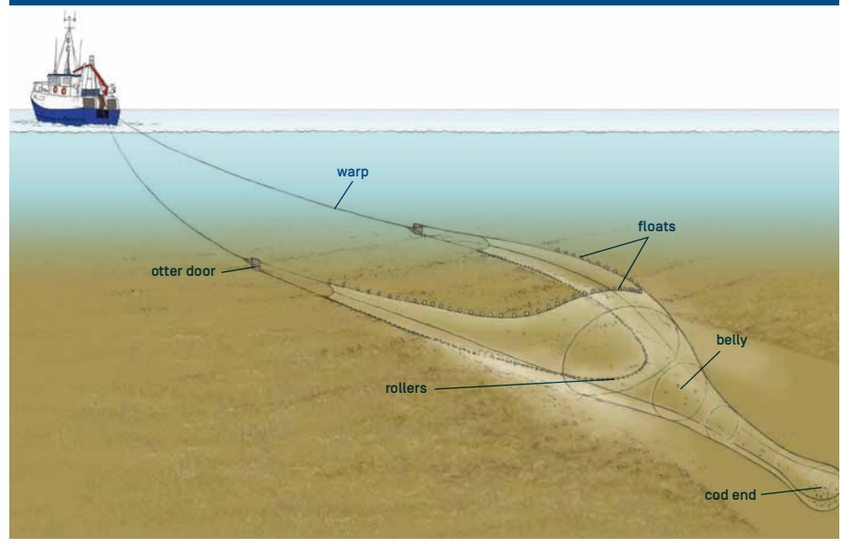
Rhizoprionodon terraenovae

Etmopterus princeps

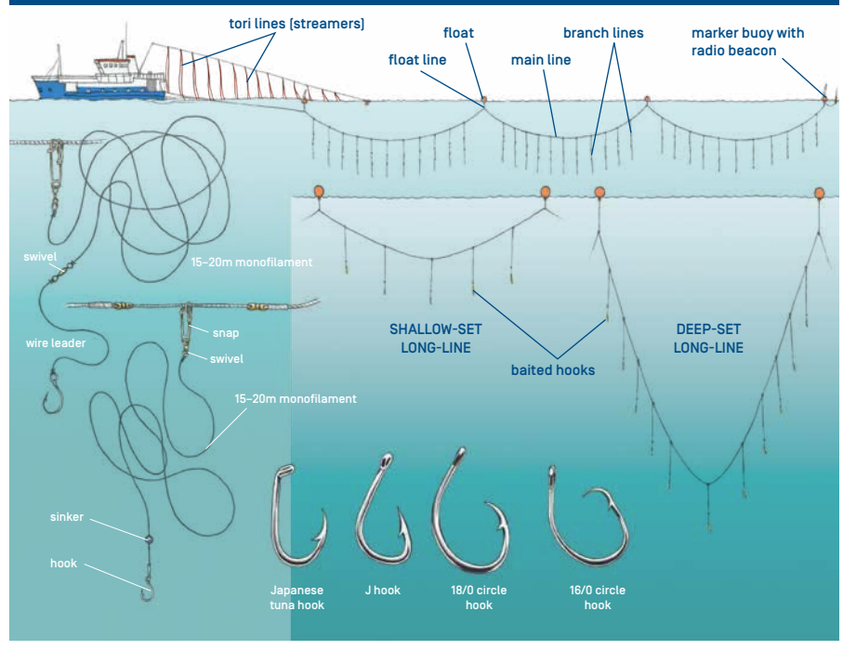
Centrophorus atromarginatus



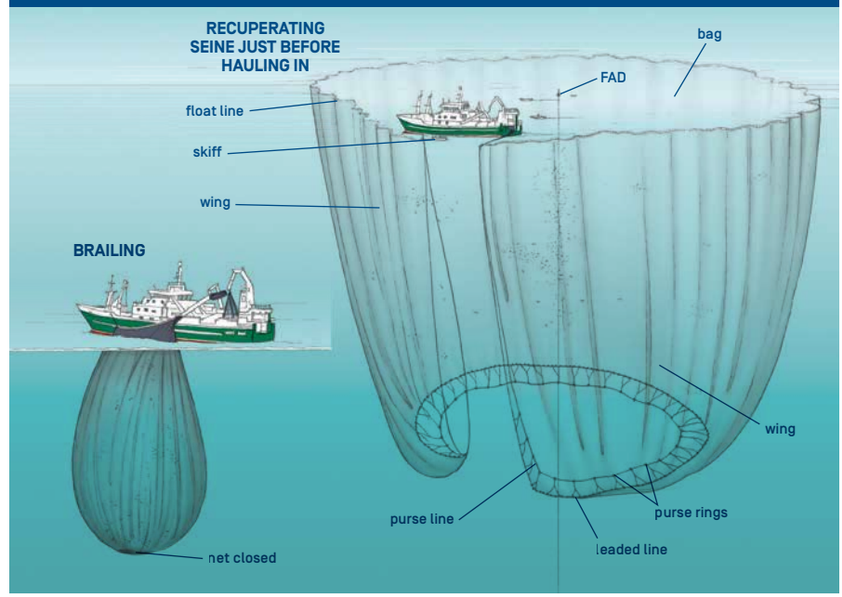
Bottom trawl



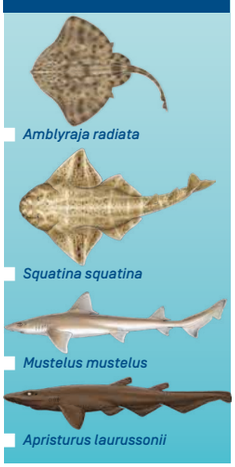
Pelagic long-lines



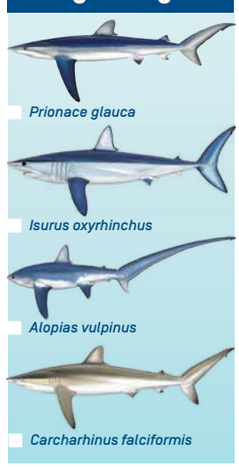
Purse seine



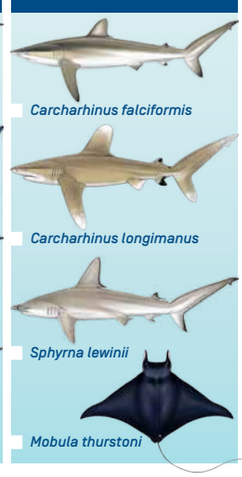
Bottom trawl



Pelagic long-line



Purse seine



Infographic design by Marc Dando | Content interpretation by Dean Grubbs and Marc Dando

Photo by Nadia Bruyndonckx

When you hear phrases like 'the sixth extinction' and 'the Anthropocene epoch', conservation efforts can seem rather futile. How do you feel about the proliferation of bad news for the environment?

There is no doubt that human overpopulation has taxed ecosystems and natural resources to unprecedented levels and reversing these trends can seem impossible. But among all the bad news there is also good news. Unfortunately, good news for the environment doesn't get the press coverage that 'doom and gloom' gets. This is what has been most frustrating to me. In my field studying elasmobranch ecology and fisheries science, there can be a robust stock assessment that makes use of all appropriate datasets and determines that a stock is stable; it will not get any attention. But if someone cherry-picks a dataset to suggest that the same stock has collapsed and the species is at risk of extinction, that will be picked up by the media and make headlines – and the general public is misled into thinking the latter scenario is true. It is critical that we highlight progress made as well as where there are problems.

What do you think are the dangers of over-emphasising conservation crises by using terms like 'regional extinction'?

In biology, the word 'extinction' is generally used to mean the end of a species. 'Extirpation' is the loss of a population or the disappearance of a species from part of its range; some call this a local or regional extinction. I think the term 'extinction' should be reserved for cases where the loss of an entire species is genuinely at risk. When we say 'extinction', its use should be truly shocking to listeners or readers. In my view, if we use 'extinction' to describe the loss of a species from one small part of its range, this cheapens or dampens the severity of the word. It also desensitises the public to

Q&A

In conversation with Dean Grubbs

Dr Dean Grubbs, the current president of the American Elasmobranch Society and scientific adviser to the Save Our Seas Foundation, has spent two decades working with sharks and rays. Philippa Ehrlich asked him for his thoughts on the future of elasmobranchs.

the concept of extinction if ecologists and environmentalists are throwing the word about in cases where there is little actual risk of a species going extinct.

How do you respond to grant proposals that are motivated by a 'sky is falling' narrative?

Whether I am reviewing grant proposals or manuscripts, I approach them objectively in the same way. Whatever the background that is informing the research questions, the proposal or manuscript needs to be well reasoned and well researched. I get somewhat annoyed at what seems to be significant confirmation bias in conservation biology though. It seems that if a paper comes out relating to fisheries with the 'sky is falling' narrative, it is readily accepted and cited without much scrutiny from reviewers or readers. Before we cite any study, whether it makes claims that all fisheries are about to collapse or that the world's oceans are pristine and healthy, we should read those papers critically and determine whether their claims are appropriate. I repeatedly see researchers choose to cite papers that support the 'sky is falling' narratives but ignore published rebuttals that challenge those findings. This is inappropriate, unless they have reason to believe those rebuttals are wrong.

Do you have advice about what a more constructive approach could be?

Objectivity, scepticism and the acknowledgement of uncertainty are critical components to conducting science. We should be objective and sceptical in conducting our own research and in reviewing the research of others. We shouldn't overstate our results, but instead should acknowledge their limitations. And we can't allow ourselves to fall victim to confirmation bias. For those of us who chose to get into study fields such as the ecology of sharks, the challenge is that we have not only an academic connection to these animals, but also an emotional one. But as scientists, we must be able to recognise and separate the emotional response from the academic one.

What is your outlook on the future for sharks and rays?

For the fate of sharks and rays in general, I tend to be very optimistic. We still have huge problems in some parts of the world where there is a complete lack of management in these species, but there are also really positive signs. In the USA, we saw our populations of large coastal sharks plummet in the late 1980s and early 1990s when commercial fisheries began to target sharks directly. This corresponded with the opening up of US trade with China, including routes for the shark fin trade. But the huge population declines were recognised in the late 1980s and since the early '90s we have had one of the most aggressively managed shark fisheries in the world. That shark fishery is now managed at a quota that is at about 8% of what the peak landings were. And we have seen recoveries in a lot of our shark populations. Tiger sharks have been increasing for 20 years. Bull sharks are increasing. Blacktip sharks have never been overfished and seem to be stable and sustainably fished. We do still have problems, however. Dusky sharks are still overfished and possibly sandbar sharks too. So there are still issues, but we have seen that we can actually recover these populations when they are overfished.

There has been a lot of interest in sawfishes in recent years. Do you think there is hope for them?

We are seeing a slow increase each year in sawfish populations in Florida. And we are seeing it for both juveniles and adults, so it probably stems from a few things. Not only has the smalltooth sawfish been on the US endangered species list since 2003, but it has been protected in Florida waters, the centre of its distribution, since the early 1990s. So the species has been protected for more than 25 years and we are finally witnessing its recovery. In addition to that, its primary habitat is protected in national parks and wildlife refuges, so we know there are the mechanisms to promote the recovery of this species.

For other species in other parts of the world, we'll see. There are only five species of sawfish worldwide and four of them occur in Australian waters. Australia also has fairly aggressive management plans to try to recover and protect sawfishes. So, between the USA and Australia, the outlook is positive for the preservation of the species. Within individual countries and individual populations, there are mixed results and the outlook may not be quite so optimistic. It's hard to see progress in some parts of the world where artisanal fisheries use nets to support individual families and villagers who need the protein from fish. So I think there are problems elsewhere.

At Sharks International a couple of years ago, sawfishes were regarded as the 'pandas of the sea', which is ironic given that the giant panda is no longer an endangered species. Do you think the same could be in store for sawfishes?

I am very optimistic that we are going to see a recovery in sawfishes. I predict that before I retire, I will be part of the team that says we can now down-list sawfishes in the USA from Endangered to Threatened, at least. Maybe we won't yet take them off the endangered species list altogether, but that is still our ultimate goal. A lot of people don't understand that. They think that if something is on the endangered species list, it's there forever. No, the goal is to recover this population to the point that it is no longer on the endangered list – and I'm optimistic that within the next 20 to 25 years this can be achieved for the US population of the smalltooth sawfish.

While the individual projects supported by the Save Our Seas Foundation (SOSF) come and go over the years, there are several relationships that we have maintained for some time and will continue to maintain for the foreseeable future. Three centres – two focusing on research and one on education – are managed directly by the SOSF, and four independent NGOs have engaged in mutually supportive partnerships with the foundation. All these organisations are dedicated to tackling, in one way or another, the huge amount of work involved in protecting the marine environment and the diverse creatures within it. Research and education are kingpins in this work and through the Shark Research Center in the USA, the D'Arros Research Centre in the Seychelles and the Shark Education Centre in South Africa, the SOSF can extend its on-the-ground reach to these countries and beyond. The NGOs Bimini Biological Field Station (also known as the Shark Lab), Cetacea Lab, the Manta Trust and Shark Spotters are carrying out long-term research and conservation work and, in terms of funding and communication, the foundation's partnership with them, as well as with the Acoustic Tracking Array Platform (ATAP), is closer than its relationship with our individual, shorter-term projects. We rely heavily on our partners' respective areas of expertise as we reach for shared conservation goals and are inspired by the passion of the individuals involved. In the following pages are accounts of the invaluable work carried out by these centres and partners.

Photo by Maya Santangelo

inside stories

Our oceans have a serious PR problem. The severe disconnect between people and the oceans they ultimately depend upon is perhaps one of the most underappreciated issues facing our blue planet. Many people simply don't know, or are seldom bothered, about the species that live beneath the waves and the threats that confront them. Such apathy presents a real hurdle for conservationists, leaving many of them stumped as to how to overcome it. Put simply, how do you convince people to care?

This question came front and centre earlier this year when discussions began between the Manta Trust and other parties about the upcoming CITES Conference of Parties in Johannesburg (CoP17) and the proposal to list all *Mobula* species in Appendix II. How could we ensure the success of the proposal?

Just like manta rays, which were successfully proposed at the previous CoP in 2013 and are now listed on Appendix II, mobula ray populations are facing significant and rapid declines that typically range between 60 and 99%. This is due primarily to targeted fisheries that hunt them for their gill plates. Unlike mantas, however, mobulas don't have anywhere near the same legislation to protect them from consumptive overexploitation. Part of the reason for this is that mobulas are not as charismatic as mantas and do not have the same universally beloved status as their larger cousins. Mobulas are smaller and tend to be more elusive, so most people don't even know what they are, let alone care about their future survival. To rectify this situation, we decided to turn to technology to bring mobula rays ('mini mantas') to the forefront of the hearts and minds of the CITES delegates.

This past summer the Manta Trust launched *#LoveMiniMantas*, a media campaign to help the mobula ray CITES effort. There were several pieces of video content, but the jewel in the campaign's crown was to be a 360° virtual reality film. Virtual reality, augmented reality and 360° films (all under the 'VR' umbrella) are a pioneering and booming new medium that is changing the way we tell stories. Unlike conventional films and photos, which are confined to a rectangular screen, VR content transports its audience into another world. Using a smartphone, a specialised headset or a combination of the two, viewers experience a story unfolding around them. In some instances they even become characters within the story and can interact with the virtual world they have become a part of.

Our big idea was that we could use 360VR technology to take the CITES delegates on a digital scuba dive, where many of them would meet mobula rays for the very first time. By enabling them to see the rays with their own eyes, we hoped that we could inspire and excite the delegates to want to learn more about the animals and why they are under threat – and to support the proposal to list mobulas. Perhaps by engaging undecided or uninformed nations on an emotional level, we could persuade them to vote in favour of granting mobulas the increased trade protection they desperately need.

After a few months of planning, we assembled a small team for a short-notice 360VR film shoot on the island of Santa Maria in the Azores. When it comes to mobulas, the Azores archipelago is a special place, one of the few locations in the world where the rays can be seen consistently on a seasonal basis. Santa Maria is particularly well known for its visiting mobulas and serves as the base of operations for SOSF-funded biologist Ana Sobral, who runs a project on the sicklefin mobula rays that visit the waters around these remote volcanic islands. We managed to rope Ana in not only to help us encounter these 'mini mantas', but also to be the central character around whom the VR film would revolve.

Creating 360VR content is no easy task. Filming requires a great deal of equipment and often involves several cameras that need to work in unison to record the world around the viewer. It may sound simple enough, but there is no end to the many things that can go wrong. The core issue is that should just one camera have a setting out of step or a technical hitch that interrupts recording, the entire sequence has to be discarded. This isn't so devastating when you're on terra firma and working with people who can reset and reposition themselves for another take. However, having cameras that are sealed in a housing with limited ability to access any controls or settings, taking them underwater miles offshore, and attempting to collect usable content of elusive rays that may not appear for days at a time – all of this creates a recipe for a potentially fruitless shoot.

As with all good film shoots, ours came down to a handful of days when the stars aligned and we were able to capture exciting and usable interactions with the sicklefin mobulas we had come to film. A gruelling two weeks of post-production followed, when we painstakingly stitched together the 360VR content and then edited it into the finished film. With this content loaded onto a handful of headsets, we were ready to transport the CITES delegates out of Johannesburg and back to Santa Maria, where we had been filming just a few weeks before.

To say that we were overwhelmed by the success of the 360VR film at CoP17 would be a major understatement. During the seven days prior to the vote, more than 350 delegates, representing just over one third of the nations that eventually voted on the mobula proposal, watched the film through our VR headsets. The booth we had allocated to the film was rarely quiet, as delegates queued for their turn to be brought face to face with the 'mini mantas' of Santa Maria. Word of mouth had clearly spread, as the majority of those who came to the booth had been encouraged to do so by their colleagues and delegates from other nations.

Photo by Daniel Copeland

On 3 October 2016, all nine *Mobula* species were successfully listed on Appendix II of CITES; the proposal had won the vote with a staggering 85% majority. Although it is difficult to quantify the exact impact of the 360VR film, everyone who saw it agreed that it was significant, extensive – and sometimes surprising! Delegates from around the world were emotionally engaged after watching the film and often asked for more information about the threats facing mobulas and the importance of their listing. Suddenly they cared. More officials than you might think removed their headsets with tears in their eyes, some having had memories brought back of a time when these vulnerable rays were seen in their own waters.

This project clearly illustrated to us the importance of engaging people on an emotional level with conservation issues and marine species that are under threat. Being bombarded with stats and numbers alone is often mind-numbing, leaving people unable to truly appreciate what is at stake. Experiences and encounters are an effective way of rebuilding the connection between people and the oceans, and VR stands to be an immensely powerful tool to engage the masses with marine conservation. Following the success of the *#LoveMiniMantas* campaign, we certainly can't wait to use VR again in our efforts to understand and conserve mobulids, their relatives and their habitats.

Virtually real mobula rays at CITES

The Manta Trust
Words by Danny Copeland

Shark senses via Virtual Reality

Shark Education Centre
Words by Eleanor Yeld Hutchings

'The world of reality has its limits; the world of imagination is boundless.'

Jean-Jacques Rousseau

There is an air of extreme concentration in the newly opened 'Shark Central' exhibit room in the Shark Education Centre. Silence – broken only by the sounds coming from the 3D model of a shark's head that, with lights flashing, is mounted above a table. Someone is seated behind the table, their face inside the shark's head. Standing around the game, a group of spectators follows its progress through the series of lights shining on the table's surface.

The game issues instructions: 'You are several kilometres away and can hear your prey. Follow the direction of the sound.'

'Bubble, bubble, bubble... Splish!
Bubble, bubble... Splosh!'

'There, did you hear that splash? That's your prey! Follow the sounds.'

And deep inside the virtual reality ocean world, the game player swivels the shark's head backwards and forwards in an attempt to swim towards the elusive sounds of the fish prey swimming somewhere up ahead. Success!

'You are several hundred metres away and can now smell your prey,' the game announces. Now it's time to follow the scent trail. And on the hunt goes, using the different shark senses one by one as they come into play, before finally – hopefully successfully – coming jaws-to-tail with that tasty tuna.

The Save Our Seas Foundation's Shark Education Centre in Kalk Bay, South Africa, has been upgrading and adding new exhibits for the past two years. The emphasis has been on creating an experience for visitors that is unique, educational and fun, and the brand-new Shark Senses VR exhibit, which uses virtual reality, is part of this. With a wide-ranging audience to consider, but targeting primarily learners aged between eight and 18 years, our intention was to curate an immersive experience that would not only communicate conservation messaging effectively, but also deliver something that was unlike anything the user had ever experienced before.

This specific exhibit was commissioned to enable the user to understand at first hand what it feels like to be a shark in search of its prey and to use all the senses that sharks deploy in their hunts, which are different and more powerful than the senses that people use every day. From the start we wanted to be able to position the user inside a model of a shark's head and allow them to see through the eyes of the shark. The question was, how to transform that idea into an exhibit in reality?

That's where Formula D Interactive came in. The redesign process of the Shark Education Centre is a collaborative project between the education centre and interpretation specialist Heidi De Maine from Sunfish Consulting. Having worked with Formula D Interactive on other projects, Heidi recommended that we take our idea to them. And, as the Shark Education Centre is based in Kalk Bay, we felt that it was important to use a local design agency so that both parties could collaborate in the creative process and share input throughout. The fact that it was logistically easier to deliver hardware and service the exhibit also played a role. In the end, however, the choice came down to the fact that Formula D Interactive offered real creativity, innovation and quality – plus a host of experience – and was willing to take on a project concept as challenging as this and make it work with us.

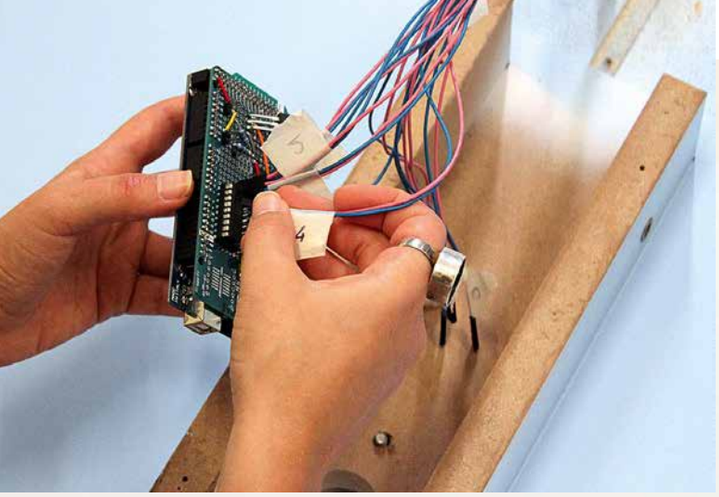
Education is changing; it has moved on from being only books, pencils and pens, and our brand of environmental and marine education has to keep up with these changes. Although the classroom will always have a role to play and experiential field learning will always be indispensable, more and more we are seeing that technology is opening up whole new pathways of learning that resonate with young people in a way that our traditional methods just can't. Today's generation of school-goers is both computer literate and game savvy and can interact intuitively with the exhibits. We need to take advantage of this and make sure that we are offering cutting-edge interactive displays that engage our visitors and also deliver our messaging. The pedagogies of constructivism and game-based learning show that children learn by doing or by being and that game-based learning provides engagement and motivation as key factors. Virtual reality offers such a wonderful opportunity for this: there really is no better way to understand something than to experience it for yourself!

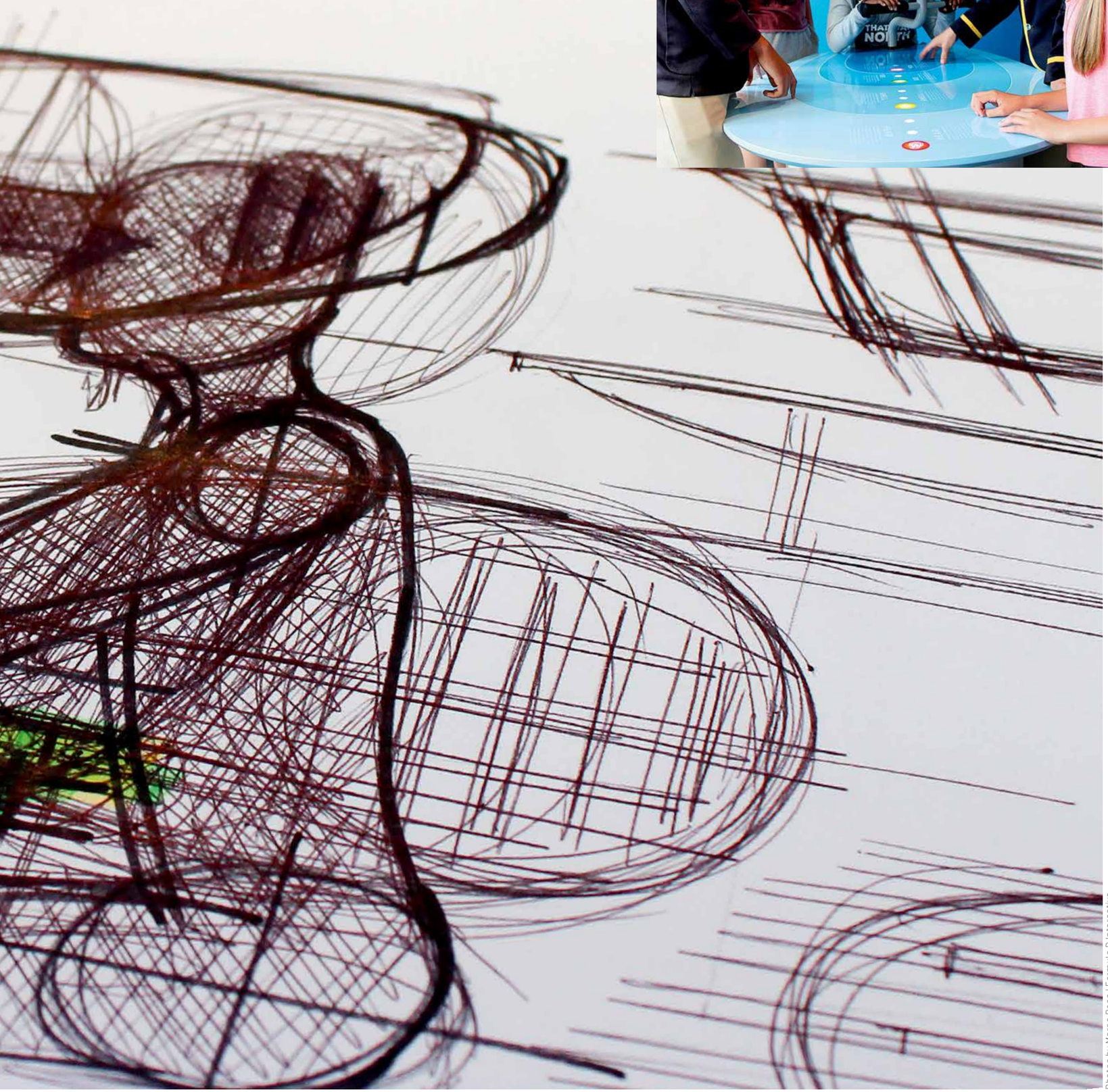
So far, the feedback we have been getting on the Shark Senses VR Exhibit has been wonderful. The exhibit is very different from anything else on offer, anywhere in the world, and this, together with the immersive user experience with its amazing attention to detail, has really impressed everyone who has used it. It has been awarded an internationally acclaimed 2016 Red Dot Award for Communication Design. We are extremely proud of our one-of-a-kind, cutting-edge interactive and we can't wait for more people to come and play.

Photo by Marco Rosa | Formula D Interactive

inside stories

inside stories





Photos by Marco Rosa | Formula D Interactive

Can shark research lead to better marine protected areas? A recent study of the D'Arros and St Joseph Special Reserve in the Seychelles suggests this could be the case. And the solution lies in changing a single word in the definition of a marine protected area's boundaries. A solution that's as good for the people of the Seychelles as it is for the sharks.

In the Seychelles, marine protected areas tend to focus on the protection of a single species or part of the coast. As a result, in this island nation they rarely extend further than 400 metres (450 yards) offshore. Even the largest marine protected area in the Seychelles, Aldabra, stretches a mere kilometre (1,100 yards) from the high tide mark of the beach. 'Given the strong historical focus on the conservation of turtles and reefs, and given the potential value of sharks, we thought we'd look at how existing models in the Seychelles work for things like sharks,' explains James Lea, lead author of the study. The D'Arros and St Joseph Special Reserve would have followed the same model as Aldabra, declaring the boundary of the reserve one kilometre from the high tide mark. However, James suspected that this would leave gaps in the protection of top predators like sharks.

He argues that the lagoon habitat found in St Joseph Atoll is rare in the Seychelles and is crucial for numerous species, from creatures at the bottom of the ocean to soaring seabirds. 'A lagoon habitat that is completely cut off from the surrounding ocean at low tide is incredibly rare in the Seychelles. There are very few atolls like St Joseph, and none close by. If they provide the only nursery habitats for species like the lemon shark and the turtles and rays and various reef fishes either regionally or in the Seychelles as a whole, they might be more valuable than they appear.'

The study used data from tagged sharks and turtles to understand how the habitat use of six species relates to the traditional one-kilometre boundary from the high tide mark. 'One of the most important things about the D'Arros and St Joseph Special Reserve is that it has a very large and wide reef flat that is completely covered at high tide,' says James. 'In some places, the reef flat at St Joseph can be more than a kilometre wide, so actually, along some of these sections there might as well be no marine protected area.' But shifting the boundary from one kilometre from the *high* tide mark to one kilometre from the *low* tide mark makes a considerable difference.

The single word change to the definition increases the size of the marine protected area by 50% and augments the protection of shark habitat by 30%. James concedes that although it's neither a perfect nor a final solution, such a minor change that leads to significant improvements in the level of protection provided looks like a win.

Two species of shark benefit the most from the change: the blacktip reef shark *Carcharhinus melanopterus* and the lemon shark *Negaprion acutidens*, which use the lagoon and flats most intensively. Shifting the boundary definition to the low tide mark protects all reef and atoll habitats, as well as any species that spend all their time in those habitats. Telemetry data tell us that juvenile lemon sharks in particular don't leave the atoll. The change to increase the size of the marine protected area affords them protection at a vulnerable life stage. 'Suddenly you're protecting these sharks until they're just about mature,' James says. Other studies on sharks have suggested that protecting individuals as they approach sexual maturity is the most important way to achieve population stability. James concurs, saying 'Protecting maturing individuals can be the most efficient way to protect a species.' For threatened lemon sharks, this is crucial.

Whereas some species receive complete protection, the protection for others is only partial. The tagging data on large grey reef sharks show them essentially patrolling the outer reefs that are not protected by the current special reserve. However, smaller grey reef sharks are protected – and that is a positive. Nonetheless, protecting sharks on the outer reefs, and more pelagic sharks in the Seychelles, will take more work. This could perhaps be the focus of future study for James.

Although his work concentrates on sharks, James is hesitant to put too much importance on sharks alone. 'One of the main goals of conservation, I think, should be to maintain the functionality of an ecosystem rather than just ensuring that one species doesn't get exploited,' he says. 'Degradation of habitat and the exploitation of other species can cause the ecosystem to fall apart anyway and then what's the point?' His study highlights the importance of understanding the use of habitat by a number of species, from manta rays *Manta alfredi* to hawksbill turtles *Eretmochelys imbricata*, if marine protected areas are to be effective.

So can shark research improve the management of these areas? Potentially, answers James. When presented with the results of the study, the Seychelles' Ministry of Environment, Energy and Climate Change listened. The study contributed to the government applying the low tide boundary to the special reserve, effectively ensuring protection to the entire lagoon system and coastal reefs. That's thanks to sharks.

Sharks, rays, turtles and many other marine species benefit from this, but James stresses that people also benefit. In the years he has spent studying sharks in the Seychelles, he's seen how they are part of the culture of the islands. 'There is a strong cultural identity with shark fishing in the Seychelles,' he explains. Historically, these waters teemed with sharks and people made the most of their abundance. Although shark population numbers have undoubtedly declined, James takes the stance that fishing for sharks and protecting sharks are not mutually exclusive. 'There is often this misconception that we just want to stop fishermen, to stop people living off the sea,' he points out. 'Actually what we want to do is ensure that their grandchildren will still be able to live off the sea.'

That's why it's so important to protect the waters around D'Arros Island and St Joseph Atoll. If these waters are as crucial to the regional recruitment of various marine species as James suspects, there is a broader benefit to the special reserve. Protection may also support the long-term sustainability of a culturally important practice. The D'Arros and St Joseph Special Reserve is good for sharks and it's good for the people of the Seychelles.

inside stories

Better for sharks, better for people

D'Arros Research Centre
Words by Clare Keating Daly

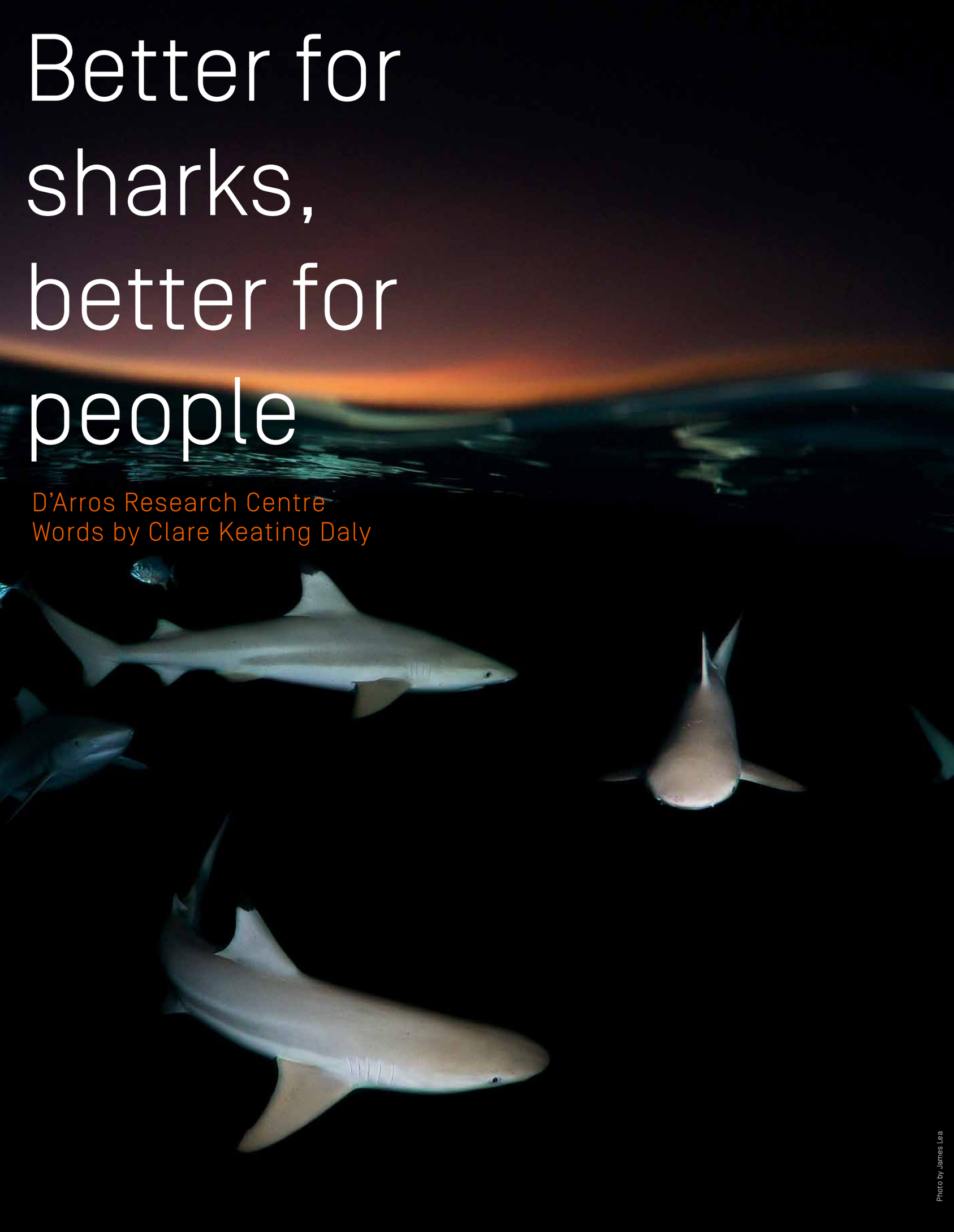


Photo by James Lea

Five years on track

The Acoustic Tracking Array Platform

Words by Paul Cowley

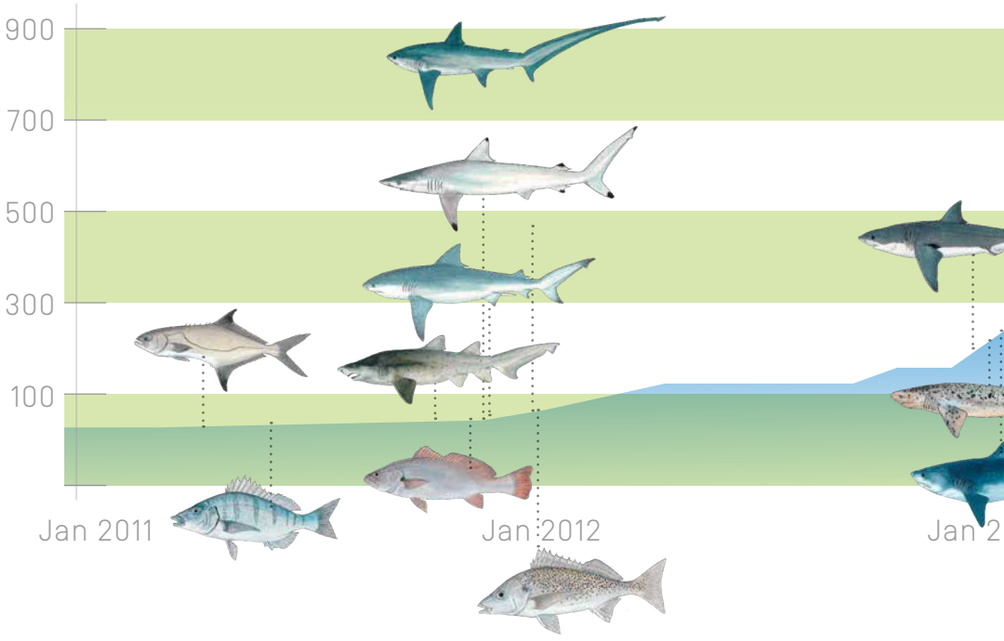
Many marine species have suffered significant population declines in recent years, due mainly to humans' insatiable demands for food. Conservation and management efforts need to keep abreast of these declines to ensure the sustainability of species that are of ecological significance, economic value or conservation concern. In most cases, the effective conservation of such species relies on an improved understanding of their patterns of habitat use and their movements and migrations.

The quest for such information by scientists and resource managers has been empowered by advances in aquatic animal tagging and tracking technologies, particularly in the form of acoustic telemetry networks. The Acoustic Tracking Array Platform (ATAP) is one of many global examples of how researchers can gather multiple-year data with high spatial and temporal resolution on animals tagged with long-life acoustic transmitters. The ATAP array off the southern tip of Africa comprises an extended network of moored acoustic receivers spanning approximately 2,200 kilometres (1,370 miles) of coastline from False Bay, near Cape Town in South Africa, to Ponta do Oura in Mozambique.

The southern African coastline is largely exposed and has few large bays, but is well endowed with estuarine inlets. Besides being a global biodiversity hotspot, the region hosts the greatest marine migration on the planet in the form of the annual sardine run. Dubbed 'the greatest shoal on earth', this migration of small pelagic fishes, often in shoals up to 10 kilometres (six miles) long, is pursued by a host of apex predators, including sharks, birds, dolphins and numerous predatory fish species. Collectively, these geographical and biological features make southern Africa a perfect natural laboratory in which to study the movement behaviour and migration biology of marine animals.

ATAP first gained momentum as a marine science platform when the Canada-based Ocean Tracking Network (OTN) project expressed an interest in lending acoustic telemetry hardware to interested partner countries around the globe. Researchers based at the South African Institute of Aquatic Biodiversity (SAIAB) who were already conducting acoustic telemetry studies recognised the benefits of creating a nationwide receiver network. They started drafting proposals and canvassing support to establish one. The greatest challenges at that stage were to secure a shared vision and develop an ethos of open-access data sharing within the research community. This was achieved by setting up a national research co-ordinating unit called the Biotelemetry Research Group. SAIAB then entered into an agreement with OTN and the securing of telemetry hardware through this partnership and additional hardware support from the National Research Foundation (NRF) led to the birth of ATAP five years ago.

Since its inauguration in August 2011, ATAP has continued to grow in terms of the number of species and number of individual marine animals tagged. To date, more than 700 individuals representing 27 species and 20 families have been tagged with acous-



tic transmitters. Current research focuses on large predatory sharks and important coastal fishery species. Prominent elasmobranch species include white sharks *Carcharodon carcharias*, sevengill cowsharks *Notorynchus cepedianus*, bull sharks *Carcharhinus leucas* and ragged-tooth sharks *Carcharias taurus*, while prominent teleosts include leervis *Lichia amia*, spotted grunter *Pomadasys commersonnii* and dusky kob *Argyrosomus japonicus*.

The ATAP management team, based at SAIAB in Grahamstown, services the deployed receivers at six- to eight-month intervals and all the downloaded data are stored on a local database. Upon receipt of a data request, SAIAB collates the information gathered on a tagged animal and sends it to the tag owner. Currently more than 20 researchers and students from 14 different organisations benefit from this data-sharing arrangement.

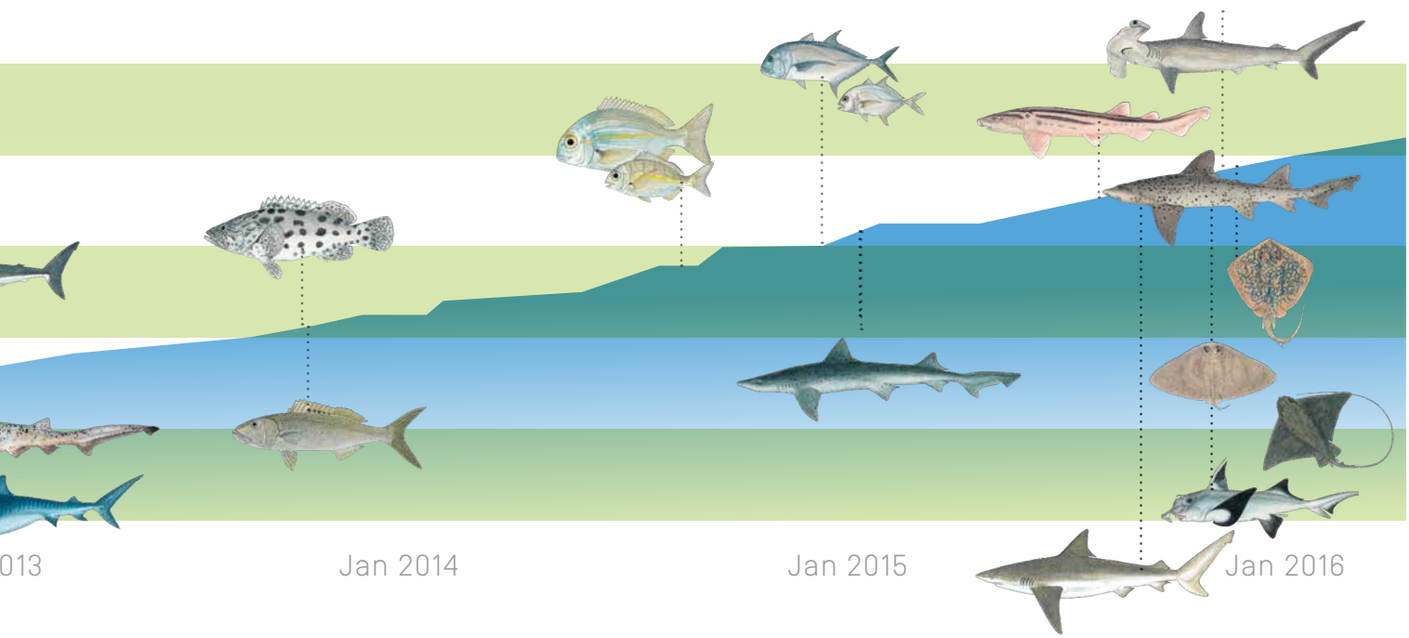
The maintenance of this significant marine research platform has not been without trials and tribulations. The South African coastline is notorious for its rough seas, which make for a very challenging work environment. Rich coastal waters also create untold problems with bio-fouling, which not only influences acoustic performance, but can also prevent or retard the retrieval of receivers that are attached to acoustic release devices. Over the past five years, ATAP has made more than 600 receiver deployments, of which most were successfully retrieved for downloading and servicing. However, approximately 40 units, and their valuable data, have been lost!

Every receiver station deployed as part of the nationwide ATAP array has resulted in the detection of at least one tagged animal, suggesting that the array design is suitable for answering a host of scientific questions at various spatial scales. These include aspects of estuarine–marine connectivity, inter-estuary and bay-scale movements, large-scale annual migrations and trans-boundary movements. In addition, some studies are assessing specific ecological questions about spawning aggregations and predator–prey interactions.

This science platform has already gathered some amazing new insights into the underwater lives of many tagged animals. For example, researchers from the KwaZulu-Natal Sharks Board and SAIAB tagged several juvenile bull sharks in the Umzimvubu Estuary at Port St Johns and recorded high levels of residency despite significant seasonal fluctuations in water quality. One of the juveniles was tagged on 28 November 2012 in the estuary, where it remained until it was logged on an offshore receiver nearby in March 2013. A month later it was recorded on a receiver about 50 kilometres (31 miles) to the north and over the winter of 2013 (May to August) it made several repeated movements between these two offshore sites. However, with the onset of summer (late 2013) it returned to its estuarine nursery, where it stayed until March 2014. Its whereabouts during the winter of 2014 are unknown, but it returned to the Umzimvubu Estuary in August and stayed there for the summer, making only a few trips to the Port St Johns offshore receivers. It left this area again on 17 May 2015 and moved rapidly northward before being recorded on a receiver off Durban (250 kilometres, or 155 miles, away) on 25 May 2015. Its movements for the rest of 2015 are unclear, but on 22 June 2016 it returned to the Umzimvubu Estuary and stayed there until 6 July 2016. Further receiver downloads will shed more light on this shark as it approaches adulthood.

Estuaries are prominent features along the south-eastern coast of South Africa and, besides juvenile bull sharks, many tagged fish species at risk – such as leervis, spotted grunter and dusky kob – are wholly dependent on them as nursery areas. The tracking of one adult spotted grunter revealed the continued importance of estuaries throughout the species' life; it was recorded in four estuaries before it moved to KwaZulu-Natal (590 kilometres, or 366 miles, away), where it was caught by a fisherman.

ATAP has celebrated the discovery of many remarkable animal movements during its first five years and will continue to provide unprecedented opportunities to gather more information about the movements of many iconic sharks and important fishery species along the South African coastline. Looking ahead, we will soon start deploying the next generation of Vemco receivers with a built-in acoustic release mechanism, provided by a capital equipment grant from NRF. Two new projects, on the economically important soupfin shark *Galeorhinus galeus* and the vulnerable giant guitarfish *Rhynchobatus djiddensis*, will also be initiated later this year. Both projects are supported by a grant from the Save Our Seas Foundation.



© SAIAB taken from
Coastal Fishes of Southern Africa (2004)
by Phil and Elaine Heemstra

Cetacea Lab

Words by Janie Wray

'What do you think as you look at me? Will you remember my face the next time we meet?' These are the first thoughts that enter my mind as I look directly into the eye of a mother humpback whale.

This was not a chance encounter. She made the contact, bringing her young calf alongside our boat. In all the years – and there are many – that I have studied the behaviour of humpbacks, never have I experienced such an intimate moment with a whale.

It all started, as it often does, with a blow in the distance. Our research intern Nigel and I were on our way to the ferry at Hartley Bay. He saw the blow and pointed towards Fin Island to let me know I should slow down. I cut the throttle and tried to position the *Elemiah* at the perfect angle to take an identification photograph of both mother and calf. They dived before I could manage this, so I put the boat into neutral with the intention of waiting quietly until they returned to the surface to breathe. We were both startled when, less than 30 seconds later, the mother took a huge breath just inches from our hull. The 28-foot *Elemiah* suddenly felt very small.

In the still waters the whale's giant body gently touched the edge of our boat. This precious moment deserved all our attention; words felt out of place. The rapt silence was broken as she exhaled deeply, leaving a spray of warm moisture to settle on our skin and clothing. In this moment we were reminded of each other, the boat and our surroundings as we took a breath ourselves and began to giggle. I had forgotten how sticky and stinky whale blow can be.

I may never understand why this mother had decided to introduce her calf to us, these two-legged creatures attached to a loud aluminium machine. I often wonder what whales perceive when curiosity sets in and they decide to research *us* for a change. How odd it must be for them to try to understand why we are not in the water; the sounds of our footsteps as we move excitedly from one side of the boat to the other; the sight of us as we hang over the edge of the boat with a camera as our eye; the 'click click click' sound as we seek to freeze this moment forever in our memories.

When she first arrived I had put the camera down in order to be fully present during such a special moment; to look directly into her eye – one species to another, one world to another – terrestrial and marine minds trying to understand one another. The entire encounter felt as though it had passed in seconds, but the reality was that she and her calf were with us for almost 40 minutes of pure bliss. The temptation to reach out and touch her during the times her immense head rose from the water, inching towards our searching eyes, was overwhelming. I was completely awestruck, unsure how to react to this incredible and rare cetacean gesture.

Although the mother was completely focused on us, her calf eventually became restless. Perhaps after so much time he had become bored with us and wanted his mother's attention. She ignored him as he swam impatiently from one side of the boat to the other. When he had had enough and breached just metres from our boat I became a bit uncomfortable. It appeared she did as well. She moved towards her calf and we thought perhaps it was time to leave. But not quite yet. They were under the water for less than a minute before she appeared again, rolling to her side for one more look at our euphoric human faces. This time I did take a picture.

Still our encounter was not yet over as something astonishing began to unfold. While she was looking at me, I turned towards the bow of the boat where the calf had just surfaced. As I turned back towards her, completing a full rotation of my body, Nigel spoke up: 'She's turning too.' By the time my eyes were back on her I was staring at her vast pleated belly. She had copied my rotation. Was she communicating to us with her body?

By now the calf had had enough and, side by side, they went on their way. In the distance, heart-shaped flukes, one large, one small, disappeared into the sea.

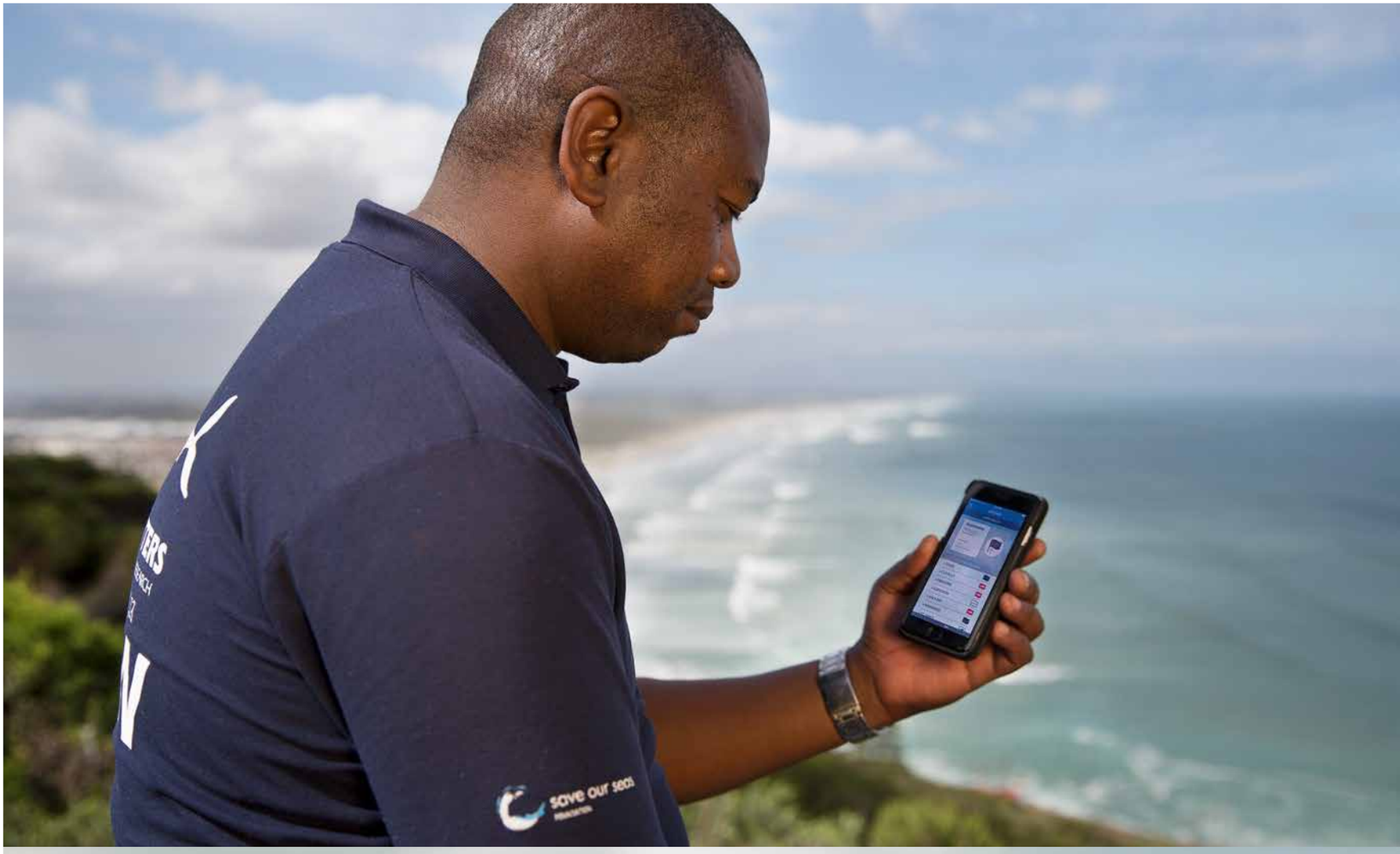
Hours later, after I had dropped Nigel off at the ferry and was on my way home, this experience became real to me. My throat became so tight I could barely breathe. I stopped the boat, turned off the ignition and sat on the bow. The sun was shining down on me as the tears began to fall. That she would show such interest in us, and such vulnerability; that she would bring her calf alongside these beings that had hunted and killed her ancestors. I felt like I had just been woken from a dream, that life was just beginning.

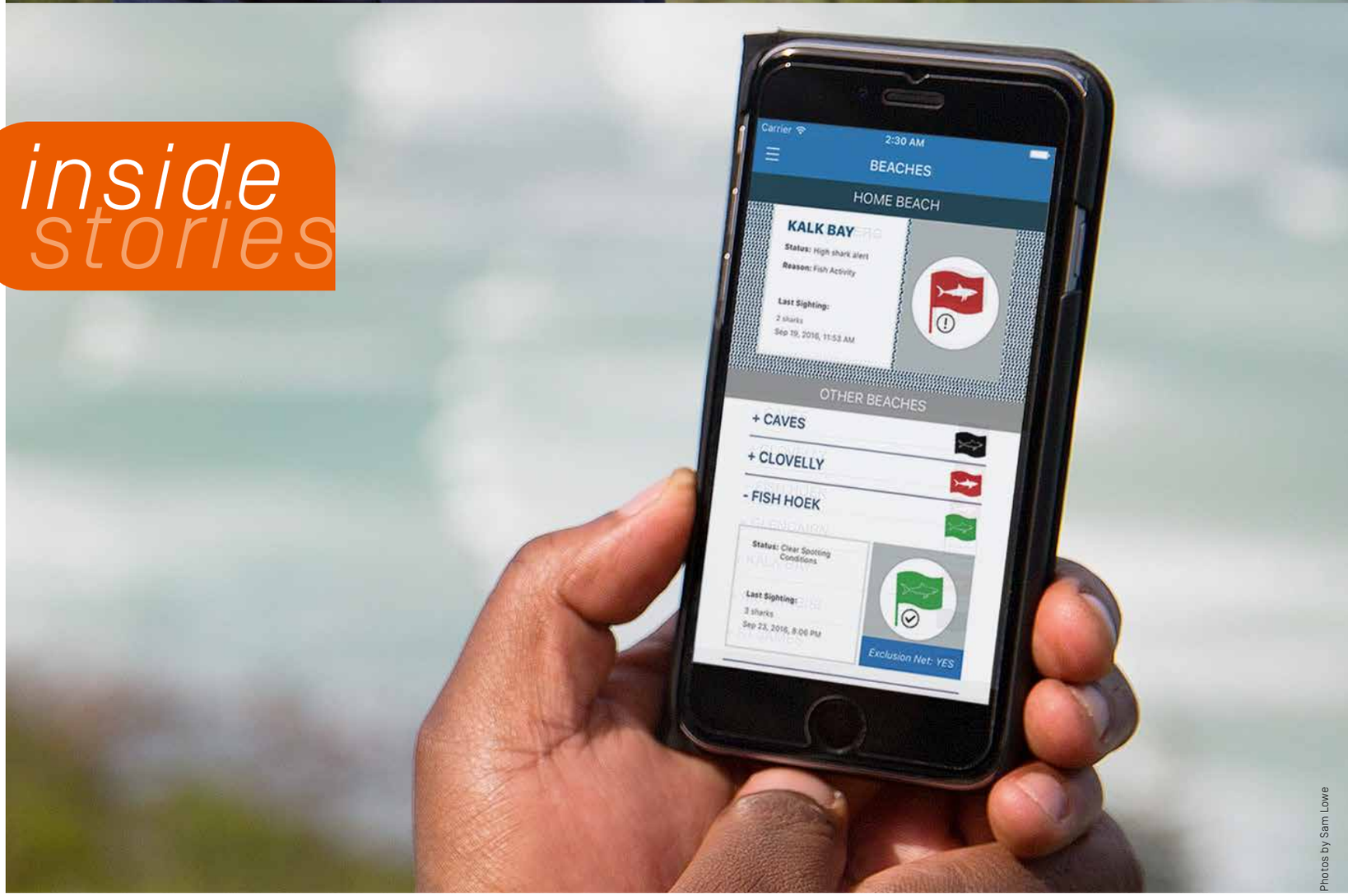
We all have times in our lives when we ask if our chosen path is the right one. This extraordinary encounter reinforced to me that my work to protect these whales, and this extraordinary place they call home, is far from over. With her beautiful eye, that gentle ocean mother looked into my soul and spoke to me. 'We are in this together, you and I.'

Eye to I

inside stories

Photo by Janie Wray





inside stories

Photos by Sam Lowe

Shark Spotters
Words by Alison Kock

Shark safety in the palm of your hand

Shark Spotters has launched its latest innovation in sustainable shark safety solutions: a new mobile app that will help swimmers and surfers to 'Be Shark Smart' at Cape Town's beaches. Inspired by requests from the community, this unique app provides water-users with current and accurate shark safety information in the palm of their hand, so that they can make informed decisions about the risk of an encounter with a shark before they even arrive at the beach.

Over the past 12 years, Shark Spotters has become a household name in Cape Town. Most water-users opt to use beaches in False Bay that are covered by the programme and when they arrive are sure to check the Shark Spotters flag and noticeboards to find out about the latest shark sightings and spotting conditions. But what if you have to travel from far to get to your favourite surf spot and when you arrive you see that the red flag is flying, indicating a high shark alert? Or what if you want to know whether the shark exclusion barrier has been deployed at Fish Hoek before you venture down to the beach? It was questions such as these that prompted the development of the mobile app to provide real-time information, enabling us to render a more efficient and effective service to the community.

The Shark Spotter app provides water-users with all the latest shark safety information at the beaches where we operate, including which flag is currently flying and why (such as poor spotting conditions due to cloud cover), the latest shark sightings at that beach, water temperature and lunar phase, and whether or not the shark exclusion barrier at Fish Hoek has been deployed. It is updated by the spotters on duty in real time, so users can be assured that they always have the most current information at their fingertips to help them make a personal assessment about shark risk when entering the water. The app also provides users with safety tips to reduce their risk of encountering a shark, as well as information about shark activity around Cape Town and the different aspects of the Shark Spotters programme.

Shark Spotters believes that education and awareness are key to a successful shark safety strategy. We are confident that the development of this app will help us to provide factual, accurate and up-to-date information about sharks and shark safety to the public so that individual beach-goers can make informed decisions about entering the water. It will also, we believe, ultimately assist in reducing the number of shark bite incidents in our area.

As well as providing shark safety information, the app tells the local ocean-going community about much more of interest, including weather conditions, marine animal activity in the area (such as whales, seals, dolphins or sunfish) and details of amenities on the beaches. It also offers a short surf video, an invaluable tool for those isolated surf spots that are covered by the programme but where webcams are not operating! All these features are included in the initial version of the app, but we hope that, after receiving feedback from its users, we will be able to incorporate their suggestions and make the Shark Spotters app an invaluable beach safety and information tool for all Cape Town's beach-goers.

The app has been developed in conjunction with Taproot Technologies and funding for it came from a successful online public crowdfunding campaign, as well as generous donations from local business BulkSMS and the Two Oceans Aquarium. By securing this funding upfront, we have been able to supply the app to the public free of charge, ensuring that everyone has access to and can benefit from this important shark safety tool. We are very grateful to all individuals and organisations that contributed to making the app a reality and are very excited to be able to provide this additional service to the community.

The app launched in October 2016 at the beginning of the spring/summer season, when the spatial overlap between recreational water-users and great white sharks around Cape Town is at its highest. More than a thousand downloads were recorded within the first two weeks, and the app is anticipated to be widely used by locals and visitors alike.

The Shark Spotters app is available on iOS and Android platforms and is free to download.

Bimini Biological Field Station
Words by Félicie Dhellemmes

EXPLORING PERSONALITY IN

Most people think of sharks as being fearless, but in reality some are bolder than others. This is true between species, as illustrated by oceanic whitetips being notorious for their curious and confident behaviour, whereas scalloped hammerheads are timid and sensitive. It is also true among individuals of the same species: divers at Tiger Beach in The Bahamas frequently comment that, of the tiger sharks encountered there, 'Hook' is timid whereas 'Emma' is more inquisitive. At the Bimini Biological Field Station, also in The Bahamas, the differences in behaviour shown by individual sharks – also called 'personality' – have been the subject of a long-term study. And now, more than four years on, we are no longer looking at a hypothesis. Sharks have personality, just like you and I!

How do we measure personality in sharks? Humans we can ask to complete a simple questionnaire and then evaluate the responses, but the challenge is far more complex when large marine predators are involved. Firstly, the model species needs to be carefully selected. It must be abundant, thrive in captive conditions and be easily recaptured for multiple testing. Secondly, the scientific team must decide on tests that are relevant to the species' behaviour in the wild. For instance, to measure individuals' sensitivity to stress, different stimuli will have to be applied to the blacktip shark (a highly sensitive species) and the nurse shark. The nurse shark's propensity for hiding under ledges justifies using emergence from a hide as a test, whereas exploration of an enclosure would work better for the more mobile blacktip shark. And finally, a series of pilot studies that enable us to clarify our protocol should be conducted in order to pick the test that will bring to light the animals' personality traits most successfully.

At Bimini, hundreds of juvenile lemon sharks *Negaprion brevirostris* can be captured and recaptured each year and maintained in semi-captive holding pens built in the shallows. For this species we found that one of the most efficient ways to perceive personality is via a novel open-field test. Put simply, the sharks are placed in a large enclosure they don't know and their movements are monitored over a 10-minute period. They are then retested a few days later to see whether their behaviour is consistent. In general, the sharks explore the new enclosure uniformly, but some consistently explore it faster than others do, proving the presence of personality.

But what are we measuring? The interpretation of personality tests adapted to animals is a recognised stumbling block for animal behaviour specialists. In our case, the rate of movement of individual sharks might vary because each one reacts differently to the stimulus provided by the new enclosure. Alternatively, the explanation could be that, in the absence of a stimulus, their baseline activity is different anyway. It is therefore important to understand how the novel open field is perceived by juvenile lemon sharks. Does this test produce enough novelty to elicit a behavioural response – and can it therefore be used as a reliable method to measure shark personality?

Photo by David Doubilet | National Geographic Creative

SHARKS

inside stories

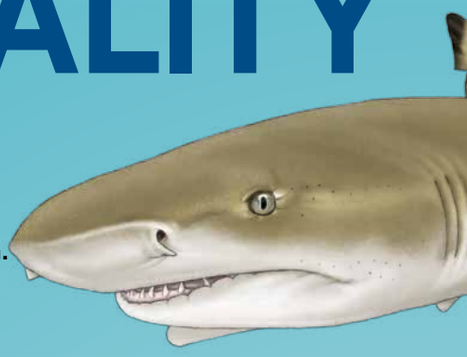
In order to understand whether the behaviour observed was a reaction to novelty or just the sharks' regular activity, we decided to use the concept of habituation. Habituation is a form of learning in which an animal decreases its response – or ceases to respond altogether – to a stimulus after repeated presentations. With this in mind for our trials, if the test pen provided a novel stimulus, we would expect this novelty to reduce after repeated visits. In this case, the sharks' movements in the pen would decrease throughout the tests (with the reducing novelty); if not, they would probably remain stable. We used a subset of 28 juvenile lemon sharks (14 males and 14 females younger than two years) to explore this problem, repeating the novel open-field test on six occasions for each shark over 12 days and recording its activity.

A first glance at the results revealed an overall effect of habituation. Our test, therefore, most likely reflected a reaction to novelty rather than individual differences in activity rate. But a closer look informed us that all the sharks habituated at different speeds and some even sensitised (increased their rate of movement). Surprisingly, the habituation rate of each shark (or sensitisation rate for some) correlated negatively with its personality. For example, sharks that were very active during the first test (bolder personalities) decreased their activity faster, whereas sharks that were less active in the first test (shyer personalities) actually sensitised, increasing their activity the more tests they experienced.

At this point it is difficult to understand why we observed such variation in juvenile lemon shark behaviour. One can hypothesise that stress played an important role in the habituation/sensitisation process. A lemon shark less attracted to novelty might have found the situation more stressful than one that is attracted to novelty. The fact that it may have been inhibited by stress would explain a low activity score in the first test and increased activity as the tests were repeated. Excitingly, this opens the door for a new question: what are the causes and consequences of personality in sharks?

Captive behavioural tests such as this enable us to prove, by means of a controlled method, that individual sharks do indeed have different personalities. They don't, however, tell us whether – or how – these differences impact the shark's ecology. For example, do sharks feed differently according to their personality? Or do some take greater risks than others, travelling further from shore or using larger areas to hunt in? And does this risk taking lead to faster growth rates or impact survival? The answers to such questions remain elusive for now, but given the long-term nature of our project at Bimini and the many recaptures and retesting of sharks, we envisage a bright, intriguing future for this project. And, in many years' time, we may encounter adult lemon sharks that were tested for personality in their early life and wonder how their personality influenced their success.

SHARK PERSONALITY



Test candidates: 14 female and 14 male juvenile lemon sharks, whose total lengths ranged from 60.5cm to 87.5cm (mean 68.5cm).

Individual recognition: Each shark was colour-tagged so that we could recognise individuals.

Housing conditions: The sharks were kept in a holding pen (10m diameter) built in their nursery area. While in captivity, they were fed every two days with a mix of fresh and frozen reef fish. In addition, the day before a test, each shark was fed to satiation (until food was left on the sea floor). No shark was kept captive for more than four weeks and all were released at their capture site.

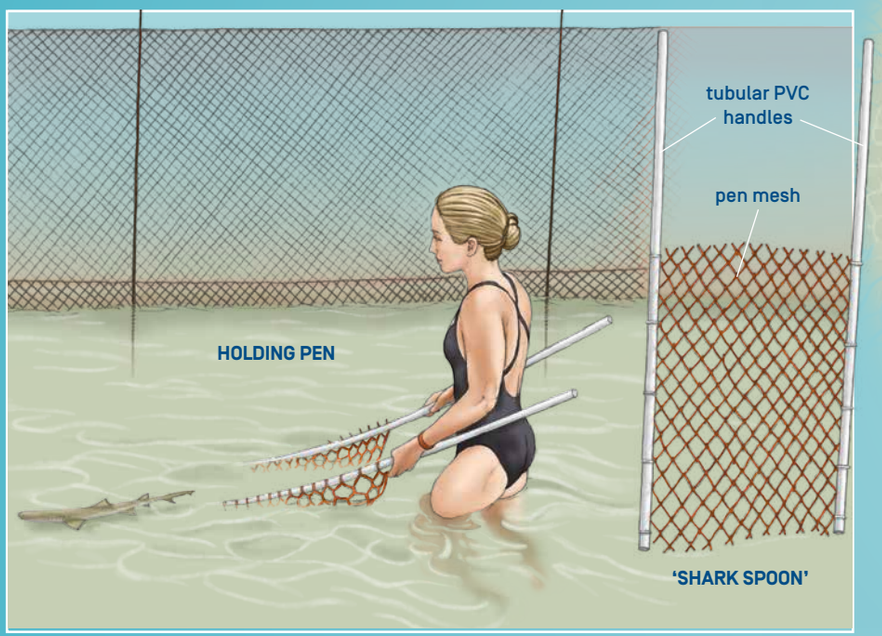
Open field: The open field consisted of a rectangular pen (6 x 12m) divided into 18 sectors by markers on the sea floor. A semi-circular start box (1.5m) provided entrance to the pen through a sliding door. An exit channel was built alongside the pen to facilitate the sharks' return to their holding pen.

Test schedule: Each shark was tested on six occasions (once every two days) according to the routine described below. Trials were conducted during the same tidal phase and three individuals were tested daily. Across a 12-day period six sharks could be tested.

Environmental conditions: For each test, the wind, cloud cover, visibility, depth and temperature were recorded and controlled for in the analysis.

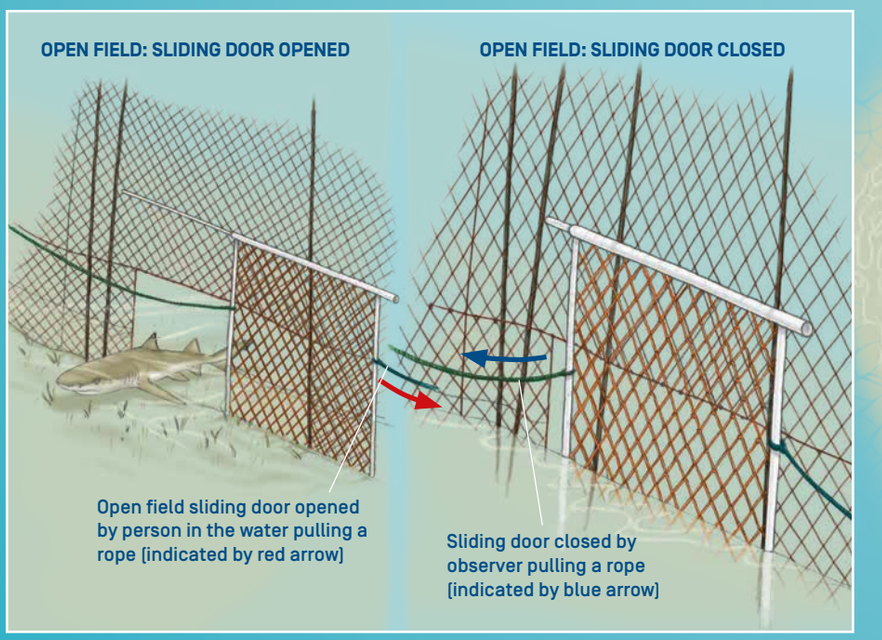
1 USHERING

To avoid stressing the sharks prior to the test, we transferred them from the holding pen to the start box by ushering them individually rather than catching and handling them. Up to four people entered the holding pen with 'shark spoons' (pieces of pen mesh mounted on PVC handles) and slowly corralled the test shark into the start box.



2 ACCESS TO THE PEN

The start box acted as a buffer zone between the holding pen and the open field. Each shark spent five minutes in it before the start of the test. This was important to standardise each shark's entrance to the open field and give it a short recovery period from the ushering. After five minutes, a sliding door was gently opened and each shark was given 15 minutes to enter the open field. The time it took the shark to leave the start box was recorded. If the shark did not enter the open field, it was ushered back into the holding pen and the test noted as incomplete.



To read the full article: Finger, J. S., Dhellemmes, F., Guttridge, T. L., Kurvers, R. M., Gruber, S. H., & Krause, J. (2016). Rate of movement of juvenile lemon sharks, *Negaprion brevirostris* in a novel open field: Are we measuring activity or reaction to novelty? *Animal Behaviour* 116: 75–82.

Personality terminology

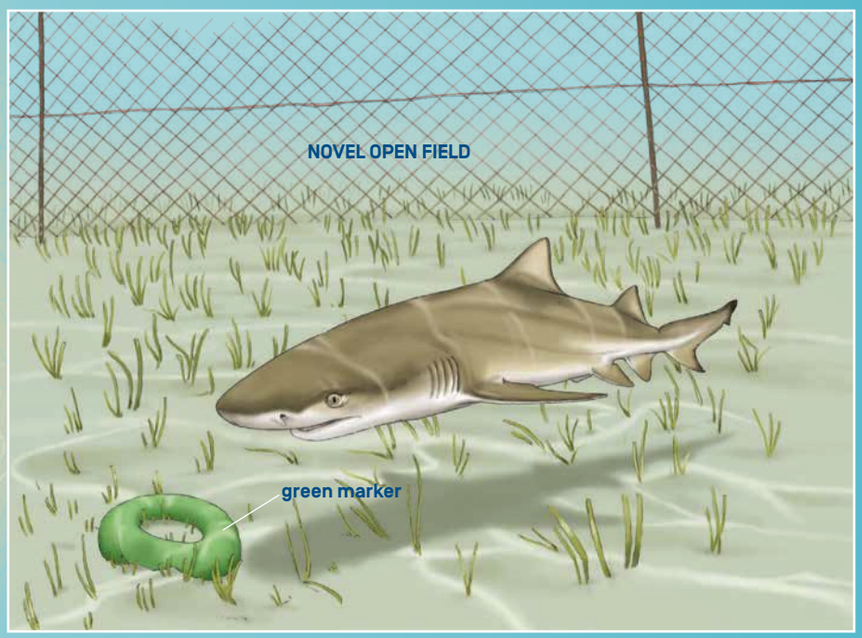
Personality is a vast and complicated concept. Through the years it has taken many different names, such as 'temperament' or 'coping styles'. Likewise, the different personality 'dimensions' or 'traits' have received many different labels and definitions.

For this study, we based our work on a framework proposed by Réale et al, 2007 (see reference below). This working tool divided personality traits into five non-exhaustive categories:

- **Shyness–boldness:** refers to the reaction of an individual to situations that are risky or stressful but not new.
- **Exploration–avoidance:** points out the reaction of an individual to a new situation (i.e. new habitat or food source). The line between exploration–avoidance and shyness–boldness is sometimes slim, since novel situations can often be perceived as risky.
- **Activity:** indicates the general level of activity of an individual. This trait can interfere with exploration–avoidance and/or shyness–boldness.
- **Aggressiveness:** illustrates agonistic behaviours towards conspecifics.
- **Sociability:** defines the reaction of an individual to the presence or absence of conspecifics (excluding aggressive behaviours).

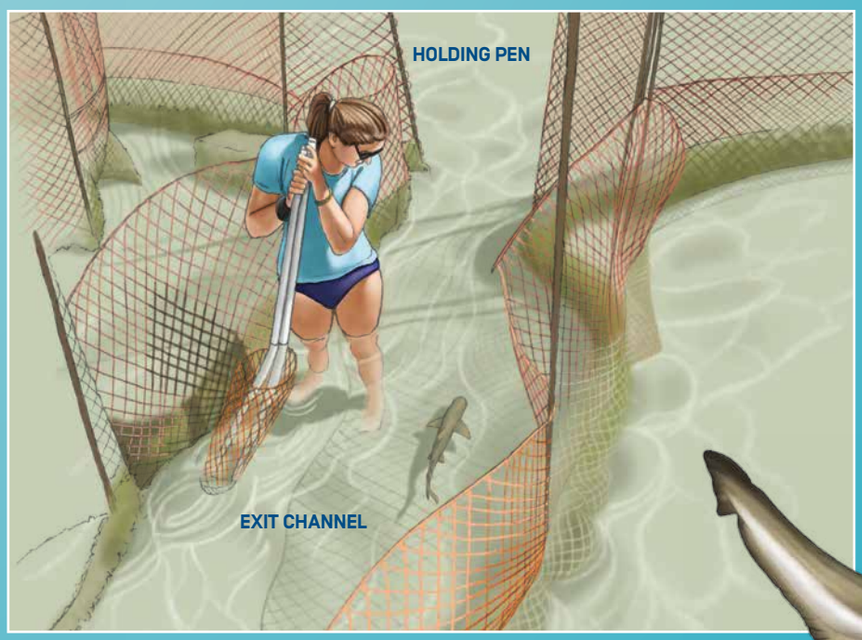
The open-field test dilemma: one test for many traits

- The open-field test is frequently used in personality literature but, depending on the study, it measures different traits. For instance, it could measure exploration–avoidance, shyness–boldness or, when the open field isn't perceived as novel or stressful to the animal, activity.
- A common method to interpret behaviour during an open-field test is to use convergent (different tests test the same trait) or discriminant (different tests test different traits) validity tests, which are very constraining logistically.
- Instead we decided to repeatedly expose individuals to the same open field. If the behaviour observed (rate of movements) is a reaction to novelty, we expect it to co-vary with the number of exposures.



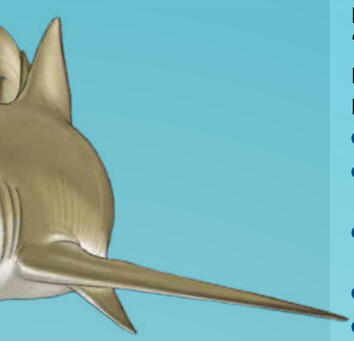
3 EXPLORATION

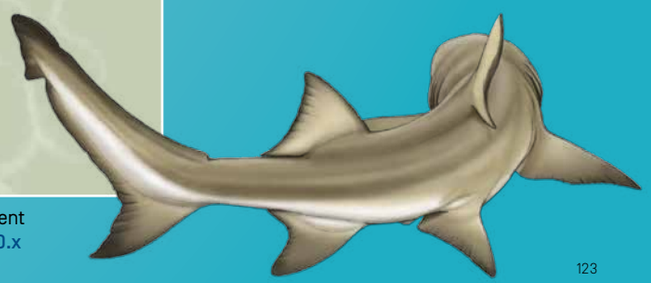
Once the test shark entered the open field, the sliding door was closed to prevent its return to the start box and a 10-minute timer was started. The open field was divided into 18 sectors (2x2m), coordinated from A to C and one to six by green markers on the sea floor, which enabled us to monitor the sharks' movements. During the 10 minutes of the test, every sector visited was recorded by a trained observer. The total number of sectors visited ranged from 140 to 240 and was referred to as 'rate of movement'.



4 RETURN TO THE HOLDING PEN

As in step 1, we wanted the sharks to return to the holding pen without being stressed. An exit channel was built to allow the sharks to return. On most occasions the sharks were ushered through this, but it was interesting to observe that after repeated trials the sharks began to exit without prompting (even if one of our team was standing in the channel, as illustrated).





Reference: Réale, D., Reader, S. M., Sol, D., McDougall, P. T., & Dingemanse, N. J. (2007). Integrating animal temperament within ecology and evolution. *Biological Reviews* 82: 291–318. http://doi.org/10.1111/j.1469-185X.2007.00010.x

Infographic design by Marc Dando | Content interpretation by Félicie Dhellemmes & Tristan Guttridge

Justin Gilligan and Sirachai (Shin) Arunrugstichai, the two winners of the second Save Our Seas Foundation Photography Grant, were assigned the tasks of documenting the interface between urban and marine life in South Florida (Justin) and recording changes to the Bimini ecosystem when commercial development moves in (Shin). Conservation Media Unit staffer Jade Schultz describes their experiences.

It was five past 10 and we'd only just made the queue for Burger King before it closed for the day at a roadside truck-stop somewhere on the Florida Turnpike between Port Mayaca and Fort Lauderdale. Justin and I were exhausted and starving after having spent a long, hot and sticky day outdoors in the humid 37 °C heat in the town of Stuart. We had started our day with him photographing the foul-smelling outbreak of blue-green algae that had shut down Florida's prized 'Treasure Coast' beaches over the Fourth of July long weekend. We had ended it surrounded by a cloud of hungry mosquitoes as Justin took advantage of the last minutes of natural light to photograph jars of green sludge on a bridge overlooking the alleged source of the blue-green algae outbreak at Lake Okeechobee. Behind us, another dramatic Florida summer thunderstorm sunset was glowing in the distance.

I thought back to when I'd told my mother I would be going to Florida to assist with the Marine Conservation Photography Grant and she had offered me a few pearls of wisdom: pack bug spray, don't forget your travel pillow and be sure to try the Key lime pie. They had seemed like sound words of advice for this virgin traveller at the time, but as we stood in that Burger King line in zombie mode, I couldn't help thinking that there were some other tips that would have been a little more useful, like where to find the best (strongest) coffee, how exactly to drive on the opposite side of the road, how to stay calm when driving on a highway seven lanes wide, and what a 'turnpike' actually is.

We sat in the car staring out into the emptiness of a dimly lit parking lot and shared a numb silence, eating yet another lacklustre meal purchased from a fast-food chain. Our minds ticking over, we wondered at what point the months of preparation and planning for this assignment would prove to be useful. Already we were about one week into the three-week Marine Conservation Photography Grant assignment that had tasked Justin with documenting the urban wilderness along the coast of South Florida. Conceptually it sounded like an easy enough mission: capture the delicate balance between encroaching urbanisation and the marine wildlife along a spectacular stretch of coastline. Justin had his shot list and the assignment required him to take photos in a region that not so long ago was considered wild and remote, boasting spans of white sandy beaches and dotted with mangroves and backwaters – a dynamic ecosystem with abundant marine biodiversity in a region where urbanisation was unavoidable. All the elements required for the brief were there. Turning them into images, however, was very different.

For Justin, this first week of the assignment had proven to be a gruelling seven days of early mornings and late evenings, rushing from one appointment at the southern tip of Florida to the next, usually a two-hour drive away, and then having to dash to the next potential photo opportunity two and a half hours in the opposite direction. Add to this shooting conditions that were not what any marine photographer would consider ideal, when limited windows of opportunity to get certain images were plagued by poor visibility or marine animals, like most wildlife, couldn't be relied upon to make an appearance. And then we'd always have to stick around for an extra 10 minutes to make sure that Justin had a couple of cracks at capturing the perfect image to tell the urban wilderness story.

Any marine conservation photographer will tell you that this is just the nature of the job. But when you are trying to impress *National Geographic* Magazine's Kathy Moran and Thomas P. Peschak, who are mentoring you throughout your assignment, there is definitely an additional element of pressure. Justin was constantly pushing himself out of his comfort zone and to his limits to get images that would surprise and excite Kathy and Tom, and I admired his determination to constantly raise the bar and get the results.

As we travelled the last stretch of the long drive home, I contemplated the challenges of navigating this urban wilderness story thus far. Suddenly it dawned on me that it's not easy for marine wildlife to navigate this urban landscape either, yet it was finding ways to adapt, survive and thrive in the midst of it.

Just as there are enthusiastic members of the community who are working fervently and tirelessly to keep this ecosystem intact and to ensure that the region and its wildlife are protected along this stretch of coast, there were some incredible individuals who would help and assist in any way they could during Justin's photography grant journey. They too showed their commitment to seeing the natural world of Florida survive, despite the rapidly spreading urbanisation and man's ever-reaching and tightening grasp on its natural resources.

Each day we would meet inspiring characters who are invested in protecting the wildlife that remains in this region: shop assistants who kindly pointed a disorientated Australian and South African in the right direction or offered us a lead or an interesting angle on a conservation issue; dive operators who took time out to arrange special excursions to assist Justin in getting the necessary images; our hosts who provided invaluable insights into Florida's natural history. They were all eager to help Justin tell the story that we all hope will ultimately help protect their national treasure.

Of all the willing individuals we encountered, the most extraordinary have to have been the Save Our Seas Foundation project leaders, with whom Justin worked closely leading up to and during his assignment. These passionate men and women have dedicated their lives to understanding and ultimately protecting 'their' species and it seemed as though there was nothing we could ask for that they wouldn't try their hardest to make happen for us. I was constantly overwhelmed by their positive, can-do attitude, and their optimism and passion were infectious.

I noticed that even though we were going to bed utterly exhausted physically at the end of each day, there was an undeniable sense of purpose and hope – and it felt both thrilling and wonderful to be a part of it. We are all stewards for this unique marine realm and are all united in working together to better understand and protect what remains.

BEHIND THE SCENES

On Assignment Justin Gilligan

Photo by Philippa Ehrlich

Photo by Philippa Ehrlich

On Assignment Sirachai (Shin) Arunrugstichai

We sat in still suspense, submerged in the shallow water, the crowns of our heads just breaking the water's surface. Our masks and snorkels had become part of our anatomy for that afternoon and there was an unspoken code that we would leave the sanctuary of the water only when the excitement of having seen one of Bimini's cherished juvenile lemon sharks became too much to take. What evil were we trying to evade? Sand fleas. These minute critters were out in full force after a brief afternoon thunderstorm and each of us was very aware that if one of these tiny menaces managed to sink their teeth into us, we would be itching relentlessly for the next week.

Together with five others from the Shark Lab, I was deep in the middle of the mangroves at Aya's Spot, one of the lab's favourite locations for juvenile lemon shark sightings. We were here accompanying Shin on a trip to this remote spot where he was hoping to get the 'kickass natural history shot' that would help him tell the story about how vital the mangroves of Bimini are as a nursery area for sharks and many other species. Like statues we waited patiently, suspended between the sea grass and the water's glassy surface, keeping our eyes peeled for a glimpse of a lemon shark.

Below the surface, time seemed to stand still. The only reminder that a reality existed outside this underwater wonderland was my audible breathing through the snorkel. I was totally mesmerised by the warm, crystal-clear water and the shadows of the mangrove trees that created a black backdrop for tiny particles of organic matter and the fallen orange and yellow leaves dancing above us as they floated past with the incoming tide.

Dappled light permeated through the canopy of the mangroves and shafts of golden sunlight streamed through the natural columns of the trees' roots. Between those roots wove curious schoolmaster snappers and other underwater residents, cautiously coming closer to investigate the alien visitors. And then I would glance up and realise that everything that was taking place right in front of my eyes was being reflected back to me on the still water's mirror-like surface.

It was one of the most surreal and magical moments I have ever experienced and, believe it or not, only one of a number of such moments we were privileged to experience during our time on assignment at the Bimini Biological Field Station.

Since I have been with the Save Our Seas Foundation, I have seen more than a thousand images from Bimini, read numerous blogs and stories about life at the Shark Lab and chatted with a number of researchers and volunteers who have passed through its famous doors. Yet absolutely none of this could do justice to the real-life experience of being at the Shark Lab. And I'm not talking about living on a small, secluded tropical island in the middle of the

BEHIND THE SCENES

Caribbean surrounded by clear, turquoise waters that are celebrated for their abundance of elasmobranchs and general marine biodiversity. Sure this has its very evident perks, but anyone who has spent time at the lab will tell you that the true magic that captivates the heart of every visitor happens within those four prefab walls.

It is hard to wrap one's mind around the set-up of the Shark Lab. Essentially it is a park home with only two bathrooms, four bedrooms, a lab, a kitchen and a common area, yet somehow it manages to sleep and feed up to 25 researchers, volunteers and visitors. The best way of explaining it to others is to ask them to imagine a field station in the Antarctic and then transfer it to a remote island in the Bahamas. Only then can they begin to comprehend that life at the Shark Lab is anything but a working holiday in tropical paradise.

When you walk through those doors, you are giving up the simple pleasures that you take for granted in your day-to-day life. Before arriving you prepare yourself for the obvious big things you'll long for, such as seeing friends and family, access to your favourite grocery store or restaurant and – a major concern in the 21st century –reliable Internet access. It turns out, though, that it is the small things that never crossed your mind while you were preparing that you find you miss the most: weekend lie-ins, a quiet personal space to retreat to for time alone, and fresh fruit and vegetables (you can't imagine how much you'll miss fresh produce!).

A stay at the Shark Lab involves more than making a few sacrifices, however. In exchange for the opportunity to spend time with residents of the Bimini waters and watch them in their natural environment, as well as the experience of witnessing world-class shark researchers at work, Shark Lab interns and volunteers have daily responsibilities and chores to carry out. These can range from being on housekeeping duty to cooking three meals a day for all the lab's current occupants or repairing gill nets in the summer sun. The team members live together in a confined space and often find themselves in high-pressure situations while out in the field or while handling live sharks, yet every day all I saw was grinning, sun-kissed faces and eager hands ready to help and get involved at every opportunity.

Despite its small size and the large number of people under its roof at any one time, the Bimini Biological Field Station – Shark Lab – works like a well-oiled machine. After only 11 days there I could understand why some of today's leading shark researchers are products of this establishment. Life is hard and demanding at this remote field station, but it is also character building. The Shark Lab provides its students and volunteers with the life skills that will enable them to succeed, while also nurturing their love, understanding and appreciation of sharks, marine life and the natural environment.

A Japanese swell shark *Cephaloscyllium umbratile* embryo inside its egg capsule.

In our next issue we will focus on sawfishes and the work of our passionate project leaders around the world as they investigate these elusive and highly endangered species. Possibly extinct in half of all countries where they used to occur, sawfishes are listed in Appendix I of the Convention on International Trade of Endangered Species (CITES), which prohibits commercial trade; in both Appendices of the Convention on the Conservation of Migratory Species (CMS); and in Annex 1 of the CMS Memorandum of Understanding for Migratory Sharks, which calls for cooperation to save these species. Collaboration between Save Our Seas Foundation principal investigators is essential if sawfish conservation efforts are to be both constructive and stable, and we will explore how our teams are contributing to these efforts.

NEXT ISSUE

Photo by David Doubilet | National Geographic Creative

The Save Our Seas magazine has a new, dedicated website! Now you can explore the world's oceans with us, discover what's new in marine science, and read and share all the magazine's fascinating articles at *www.SaveOurSeasMagazine.com*
You can also read the magazine for free online at either *issuu.com* or *zinio.com*
View it on your desktop, tablet or phone – anywhere you like!

ABOUT THE FOUNDATION

In the effort to protect our oceans, the Save Our Seas Foundation (SOSF) funds and supports research, conservation and education projects worldwide, focusing primarily on charismatic threatened wildlife and their habitats. From a small not-for-profit organisation funding just five projects, in just over 10 years the Save Our Seas Foundation has grown to become a major player in the fight to save the world's oceans and the wealth of marine life they contain. While the SOSF itself is not a research institute, its generous contributions of financial, practical and scientific support have, to date, facilitated more than 200 marine research and conservation projects around the world.

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

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