THE SAVE OUR SEAS FOUNDATION MAGAZINE

saveourseas

GREAT BEAR RAINFOREST | ORCAS | WHALES

IAN MCALLISTER
Ian is an award-winning photographer and the author of numerous books, including most recently *Great Bear Wild: Dispatches from a Northern Rainforest*. Ian is a co-founder of Pacific Wild, an organisation dedicated to achieving lasting protection for the Great Bear Rainforest.

JANIE WRAY
Co-founder of the North Coast Cetacean Society, Janie is dedicated to the research and protection of whales in the coastal waters of British Columbia, Canada. In 2001 she jointly built the CetaceaLab research station in the heart of the Great Bear Rainforest.

RAMÓN BONFIL
An independent scientist and consultant working on the research and conservation of sharks and rays, Ramón is also the executive director of the Mexican non-profit organisation Océanos Vivientes A.C.

LISA-ANN GERSHWIN
Marine biologist, jellyfish expert and science communicator based in Tasmania, Lisa-ann has described more than 200 jellyfish species and is the author of the acclaimed book *Stung! On Jellyfish Blooms and the Future of the Ocean.*

Front cover: A white-sided dolphin *Lagenorhynchus obliquidens* skims along the ocean's surface in the waters abutting the Great Bear Rainforest, Canada. Photo by Thomas Peschak

Back cover: A pod of Steller sea lions *Eumetopias jubatus* in the Great Bear Sea on the west coast of Canada. Photo by Ian McAllister

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Photo by Thomas Peschak

04 GREAT BEAR SEA

Western Canada's Great Bear Rainforest is a 400-kilometre stretch of wilderness where icy seas meet temperate rainforest to create an abundant ecosystem for wildlife on land and in the ocean. Thomas Peschak reveals this ancient paradise in a photographic portfolio.

38 GREAT BEAR WILD

The Great Bear Rainforest is home to First Nations who have been here longer than the cedar trees. They are stewards of the environment they share with whales, wolves and bears. Like them, Ian McAllister is working to protect this pocket of the world's largest remaining temperate rainforest.

72 THE CALL OF THE WHALES

Janie Wray came to Great Bear to study the secret lives and languages of orca communities, but expanded her research when, with time, other whales returned to the area. Now Janie has spent almost 15 years with the whales of Gil Island.

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

THE FOUNDER | SAVE OUR SEAS FOUNDATION

Photo by Thomas Peschak

In the seas off the Great Bear Rainforest, humpback whales feed by releasing a circular curtain of bubbles beneath a school of herring, trapping the fish and pushing them upwards. The whales follow the fish and break the surface with open mouths.

GREAT BEAR SEA

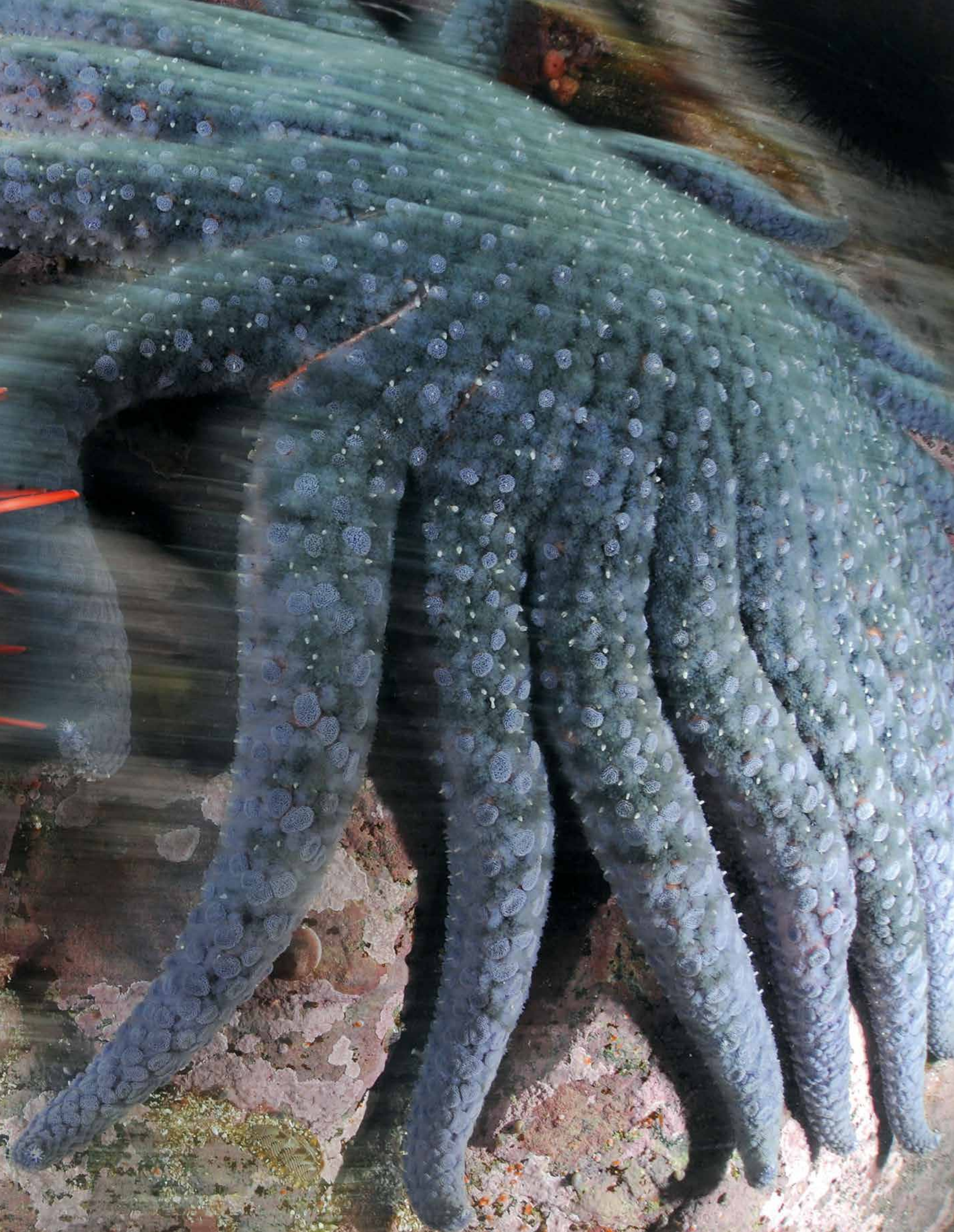
Photography by Thomas P. Peschak

Coastlines are magnets for development, which means that wilderness is constantly being pushed further and further into remote reaches of the interior – and that the natural flow of wildlife and ecological processes at the world's ocean–land interface is disappearing fast. The Great Bear Rainforest along Canada's west coast is one of the few places where a wild landscape still meets a wild ocean. Photographer Thomas Peschak spent three summer seasons exploring the Great Bear Rainforest. He hopes that his images will instil a sense of wonder, and help foster a sense of responsibility for the fate of this unique coastal wilderness.

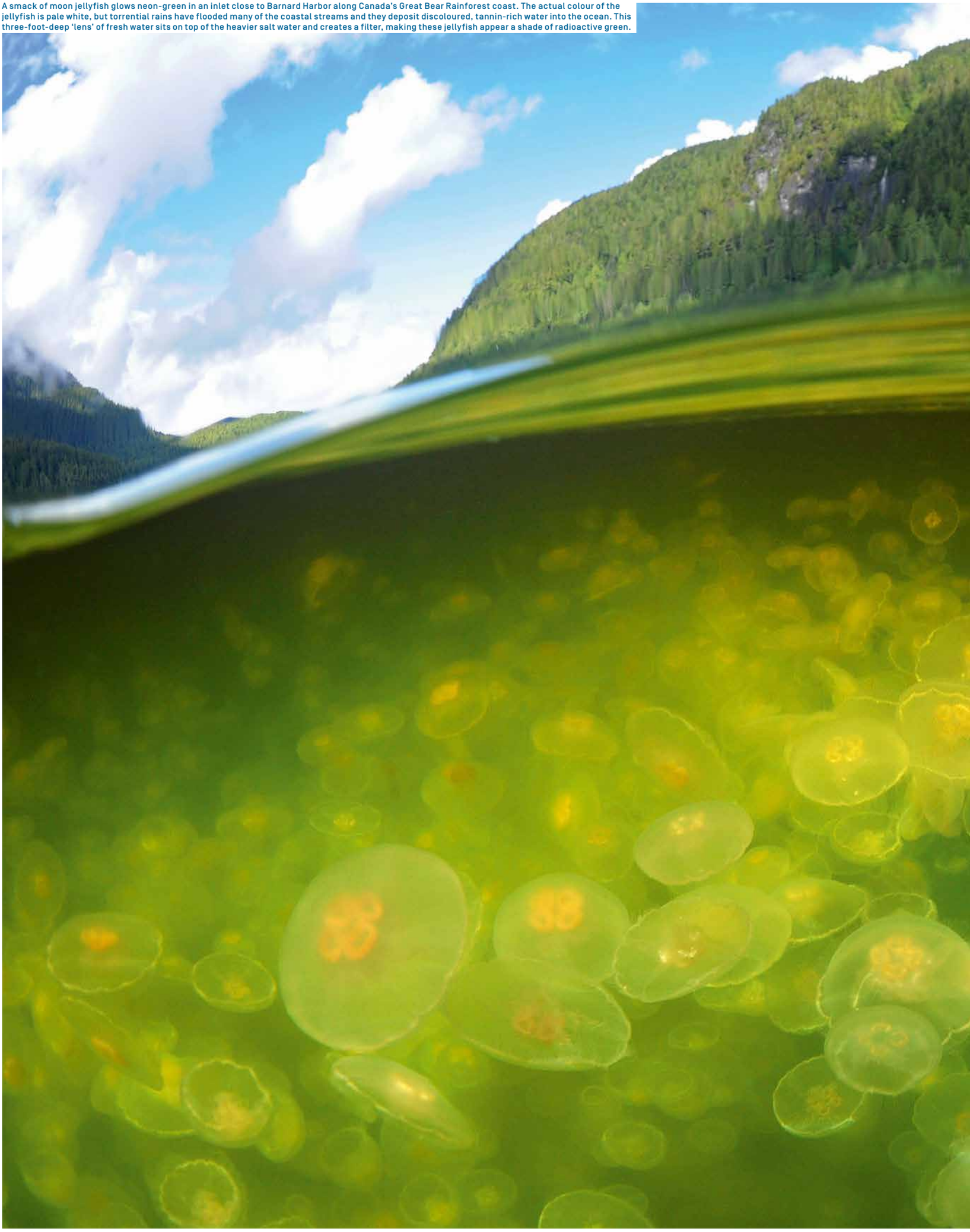
A wild, rocky point juts out into the North Pacific Ocean. Steep cliffs and wind-stunted trees are the signatures of the outer coast. This is one of the few places left on our planet where a truly wild landscape clashes with a wild and untamed ocean.

Steller, or northern, sea lions are the largest of all the sea lions, reaching a length of three metres (10 feet) and a maximum weight of 350 kilograms (770 pounds). The population off the coast of British Columbia and nearby Alaska has declined by 50% since the 1960s, resulting in these sea lions now being listed as threatened under the US Endangered Species Act. One theory for this dramatic decline is the overfishing of ground fish, an important prey item.

The sunflower sea star is one of the most voracious invertebrate predators in the world. Its preferred prey is the red sea urchin, which is usually a rather sedentary creature. However, when this giant sea star is on the prowl, the sea urchin quickly springs to life and tries to crawl to safety at surprisingly great speed.



A smack of moon jellyfish glows neon-green in an inlet close to Barnard Harbor along Canada's Great Bear Rainforest coast. The actual colour of the jellyfish is pale white, but torrential rains have flooded many of the coastal streams and they deposit discoloured, tannin-rich water into the ocean. This three-foot-deep 'lens' of fresh water sits on top of the heavier salt water and creates a filter, making these jellyfish appear a shade of radioactive green.



The seas of the Great Bear Rainforest are home to more than 75 species of jellyfish. This dense school, though, is made up mainly of just two species: the lion's mane jellyfish and the moon jellyfish.

Salmon are the keystone species of the Great Bear Rainforest. Every year in summer they abandon their life at sea and return to their natal rivers to spawn. A deep pool at the base of a small waterfall is alive with pink salmon waiting for just the right moment to leap up the falls and continue their migration upstream.

Despite its name, the North American river otter also forages in the cold waters of the Pacific Ocean. It prefers to hunt fish and a single animal can consume up to 1.5 kilograms (3.5 pounds) in a single day. A river otter's metabolic rate is 50% higher than that of a similar-sized land mammal, which accounts for the high daily intake of calories.

Every morning Gitga'at fisherman Wally Bolton heads out to sea in his small aluminium skiff. Just beyond Hartley Bay the water is more than 300 metres (1,000 feet) deep and this is where he sets his lines for Pacific halibut, the largest and heaviest flat fish in the world.

Considered to be the world's most delicious crustacean, the Dungeness crab is an important food source for the Gitga'at First Nation. Schoolteacher and Hartley Bay councillor Cameron Hill pulls up one of his traps filled with crabs.

Ernie Hill, the hereditary chief of the Eagle Clan, welcomes more than 200 First Nations young people to the village of Hartley Bay in Gitga'at territory. These youngsters travelled more than 460 kilometres (285 miles) in ocean-going canoes along British Columbia's north coast.

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The adventure begins with an epic journey to the far reaches of our planet: the north-western shore of Canada's British Columbia, where the coastal rainforest is as remote and difficult to access as its tropical counterpart. Looking down from a small aircraft upon the innumerable straits and fjords, the islands and the lush coast of seemingly endless forest that is spotted with lakes, rivers and streams, I'm already dreaming of the adventure ahead. At Prince Rupert, just a few miles from Alaska, we'll board the local ferry that takes us to Hartley Bay and during the four-hour journey will have the opportunity to meet people who have called this incredibly rich region their home for thousands of years: people of the First Nations.

Eager to present the beauty and uniqueness of their region and of their culture, these people are happy to talk to us, and their connection with nature is immediately apparent. The conversation soon turns to their concerns about development, the exploitation of resources (on land and in the sea), and how difficult it is to find support for their attempts to protect a coast that the world knows so little about.

Photo by Yoann Vidoz

The CetaceaLab and Pacific Wild teams with the editor. Meet Ian McAllister, Michael Scholl, Janie Wray, Karen McAllister, Hermann Meuter and Diana Chan (from left to right).

In this region, the Save Our Seas Foundation is funding two projects that are uncharacteristic for us. They may be atypical in that they focus on cetaceans, but they are certainly representative of the kind of people we strive to work with around the world. In this issue of the *Save Our Seas* Magazine, we tell you their stories and introduce to you this truly magnificent region.

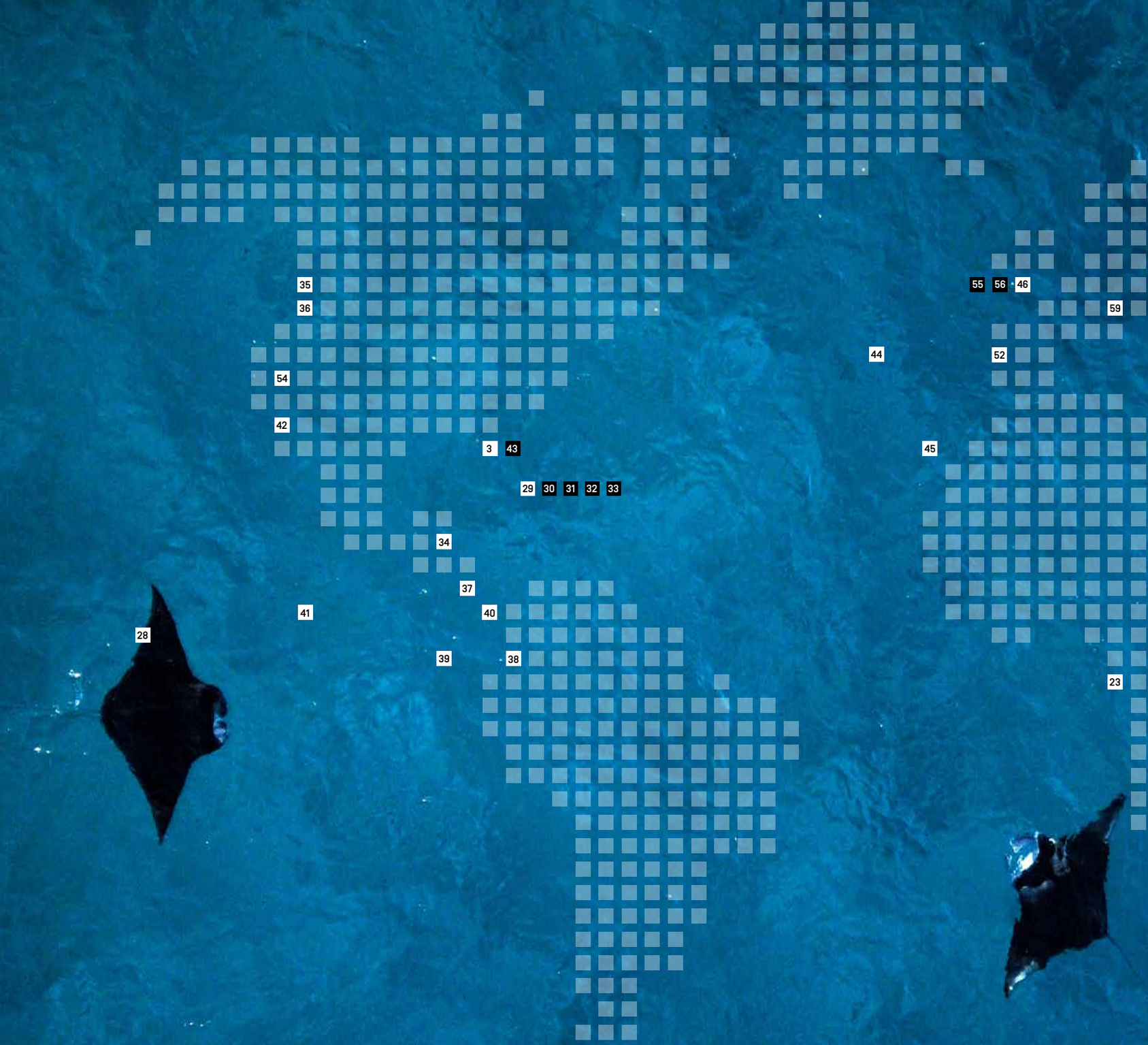
The journey to the Great Bear Rainforest reminded me of the book *Into the Wild* – except that my travels were taking me to some of the most incredible, dedicated and friendly people I could wish to meet: Janie Wray and Hermann Meuter, who established and run the Cetacea-Lab research field station on the southern coast of Gil Island in the territory of the Gitga'at (People of the Cane) of the Tsimshian First Nation; and Ian and Karen McAllister, who founded and manage Pacific Wild, an environmental NGO based out of Bella Bella in the Heiltsuk (To Speak and Act Correctly) First Nation's territory.

Good conservation can only be achieved by passionate people and solid science. The Save Our Seas Foundation is dedicated to these passionate people who devote their lives to a cause: to saving a species, a habitat, an ecosystem. The Founder of the Save Our Seas Foundation is dedicated to people who have this vision, enthusiasm and drive, and our support for these two projects and their leaders reflects our respect and appreciation for their work, dedication and achievements.

'The only way to do great work is to love what you do. If you haven't found it yet, keep looking. Don't settle. As with all matters of the heart, you'll know when you find it. And, like any great relationship, it just gets better and better as the years roll on.' Steve Jobs

I know that the images and stories presented through the eyes and pen of Thomas Peschak, Ian McAllister, Janie Wray and Hermann Meuter about the Great Bear Rainforest will make you dream of the true meaning of untouched nature, and will ensure that the voices of the people who live and love this ecosystem will be heard.

Michael C. Scholl
Chief Executive Officer
Save Our Seas Foundation



WHERE WE WO

The Save Our Seas Foundation was established in 2003 with a mission to protect our oceans by funding and supporting research, conservation and education projects around the world, focusing primarily on charismatic threatened wildlife and their habitats.
In that time, the foundation has sponsored 160 projects in more than 40 countries, proudly supporting outstanding researchers, educators and conservationists who have contributed to the continued existence of more than 60 of our planet's precious marine species.

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

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2 SOSF Island School Seychelles | Abi March
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Photo by Thomas Peschak

Angels' Kingdom

A male angel shark rests on the ocean bottom at Lanzarote, one of the Canary Islands in the Atlantic Ocean. These masters of disguise can reach lengths of 2.5 metres.

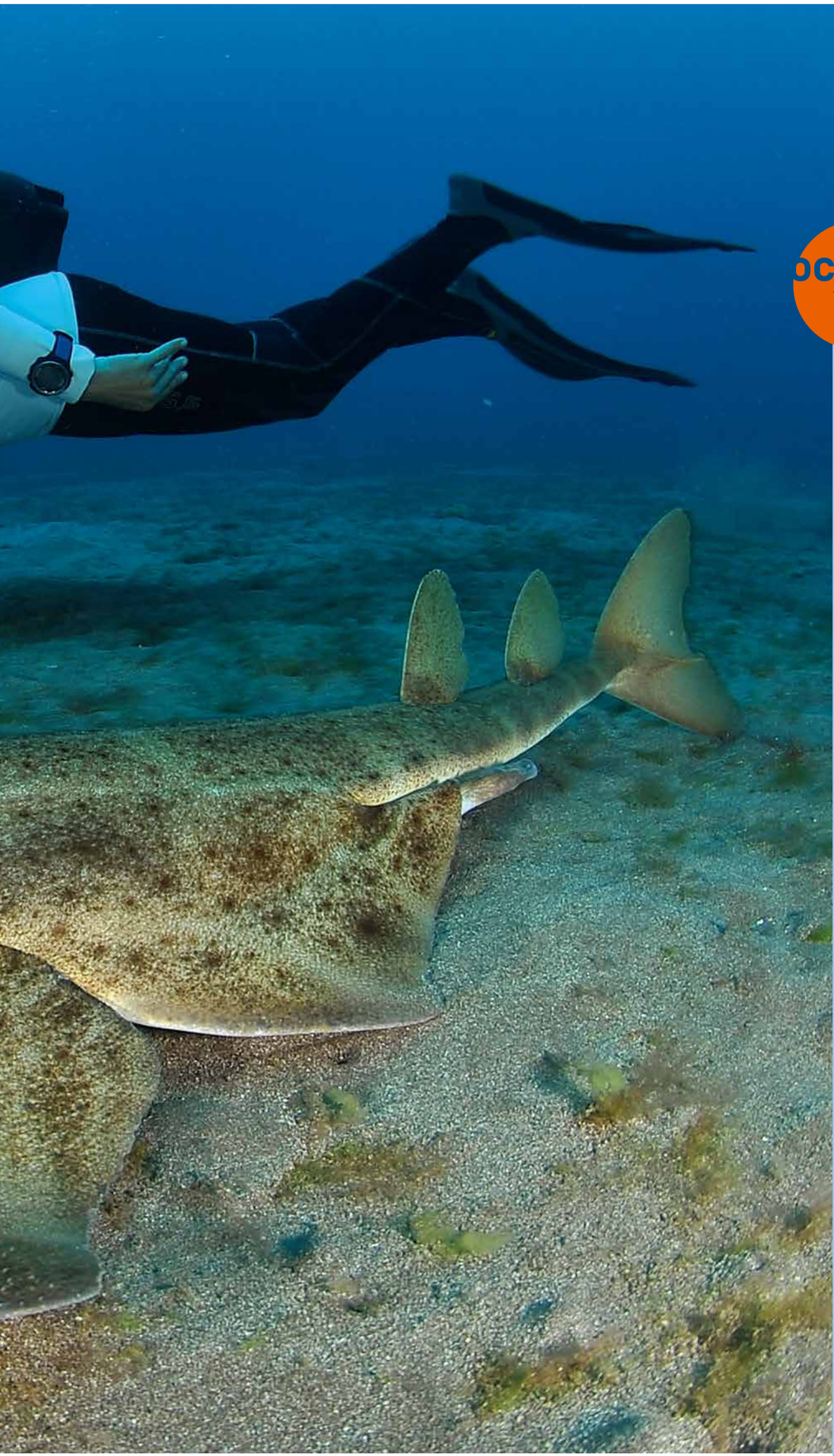


Photo by Carlos Suarez | Océanos de Fuego

ocean view

The Canary Islands, off the coast of Spain, are the last known stronghold of one of the world's most critically endangered sharks. The angel shark, once prolific throughout Europe, is now extinct across most of its historical range. However, in the Canaries, a beautiful archipelago of seven volcanic islands in the Atlantic Ocean, the species continues to thrive. Local researchers have found, in addition to an apparently healthy adult population, a critical nursery site for the unusual-looking animals.

Las Teresitas beach is located only 15 minutes away from the capital, Santa Cruz, on Tenerife Island. This artificial beach, created in the 1970s with white sand from the Sahara, is very popular with tourists. It is also the largest known pupping area for the rarest shark species in Europe. During the day, beach-goers laze in the shallows and drink cocktails under umbrellas while the angel sharks lie buried in the sand. At night, scores of hungry little sharks emerge into water that is less than half a metre deep – and Eva Meyers and her team are ready to tag them.

Meyers, a student from the Zoological Research Museum Alexander Koenig and the University of Las Palmas de Gran Canaria, leads the Angel Shark Project. It aims to secure a future for the sharks in the Canary Islands by means of conventional research as well as by engaging communities through citizen science. The sharks are a major attraction for the local diving industry and the islands represent what may be our last opportunity to gain basic ecological knowledge about these muppet-like elasmobranchs.

Although rumoured to be tasty, angel sharks are not targeted by commercial fisheries. The large, flat sharks spend most of their time lying stationary on the ocean floor, a practice that has led to their demise because it makes them vulnerable to becoming by-catch in trawl nets. This has been aggravated by the sharks' sensitive biology, which results in very slow recovery when populations are depleted.

Photo by Rich Carey | Shutterstock.com

Juvenile turtle breaks long-distance world record

ocean view

A juvenile hawksbill turtle tagged at St Joseph Atoll in the Seychelles' Amirantes Islands has been discovered just north of Malindi in Kenya. The 40-centimetre turtle travelled at least 1,500 kilometres across the Western Indian Ocean, earning for itself the world record for the longest migration of a turtle that size.

After surviving for 15 years adrift in the open ocean, juvenile turtles that arrive at St Joseph Atoll are in for the good life. The lagoon and surrounding habitat teem with turtle life. It is estimated that more than 700 hawksbill turtles and 1,500 green turtles live here, thriving in the atoll's sea-grass beds. It is hard to imagine then, why one adventurous little turtle would chose to brave the open ocean once more and, after an epic year-long journey, make its way to a beach in Kenya.

According to Casper van de Geer, project manager for the Local Ocean Trust: Watamu Turtle Watch, the young hawksbill was accidentally caught on 3 October 2015 by fishermen who brought it to the organisation in response to its By-Catch Release Programme. The programme motivates fishers to release turtles that have been caught in their nets by compensating them financially.

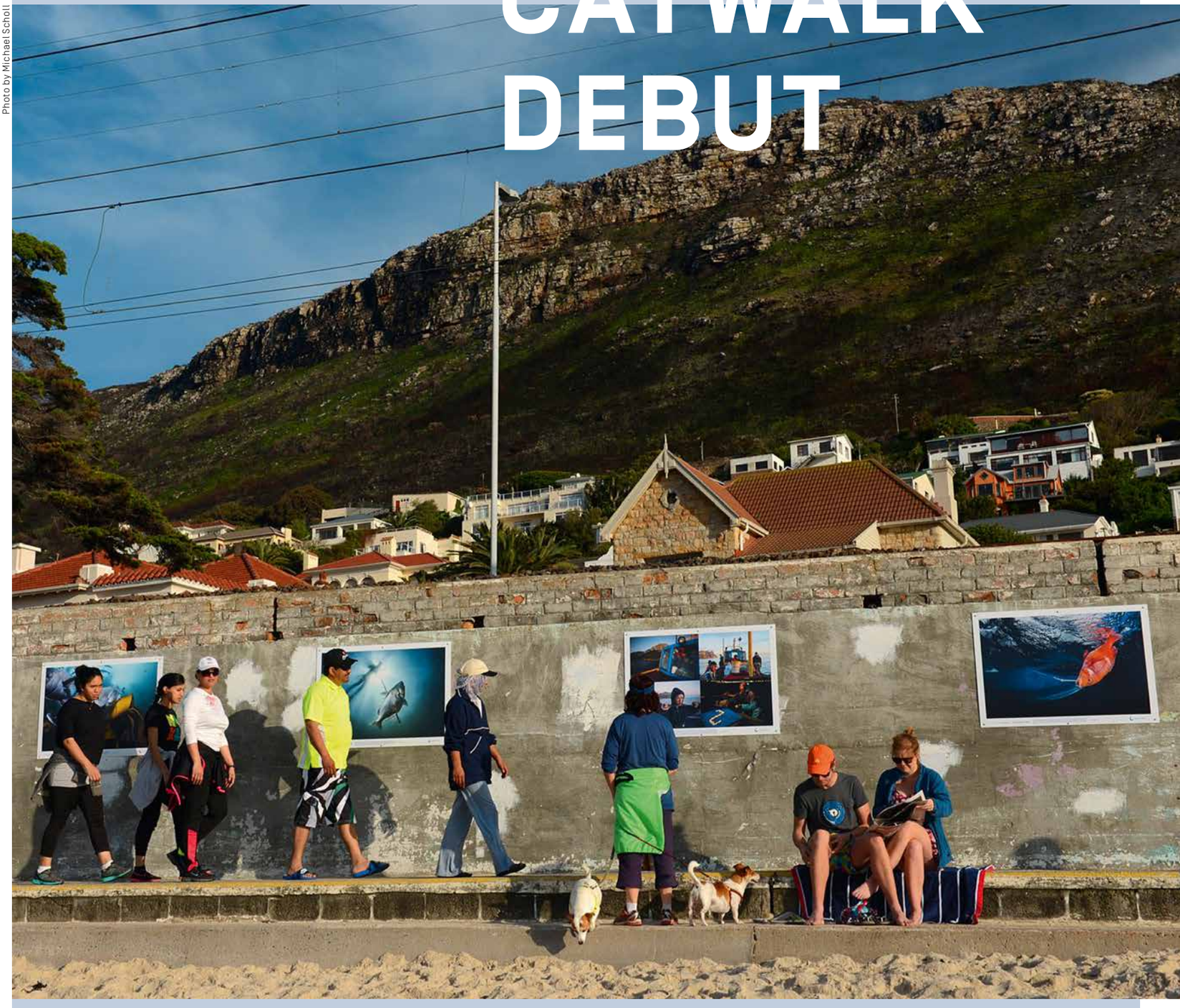
Van der Geer used information on the turtle's flipper tag to contact Dr Rainer von Brandis of the D'Arros Research Centre in the Amirantes, who had originally captured the hawksbill in the shallow waters of St Joseph on 2 July 2013. Judging by the build-up of algae on the turtle's shell, von Brandis believed that the turtle had been resident in the lagoon for several months at that time. He and his team tagged the turtle with an acoustic transmitter in addition to flipper tags. For the next 14 months, it was detected regularly in the same area, but after 23 September 2014 it disappeared, presumably to begin its record-breaking swim. 'It has now been released unharmed in the Watamu Marine National Park where it will certainly enjoy a good life,' reports von Brandis.

MARINE LIFE MAKES CATWALK DEBUT

False Bay's sharks and reef fishes can be seen strutting their stuff on the popular catwalk that runs parallel to the sea between Muizenberg and St James in Cape Town, South Africa. The Save Our Seas Marine Conservation Grant outdoor photography exhibition has been on display since early September and showcases the work of grant winners Joris van Alphen and Mac Stone.

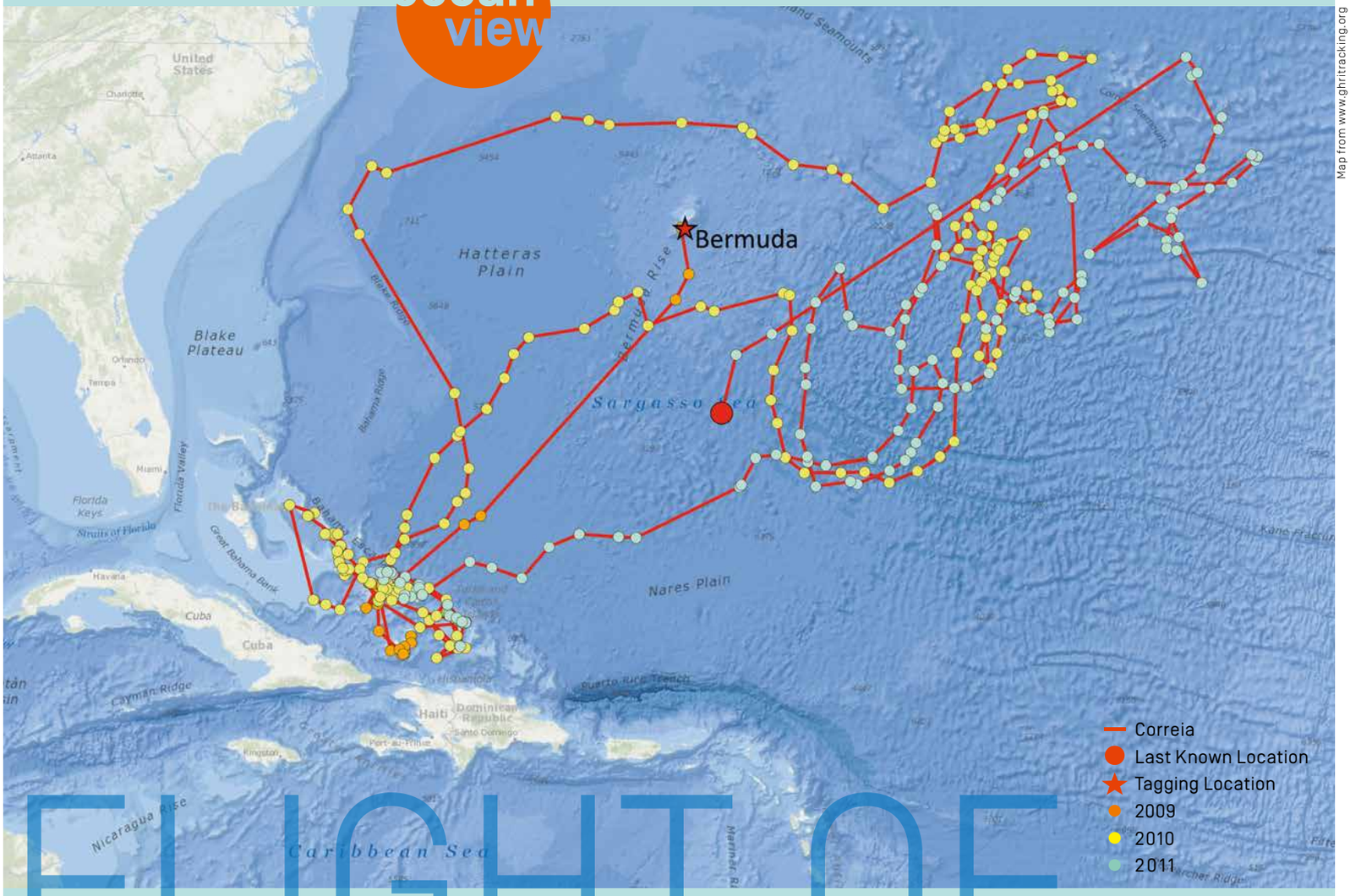
Van Alphen and Stone were sent to False Bay in December 2014 on assignment for the *Save Our Seas* magazine. Van Alphen's work chronicles the plight of South Africa's diverse community of rocky reef fishes, while Stone's portfolio examines the complex relationship between False Bay's water-users and its famous population of great white sharks.

These photographs represent an important opportunity for Cape Town's residents and visitors to connect with this unique marine ecosystem and inspire them to take ownership of its protection.



An outdoor exhibition featuring photos of False Bay is now on in Cape Town, South Africa. The images are among those captured by the Save Our Seas Foundation's 2014 Marine Conservation Photography grantees.

Photo by Michael Scholl



Map from www.ghritracking.org

FLIGHT OF THE TIGER

Much like the overwintering birds we are familiar with – swallows, geese, storks, terns and the like – tiger sharks in the Atlantic repeatedly migrate over thousands of kilometres each year to spend summer months in the north and winter in the Caribbean. This has come as a surprise to shark scientists who largely thought of tiger sharks as coastal even though, until now, we knew very little about their long-term movements.

The recent study that shed light on this migration was the first to satellite-track tiger sharks for long periods. We now know the sharks make round trips of 7,500 kilometres a year – further than the distance between New York and Rome – to get to and from two very different environments: the warm, coral reef-filled waters of the Caribbean in summer and the open, emptier waters in the middle of the North Atlantic in winter. The distances are vast, the environments are disparate and the behaviour is unusual among fish.

'The only other sharks known to do such regular, long-distance migrations between contrasting habitats are the comparatively warm-bodied salmon and white sharks,' says James Lea, who co-led the study with Brad Wetherbee.

Why would a shark embark on such an epic migration? Unfortunately we don't know for sure – yet. But whatever makes them go, it would have to be 'something really good', says Mahmood Shivji, a co-author on the study, who is also The Save Our Seas Foundation Shark Research Center director.

The track of a male tiger shark showing repeated migrations between Caribbean and open Atlantic waters. This shark travelled more than 28,500 kilometres in the 747 days it was tracked.

High-tech fin recognition

The world's first fully automated fin recognition platform for white sharks is in the final stages of development. The new FinPrinting technology is the result of collaboration between the Save Our Seas Foundation's Michael Scholl and Benjamin Hughes from the University of Bristol. The system will allow researchers to upload a photograph of a fin, which will then be automatically matched against an existing database – much like Facebook's facial recognition technique.

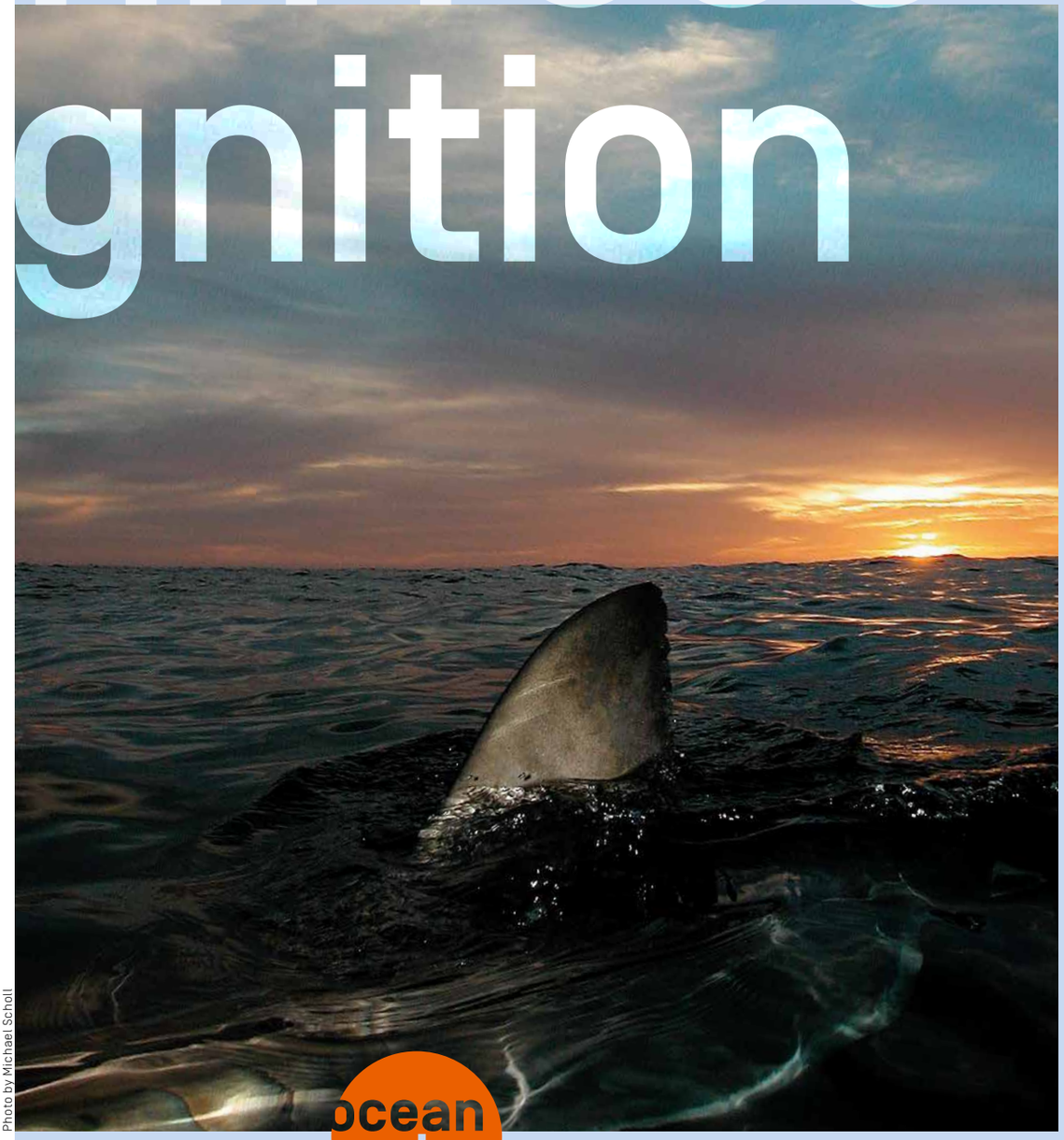


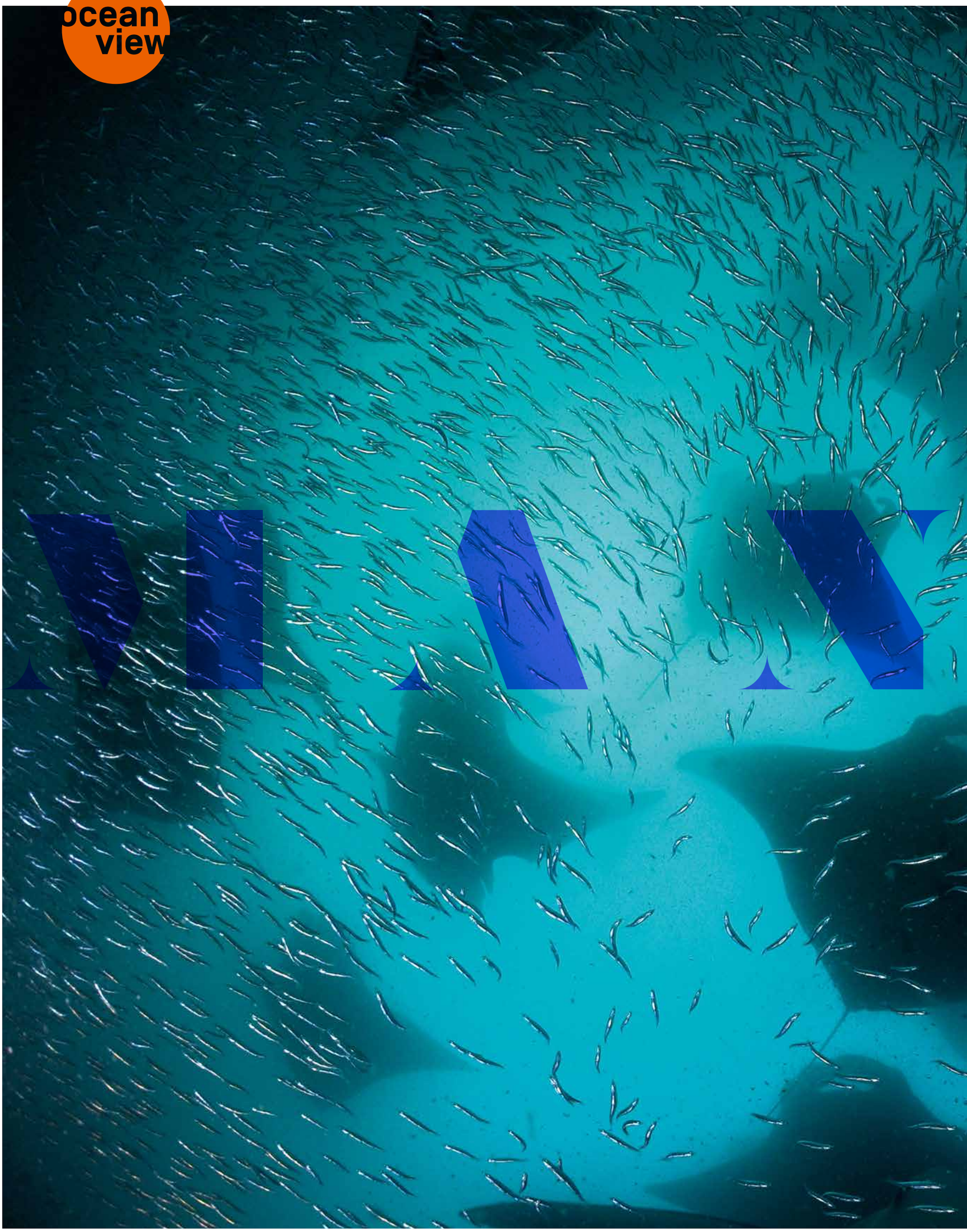
Photo by Michael Scholl

The ultimate goal of the platform is to create a global database of fin identification photographs that will enable researchers to see where individual white sharks have been spotted. By plotting the locations of these endangered sharks, ecologists will be able to get the most accurate estimate of the species' population size. The platform will also help them to track white shark movements between hotspots along coasts and even between continents. Scholl and Hughes have been working on the project since 2012 and hope that the free-to-use system will be available within the next year.

While studying white sharks at Dyer Island in South Africa, Scholl was researching one of the largest aggregations of the species in the world. To answer important ecological questions about the population, he needed to find a way to recognise individual sharks visually. Dolphin biologists were already using fins to identify individual animals, and the dorsal fin of a white shark is the one part of its anatomy that is sometimes visible from the surface. Having collected thousands of images of dorsal fins over time, Scholl realised that his growing database of photographs would enable him to paint a fairly comprehensive picture of Dyer Island's white shark community.

'In comparison to tagging methods, FinPrinting is a non-invasive and lasting technique for identifying individual sharks. It is, however, extremely time-consuming and can be prone to human error,' said Scholl. 'The first important evolution happened when we moved from film to digital, saving thousands of hours. This will be the most important technological jump since that transition.'

Scholl initiated the project with Hughes, a computer science PhD student who wanted to use his skills for conservation, to develop a faster way to match fins than manual comparison. 'Using the new technology, we can visually recognise individuals, fully automatically, in less than a minute,' explained Hughes.



VIEW

Mantas are flying high

2015 is proving to be the most exciting season for the Maldivian manta ray project since 2010. In the first few months researchers confirmed seeing at least 176 mantas feeding at Hanifaru Bay in Baa Atoll during a single event, making this one of the largest aggregations of reef mantas witnessed so far. 'The season will carry on until early December, but already the large number of sightings and the consistency of mass feedings at Hanifaru have made this an extraordinary year for the mantas of the Maldives,' said Niv Froman, the leader of the project.

The surge in manta ray numbers is made even more remarkable by the number of manta pups that have been born in 2015: 18 have been seen so far. Such a high tally has not been observed in the past five years, and growing evidence of mating activity and the increase in progeny suggest that Baa Atoll's population could be thriving.

This has been very encouraging for the Manta Trust team. Guy Stevens, the trust's chief executive officer, started studying the Maldivian mantas in 2005 and he and his colleagues have been concerned about the decline in the population since 2011. Sightings started decreasing after 2010, when many females disappeared and very little mating activity by those remaining was observed. Despite this season's positive increase, the number of pregnant females is still far lower than it was before 2010.

The Manta Trust attributes the surge in manta ray numbers to environmental and political factors. The first few months of the south-west monsoon bring the consistent strong winds that create the powerful currents needed for the upwelling of cold water and the concurrent increase in concentrations of zooplankton at the surface. It is these concentrations that attract mantas, but the necessary conditions have not occurred during the past five years and mantas have presumably had to feed at greater depths.

Hanifaru Bay became a marine protected area six years ago and last year the Maldives were declared a sanctuary for manta rays. This protection may be an important contributing factor to the return of the Maldivian mantas. 'While we see the number of mantas declining in most countries because of fisheries, observing the opposite trend in the Maldives gives us a good example of how national protection of mantas does make a difference,' commented Froman. 'We hope other countries will be inspired by these great results.'

Photo by Guy Stevens | Manta Trust

from the field

A short interview with Frances Humber

Photo by Garth Cripps

As a girl from the UK, how did you come to work in Madagascar?

It all started with an opportunity to work for the marine conservation organisation Blue Ventures when, during its early days, it sent out a random call to UK universities looking for interns. Its first project was in Madagascar, so it was more by luck than by planning that I was able to work in this country!

How much time do you get to spend in the field these days?

Unfortunately not that much today. However, as I've got older, and hopefully wiser, I've realised that the best way I can support our projects and the communities they work with is to do what I do best. That means sitting at a computer in the UK, trying to give those in Madagascar more time and energy to focus on activities they excel at.

Can you describe your impression of the Vezo people the first time you met them?

Indomitable and resourceful! It was sunrise the morning after our lorry had broken down in the middle of the spiny forest in south-western Madagascar and we had spent the night in it waiting to be rescued. A large group of men, women and children appeared along the dust track in the early morning sun with carts pulled by zebu (humped cattle) to help take us and our belongings to the nearest village. The mingling of the dust, sunlight, people shrouded in blankets against the early morning cold, and animals was an image I haven't forgotten.

What have you learnt from the local people you work with?

That we should be ashamed of ourselves in the UK! That people who may only make US$2 a day are willing to give marine conservation and management a go and yet we struggle to make the smallest sacrifice towards better fisheries management and marine conservation in wealthier parts of the world. And that you do not need to convince fishers in Madagascar that climate change exists – they might not know the technical terms, but they understand that the weather and ecological systems are changing and that this is already impacting their daily life.

What is your hope for the Vezo people of Madagascar?

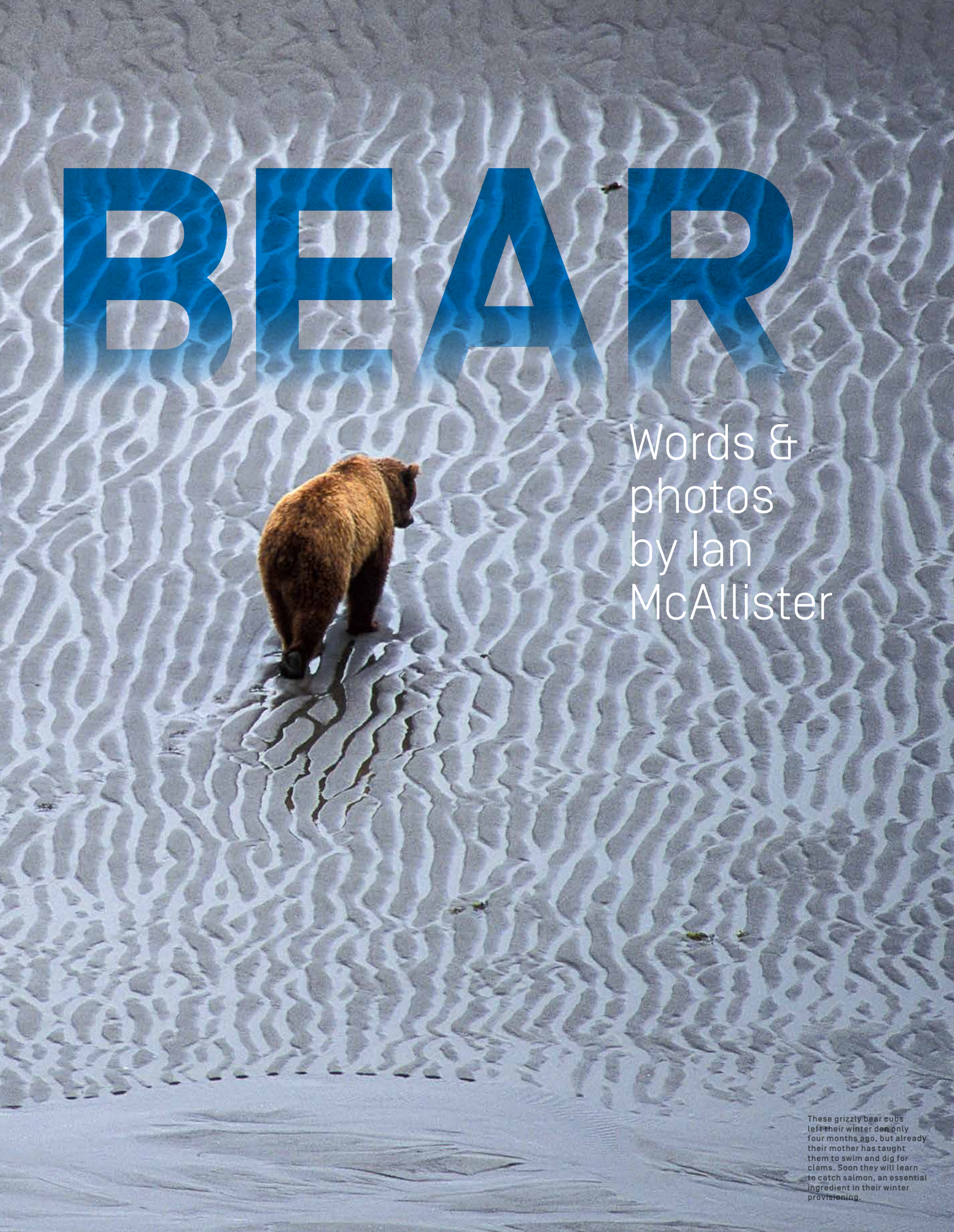
A fairer life. One in which they have the right to manage their own fisheries and receive a good income from well-managed fisheries, and where outside interests are not put above the interests of the fishers of Madagascar.

GREAT WILD

Where forest meets sea on Canada's Pacific coastline, First Nations have sustainably used an incredible natural bounty for thousands of years. Ian McAllister of Pacific Wild wants to continue their traditions of protection.

BEAR

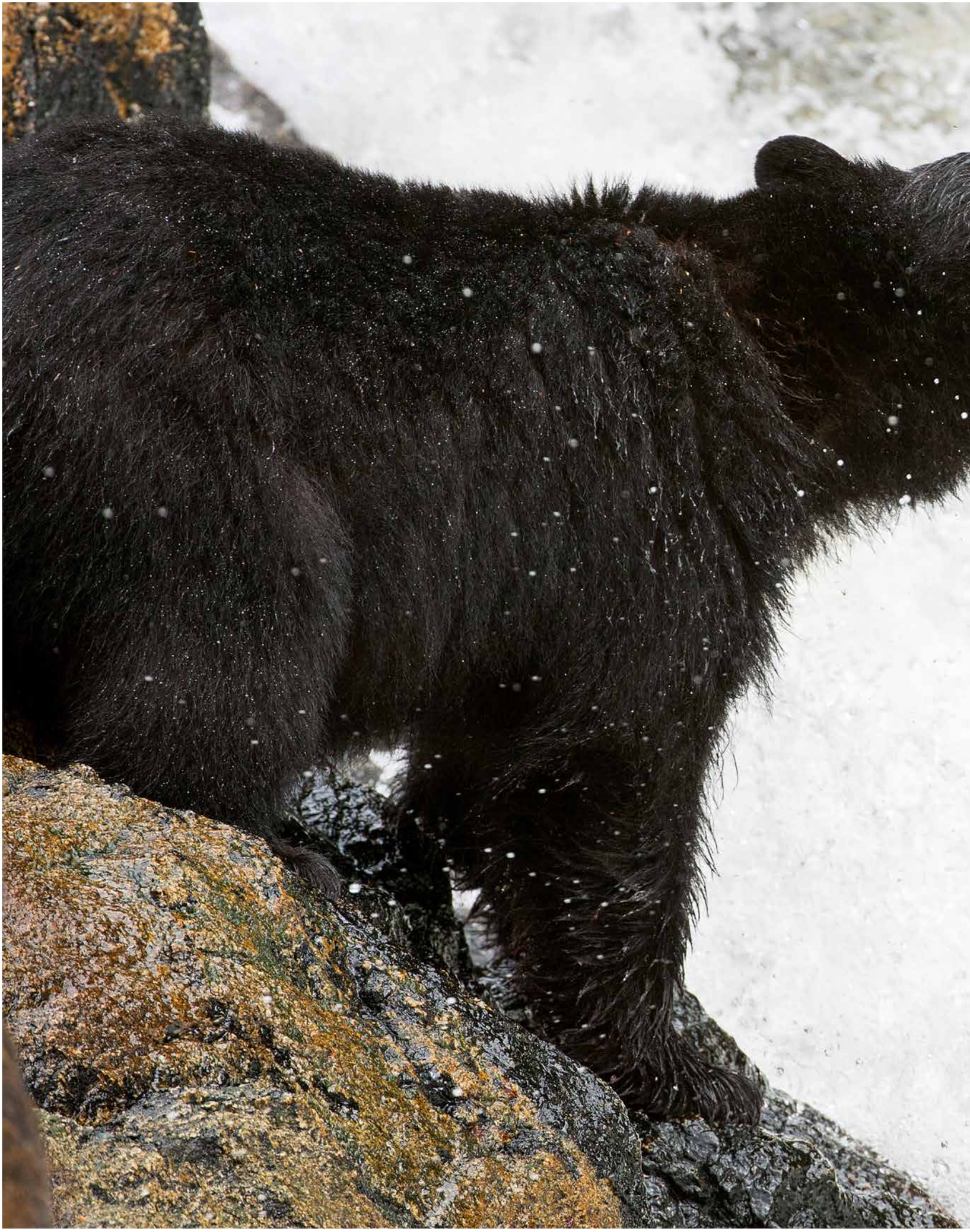
Words & photos by Ian McAllister



These grizzly bear cubs left their winter den only four months ago, but already their mother has taught them to swim and dig for clams. Soon they will learn to catch salmon, an essential ingredient in their winter provisioning.

Although grizzly bears may give the impression of being robust and resilient, their populations are extremely vulnerable to disturbances in their habitat and food supply. They thrive only in areas that remain relatively intact, like the Great Bear Rainforest.

A mother black bear and her cubs walk across their favourite bridge, which every day takes them to the best salmon-fishing opportunities. The Great Bear Rainforest is home to more than 2,000 distinct runs of wild salmon that feed a plethora of creatures from bears to birds and wolves to insects.



A large coho salmon is reward for this black bear's patience and fine fishing technique. Bears emerge from hibernation in the spring and are known to feed on more than 50 species of plants before switching to a salmon-based diet in the fall.

In the Great Bear Rainforest a mother black bear, whatever her colour, can have white or black cubs. The white bears, also known as spirit bears, carry special significance for First Nations in the region.

The white sandy beaches and rocky headlands of northern Vancouver Island disappear behind my wake. Off to the east the Great Bear Rainforest's snow-capped peaks are silhouetted against a darkening sky. Through the salt-water mist a chain of serrated islets and islands appears.

These islands form part of the southern boundary of the Great Bear on the west coast of Canada, separating two worlds. The one I'm heading towards is a lost world of kelp forests, rock, towering trees and ecological riches. South of here the forests have largely been converted to tree plantations. The paradise to the north represents more than half of Canada's Pacific coast and much of the world's remaining intact temperate rainforest. It constitutes more than 1,000 uninhabited islands, 2,000 river valleys hosting wild salmon, and one of the largest unexplored, unprotected marine ecosystems on the planet. I'm traversing the wide-open Hecate Basin, the body of water between Vancouver Island and Haida Gwaii and the northern coast of mainland British Columbia. It remains as inspiring, fascinating and mysterious for me as it did when I first ventured here 25 years ago as part of a research team assessing the region's endangered river valleys.

On days like today it is difficult to imagine living anywhere else. Some colleagues from Pacific Wild, the conservation group I founded with my wife, Karen, sailed with me to Vancouver Island on our 14-metre (46-foot) catamaran *Habitat*, a 15-hour journey from my home on Denny Island, to pick up crew and supplies. Now a stable air mass is giving us a window of reasonable weather for a few weeks of underwater and offshore exploration. By voyage end we will finish up on Denny Island, in the traditional territory of the Heiltsuk First Nation and also the location of the research field station for Pacific Wild. For more than 20 years, the staff at Pacific Wild have been working on wildlife conservation campaigns to protect this coast and today we work primarily on developing marine protected areas and large carnivore research, as well as youth education initiatives and science-based advocacy campaigns. Pacific Wild also operates and maintains a large hydrophone network coupled with remote cameras to research the underwater acoustic world.

Idling alongside one of the many islands, we are visited by gangs of Steller sea lions and an occasional California sea lion. Car-sized elephant seals bask on the few pockets of gravel found in isolated coves, harbour seals bob out of the water and in each kelp bed sea otters drift on their backs. The air is filled with calls – shrieks, groans, barks, chirps, whistles. One large flock of rhinoceros auklets begins to dive, forcing the schools of silvery sand lance to the surface. Hundreds of other birds swoop towards this new activity. The water is soon black with acres of surf scoters and more keep coming in to feed. There is life simply everywhere.

The connections between the ocean and rainforest along this coast are so complete that often it seems there is no differentiation between them. The rivers are constantly fuelling estuaries with nutrients and the cold-water upwelling brings an ocean of life to the intertidal zone; even the ocean air is saturated with marine nitrogen that feeds the forest itself. Bears and wolves, whales and salmon – and countless species

Estuaries such as this one on the Ecstall River provide critical shelter and food for countless aquatic and terrestrial species. Birds, juvenile salmon and ungulates rely on this vital habitat, and small insects complete much of their life cycle in the estuary environment.

in between – all depend on this terrestrial–marine interface.

Thomas Peschak, a colleague with the Save Our Seas Foundation and an underwater photographer from South Africa, and I are getting our gear ready: scuba tanks are filled, camera housings and strobes are checked. Max Bakken, a mariner with Pacific Wild, steers us to an underwater pinnacle that rises almost to the surface, one of many underwater features we plan to explore while the weather holds. The anticipation of a new dive location never changes as we suit up and get ready to drop over the side.

Underwater in the Great Bear Rainforest the reef diversity changes abruptly, unlike anything on land. British Columbia has approximately 7,000 known marine species, a number that could double if we started looking seriously. The lion's share of these, about 95%, are invertebrates, including 68 species of sea stars, 75 species of sea anemones, nearly 500 species of polychaete sea worms and more than 100 species of nudibranchs, a type of mollusc. The number of the much more celebrated vertebrate species of marine mammals, birds and fish hasn't yet topped 600. Going slowly and focusing on this smaller world under water, I'm reminded of how globally exceptional the diversity of our marine environment is.

The steep rock face has a dusting of feather stars and a few rock scallops, and a resident candy-striped shrimp scampers about in the embrace of a crimson anemone as a lumbering, teacup-sized orange nudibranch forages on soft purple coral. Off to the side, a great school of quillback and grey-black rockfish swim uphill against the surge.

The substrate of broken shells in the underwater alcoves is marked by occasional orange sea pens and long strands of frondless bull kelp, weather-beaten remnants of the vast fields that occupied this exposed reef only weeks ago, before the first storms uprooted the poorly anchored ones. Now the reef is covered with hooded nudibranchs, translucent predatory sea slugs that I can watch for hours. They are beautiful and graceful as their bodies wave back and forth while their rows of stout, paddle-like feet propel them. They open half their bodies up like a sail to catch tiny unsuspecting prey as it passes by, like an aquatic Venus flytrap. Fields of them make a heavenly backdrop. Further along, massive waves of opossum shrimp ride the current and surge, sometimes so thick they black out the light from above.

Move another 20 metres (65 feet) on the horizontal plane and the scene changes again. The same is true for the vertical plane: drop through a succession of atmospheres – and darker, colder water – and an incalculable new set of species, life cycles and evolutionary adaptations present themselves. Forty metres (130 feet) or so below, conventional scuba equipment reaches its limit. Below this dark frontier, undiscovered species lie waiting in the vast abyss.

Later in the day, after three separate dives, Thomas, my team and I sail further west. As far as five kilometres (three miles) away we can hear above the ocean surf the deep roar of a thousand Steller sea lions barricading the verdant slopes of honeycombed nesting burrows that rise into the clouds above one of the islands. I look at Thomas. We are both

Two sub-adult grizzly siblings play along a coastal estuary. These bears have just left their mother after having spent the first three years of their lives as part of a close-knit family.

This wolf belongs to a genetically unique coastal population of wolves referred to as 'sea wolves', and this pup has their characteristic ochre-coloured highlights.

Artwork by Roy Henry Vickers

contemplating all that we have just observed on the dives. Thomas has dived professionally for *National Geographic* in most of the world's remote oceans. 'The best of the best, my friend,' he says. I couldn't agree more.

As the longer days of spring loosen winter's grip, the people of Bella Bella, Klemtu, Gitxaala and other traditional herring-spawning territories on the north coast focus on what locals call 'herring weather'. The great diversity and plethora of wildlife in Great Bear is mirrored by the richness of its people, with whom we have worked closely. There are a dozen different First Nation groups along the Great Bear and each one has diverse and unique environments in their traditional territories. The Heiltsuk Nation is fortunate to have some of the most productive herring spawning grounds in its territory and has been at the forefront of the conservation battles to protect this endangered foundation fish species.

The tides, bird and mammal life, and air and water temperature indicate much about when the herring spawn will begin. People here follow the lunar cycle closely, and in Heiltsuk culture 'when the moon tips over' marks the beginning of one of the greatest and rarely observed natural events on the planet. This seasonal spawning event is so important, so vital and culturally revered, it signals the beginning of the traditional Heiltsuk New Year.

The connection between herring and people here is older than the cedar trees; historically, herring may have been relied on more than salmon as a food source. Herring bones 6,000 years old were unearthed from a recent shoreline archaeological dig at Hakai Passage. Not long ago, researchers from Vancouver's Simon Fraser University looked at 435,777 bone samples collected from 171 First Nation archaeological sites from Washington to Alaska – including 34 British Columbia locations – and found that herring was the dominant fish species throughout the Holocene.

Most fisheries on this coast have modern equipment: monofilament lines and nets, hydraulic winches, digital sounders. There are few, if any, places that fish can escape us and our efficient, technology-driven fisheries. But one fishery remains elegant and traditional: the spawn-on-kelp, or SOK fishery. Yes, canoes have been replaced by flat-bottomed, aluminium herring punts, but in all other aspects this traditional herring-spawn fishery has operated in the exact same way for millennia.

Before the spawn, fishers harvest hemlock boughs from protected groves and kelp fronds and *yaga* – stringy seaweed – from the more exposed outer coastal beds. In the quiet coves and channels of the traditional spawning areas the branches or seaweed are suspended from floating logs anchored to rock. The reason the herring choose these particular sites to spawn is known only to the herring themselves. First Nation families often choose multiple spawning locations to increase their odds of intercepting the spawn with their newly formed hanging gardens. The spawn is a valued resource and not all First Nation territories have such widespread herring-spawning grounds as the Heiltsuk.

Soon after the herring schools move inshore and the ocean turns milky with milt and sperm, the females discharge their eggs, 20,000 per fish. Eventually six million eggs per square metre (about half a million eggs per square foot) will float with the tide, waiting to rest on seaweed, rock or other substrate material. One out of every ten thousand eggs will produce an adult. With luck, the logs begin to dip under the weight of multiple layers of tiny eggs building up on the hanging garden below.

It is one of those calm mornings in early spring when fog hangs over the coast. The water in Seaforth Channel is covered in a thin layer of bubbles as the herring rise from the depths and expel air from their bladders. These curtains of bubbles are thought to confuse predators. As each herring expels air, a small acoustic blip can be heard like hard rain hitting the water. The late Heiltsuk elder Ed Martin told me that hunters used to carry small round pebbles in their canoes and gently toss them into the water to mimic the sound of herring; sea lions, dolphins and other prey would come inshore attracted to the familiar sound.

Thousands of surf scoters rafted in large black mats are bobbing on the water's surface, the current, wind and tide ensuring they are never in one spot for long. The males have large, distinctive bills – bright orange and white with a black gonydeal spot. They are breathtaking when they take off and gather momentum; like a wave gathering speed, the air is soon filled with the harmonic whistling of thousands of beating wings.

In a nearby cove a Heiltsuk family is leaning over the side of their herring punt, inspecting their lines. More boats are spread out along Spiller Channel. These boats travel slowly, keeping as quiet as possible. There is a dignified calmness on the herring grounds. People whisper. A paddle dropped in a boat can be loud enough to spook herring back down to the depths and ruin a potential spawn.

Generally the herring remain deep down in the daytime unless they start spawning. Today, though, the shoreline is revolving with rising schools. When caught in a seine net these fish are so powerful that, working together, they can pull a 25-metre (80-foot) commercial boat over.

I make my way over to three younger fishers who are out: William Housty, Jordan Wilson and Ian Reid. I watch as they methodically pull up hemlock branches, leaning far over the water. Each branch could weigh 45 kilograms (100 pounds), and they pull them into the punt deftly. Ian pauses for a bit and looks up at the beach. A wolf is walking along the point, one of the pack that has been feasting on the eggs this past week. He smiles. 'All these worlds trying to get by in amongst ours,' he says and continues to pull up the branches and eggs like his ancestors did before him.

Sea wolves, like this pup, were fortunate to avoid the persecution suffered by their continental kin. It is estimated that more than a million wolves were slaughtered in North America during the 1800s.

Coastal temperate rainforest historically occupied less than 0.2% of the earth's land mass and today most of what is left intact is found throughout the Great Bear Rainforest. Until there is a legislated ban on tankers in the Great Bear, the future of this coastal paradise remains uncertain.

The monarch of the rainforest, the grizzly bear in British Columbia continues to be hunted for sport and trophy – even in parks and protected areas. The British Columbia government also currently allows resident licensed hunters to kill wolves in the Great Bear Rainforest, with no special permit necessary.

After the polar bear, the grizzly is the second-slowest reproducing land mammal in North America. This is one of the reasons that grizzly mothers are so protective of their cubs, and why habitat loss and human-caused killing have led to the extirpation of the species from large parts of North America.

Jordan says the roe taste sweet and spicy. I eat a chunk of rich and fatty eggs that have fallen off the thick clumps now piled a metre (three feet) high on a blue tarp in the boat. Deep inside the catacomb of eggs I taste hemlock needles. It is the ocean and rainforest in one bite. At first the eggs taste almost acidic or bitter, but then the after-bite kicks in and spicy sweetness emerges. They are almost fruity. The eggs are a delicacy as fine as anything I have ever tried from the ocean.

On shore the intertidal rockweed is exposed and covered with kilometres of shorebirds: black turnstones, spotted sandpipers, surfbirds. Chatting, chirping and low rattling and rasping sounds fill the air as they devour the herring eggs attached to the rockweed. They know the tide is rising and they have only a couple of hours to feed. Well over a thousand eagles can be seen from any vantage point, and there are countless gulls, grebes, loons, ducks, oystercatchers, terns, murrelets, murres, brants, herons, scaups and others – this avian drama is spectacular. For many of these birds this nutritious, predictable and easily accessible food source may mean the difference between nesting success and death, located as it is midway on their 10,000-kilometre (6,000-mile) – or more – migration from their wintering grounds of Mexico and Central America to the open Arctic.

Finally the chatter fades as the birds go off to rest on various islets and in quiet coves, waiting for the next tide. Then the next major event unfolds as the surf scoters come inshore. These black birds with their red, webbed feet can't go ashore, so they wait for high tide to dive for eggs, preferring the ones attached to eelgrass. I put on my dry suit and underwater gear, dive down about half a kilometre (600 yards) away from them and slowly swim and drift with the current.

Schools of herring flash silver in the milky distance as I settle in about 10 metres (30 feet) of water. Soon the light dims as thousands of surf scoters begin paddling above me. I hold my breath, trying not to laugh at the comical sight. Soon birds are diving down all around me, lunging into the flowing eelgrass headfirst and, with a fast beat of their wings, propelling themselves back toward the surface, long fluorescent-green, egg-encrusted strands of eelgrass trailing in their beaks. They pull the delicate strands of eelgrass off the bottom easily, and it probably digests easily too. Errant strands float gently back down to the ocean bottom. The sheer number of diving birds reduces the sight to bubbles, floating eelgrass and guano, and the flash of black feathers, orange-red feet and bills.

Out of the water, on the next low tide I see a flock of shorebirds lift off suddenly. A pack of six wolves appears from the rainforest edge. They move to the shoreline and with heads down quickly begin to gorge on the herring eggs. Their intensity is born from a long winter in which food is harder to come by. A harbour seal rises through the milt with its face covered in sticky eggs. A mother orca and calf swim through soon afterwards, their backs and dorsal fins covered with a translucent sheen – to be encased in herring eggs must be comforting. For five years in a row the same black bear has shown up along this stretch of spawning ground to eat eggs. Apart from salmon season, this is the only time that wolves and bears predictably show up along the shoreline.

The Great Bear Rainforest and all that it represents is one of our planet's greatest hopes to protect a globally significant coastal wilderness while respecting the indigenous rights and culture of people who have called this place home for more than 10,000 years. But this opportunity is closing quickly, unless a concerted effort is made to reverse the industrial proposals that are lining up to transform this coastal paradise. Unsustainable fishing practices are causing the decline of foundation species such as herring and salmon. Deforestation of an irreplaceable rainforest continues to impact fish and wildlife. Energy proposals, if approved, would facilitate pipelines through the rainforest and oil tankers in our pristine waters to transport oil and gas from the interior of Canada through the Great Bear to Asia. Everything is at stake here, from the headwaters of countless salmon spawning rivers spread across the world's largest intact temperate rainforest to the offshore reefs and deep blue water.

But this is also a coastline of hope because of the passion and determination of British Columbians to protect it. First Nations also continue to choose the environment over promises of short-term wealth offered by the proponents of pipelines and other industrial projects. Most of the hope lies in the fact that this is not a coast that tells the story of loss and what once was. The ecological structure and the species diversity are still here and our job is relatively simple and cost effective: we only have to protect them. We are not in the unenviable and nearly impossible position of having to bring back species and ecosystem function that have been lost. Canada has the longest coastline in the world and has protected less than 1% of our jurisdictional waters. There is plenty of work ahead, but the conservation opportunities for this coast are immense.

Artwork by Roy Henry Vickers

SPIRIT BEAR

Before long a large, brown-faced black bear emerges from the forest edge and ambles straight for the fishing spot. By the end of the day I have counted 19 individual bears. Through daily observation over the week I will count 27 in total, more than a third of them in family units, congregating at various times within 50 metres (55 yards) of this one fishing spot. Three of them are pure white.

One of the most striking examples of polymorphism in the animal world, the spirit bear – or Kermode bear *Ursus americanus kermodei*, named after the museum curator Francis Kermode – is not an albino bear but a genetically distinct, pure-white black bear produced by a recessive gene. These bears offer a fascinating entry to the study of population and quantitative genetics, and the obvious question is: why white? What possible evolutionary advantage would there be to turning white from black in a dark, shadowy rainforest environment?

According to Dr Tom Reimchen from the University of Victoria, these coastal bears diverged from their interior relatives about 360,000 years ago, probably during an ice-free refugium predating the Wisconsin glaciation about 100,000 years ago. So perhaps when the coast was dominated by snow and ice these bears evolved a colour more suited to their environment.

However, another University of Victoria researcher, Dan Klinka, looked at an alternative possibility: that these bears' colour relates to their main food source, salmon. After three seasons of research, Dan was seeing a pattern emerge: white bears were at a distinct advantage in fishing for salmon during daylight and crepuscular hours. By analysing marine-based nitrogen in hair samples at the end of a salmon season, Dan discovered that white bears appear to consume more salmon over more days than black bears do. Salmon are so important to this coast they may actually have changed the colour of a bear.

During the past 300 years, human beings have reduced global grey wolf populations by 80%, and the wolf's former range has decreased by 40%. Yet hunting, trapping and government-sponsored kill programmes continue.

Sea wolves live almost exclusively on deer and what the ocean provides, unlike wolves closer to the mainland, which have access to mountain goats, moose and beaver.

These wolves are foraging for herring eggs that are found at low tide in the spring. After the herring season, they will hunt seals and sea lions, fish for salmon and search the shoreline for beached whales and other marine mammals.

'Playtime' is a ritual that helps to establish the social hierarchy on which wolf families are structured. Unfortunately, few protected areas are large enough to fully protect a wolf pack's large home range and sustain the species over time. Promoting large-scale habitat protection, sustainable fisheries and community stewardship projects will safeguard the Great Bear Rainforest and its wildlife for future generations.

GOING IN FOR THE KILL

Like First Nations on this coast, herring have had a troubled relationship with the colonial powers of the past hundred years. The herring have experienced one of the least publicised – yet tragic and unforgivable – examples of government mismanagement of a Pacific coast foundation species.

It's difficult to understand the Department of Fisheries and Oceans (DFO). Logic would suggest that the agency would support a community-based fishery that is infinitely more sustainable than current 'kill fisheries', as they are known, that scoop up thousands of tons of fish just to extract the roe; the rest of the fish ends up as fish meal, cat food or bait. For a fish that can successfully spawn more than 10 times in its life, this is a barbaric end to future spawning options and a sure way to reduce genetic diversity.

The herring kill fishery is an industrial insult to one of the most sensitive and important species in the North Pacific. But this has been the story of overexploiting forage fish for a long time. Sardines were the first to go in the 1940s, and when the nets turned toward herring it took only 20 years for that fishery to collapse too. As soon as the stocks begin to recover, the DFO opens the fishery again. The agency in charge of fisheries management in Canada rarely closes a fishery until the biological extinction of a stock or a species is well under way.

With the herring fishery shut down in Heiltsuk territory, it is blessedly quiet compared to years past, when the arriving seine fleet would also bring Royal Canadian Mounted Police boats to keep the peace between local Heiltsuk protesters and the kill fishers. Perhaps because of this reprieve the stocks are now showing a glimmer of recovery, or at least better returns since the closure.

Photo by Janie Wray

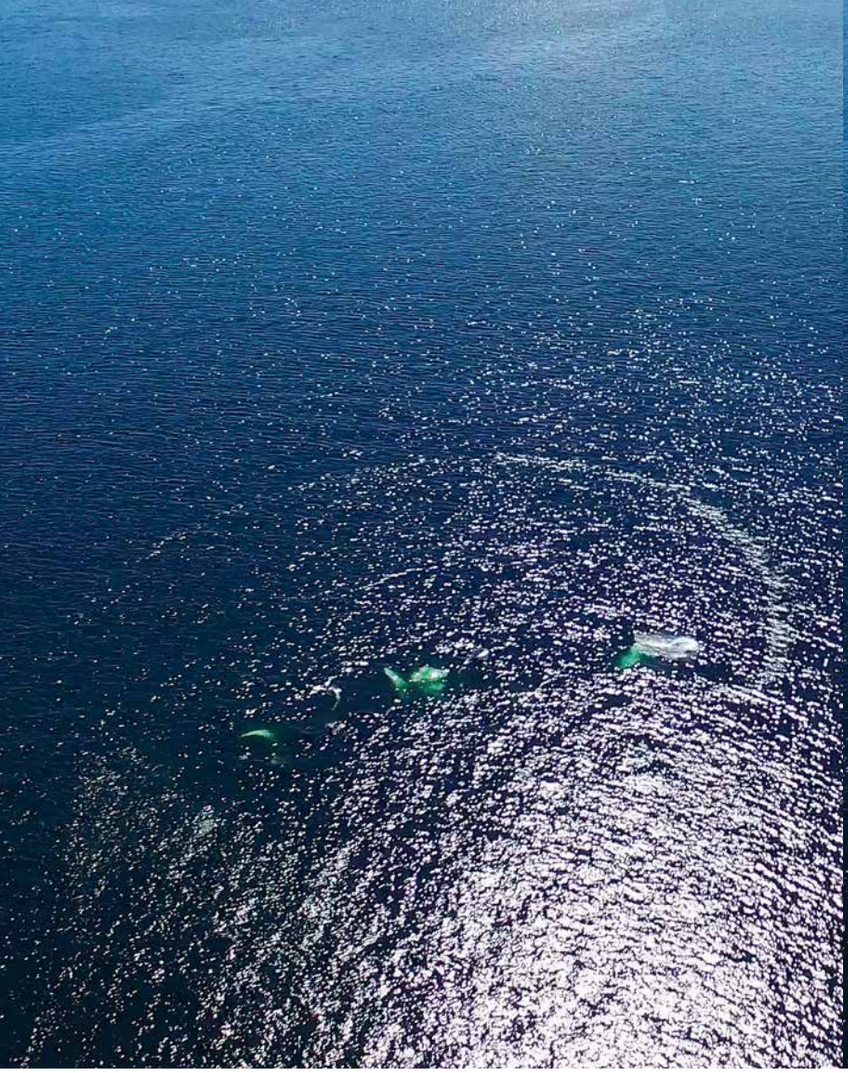
of the

Words by Janie Wray

More than a decade of surveying the whale populations of British Columbia's northern coast has given Janie Wray a deep appreciation of the Great Whale Sea – and brought not a few surprises!

A female orca travels towards the stern of our boat. At the moment before she surfaces, the water acts as a perfect lens, giving us the opportunity to make eye contact with this highly intelligent creature of the sea.

Photo by Janie Wray



Photos by Michael Scholl

It was late summer in 2001 when Hermann and I travelled north along the Inside Passage of British Columbia, Canada, in our small, wooden, live-aboard boat *Karmus*. Our destination was Hartley Bay, a First Nation village on the province's picturesque north coast, for a meeting with the hereditary chief Johnny Clifton and his wife Helen. We were going to ask for permission to build a land-based whale research station in Gitga'at territory.

The farther north we travelled, the more we felt as though we were going back in time. Giant cedar trees stood tall, their roots embedded in the rocky, barnacle-covered shoreline. Thick branches covered in giant bundles of green moss and lichen bent towards the water's edge and were reflected in the calm, emerald sea. The midday heat might have tempted us to dive into this clear green water, but common sense prevailed; just dipping a foot into it would have sent shivers up our spines. At temperatures ranging from nine to 13 degrees, the water is extremely cold – cold enough to cause hypothermia in just 30 minutes.

Many of the marine passages along this coast are fjords, carved out by glaciers long ago. For this reason, the depth of the water increases sharply just metres from the shoreline. On some days the water is so clear you can see all the marine life up to 10 metres (30 feet) down. Hundreds of bright purple and orange starfish cling to the underwater cliffs, surrounded by deep red sea urchins, white and green sea anemones and clusters of pink coral. The water bubbles along these shores with thousands of forage fish swimming through forests of golden bull kelp. Seals and sea lions are plentiful, basking in the sun on rock haul-outs or showing off their acrobatic skills underwater. In winter this area is known for fierce outflow winds that are so cold they can freeze the rain along the side of your boat – a very dangerous situation! When these winds subside, a south-easterly sometimes moves in at storm to hurricane force. During the summer months, though, the waters can be as peaceful as a giant pond.

We were extremely fortunate and our meeting with Johnny and Helen went very well. They embraced our idea for a whale research centre in their territory and shared with us their traditional knowledge of the whales in the area. They suggested we build in Taylor Bight, along the southern end of Gil Island. The next step – trying to raise funding to build in such a remote area – was a lot more difficult. There were no roads and no power. Everything would have to be brought in by boat and carried over a rocky shoreline, and we would need to generate our own power from water, wind and solar energy. Here you go back in time and every decision you make is ruled by weather, water and the need to be safe. We learned many lessons through trial and error, the most crucial of which was that nature decides who stays and who goes. We were fortunate that nature was on our side, and 15 years later we are still here on Whale Point.

Our initial goal with regard to research was to install hydrophones so that we could follow the underwater acoustic world of orcas and, with any luck, solve the mystery of their winter hangouts. Our research background is in orca dialects and how an acoustic tradition is passed on from the oldest female of a family to each new generation.

In our area, there are two populations of orcas: resident and transient. The main difference between the two is their diet. Resident orcas feed on salmon and their preferred species is the huge Chinook salmon, a fish that can weigh up to 18 kilograms (40 pounds) and has a higher fat content than other species. Transients, on the other hand, are the wolves of the sea, silently hunting marine mammals such as seals, sea lions, Dall's porpoises and even baleen whales. It is this behaviour that led them to being called 'killer whales'. After

years of studying orcas, Hermann and I have a hard time using the word 'killer' for them as they – or the residents at least – are in all honesty the most gentle creatures we have ever observed.

This particular population has taught us so much about community and family. A male resident orca will never leave his mother's side for more than a few hours, spending his days in her presence for his entire life. As a mother has more and more offspring and as her daughters have offspring of their own, she may well become a great-great-grandmother. At some point an older female may break away from her mother, taking with her the dialect of that matriline that has been passed down for generations. Matriline groups form a pod and every member of this pod will use the same call types, but with a slightly different dialect. A number of pods form a clan. There are three clans in the resident community we study, each with its own language. It is truly amazing that when these clans get together, they appear to understand one another. When this happens, the underwater world explodes with orca chatter from all the excitement of the grand reunion. Orcas appear to love company!

Transient orcas have a slightly different culture, due mainly to their diet preference: a transient will not eat a fish, and a resident will not eat a mammal. We think it may be for this reason that the two populations do not mix and avoid each other completely. When we approach a group of orcas and are unable to determine at first glance which population we are with, we only have to watch how other mammals react to them. If sea lions continue to travel or play or if Dall's porpoises approach the orcas, we know we are with residents. How these mammals know the difference we are not sure; a mistake would be deadly for them. If the porpoises take off or the sea lions freeze in the kelp or throw themselves onto a nearby rock, we can be sure we are with transients. There are slight physical differences too. The dorsal fin of a transient orca is more pointed than that of a resident, which has a rounded tip – a feature more noticeable in females than in males.

Of course, if we have a hydrophone and the whales are vocal, we will know for sure, as the call types of each population are very different. Transients often travel in silence so as not to alert prey to their presence. We sometimes see a pod of transient orcas travelling along the shoreline and then split into two groups that are about 300 metres apart. If some unsuspecting sea lions or Dall's porpoises happen to swim between these two groups, the transients will have the advantage of surprise. It is usually only after a kill, after having travelled for hours in complete silence, that transient orcas open up and become very vocal.

During our first years at Whale Point we spoke with many fishermen who had made a living in past decades on a surplus of the salmon that once thrived in these coastal inlets. 'Sure, we see lots of orcas in these waters from April to July,' they would say, 'but lately we have been seeing a much larger type of whale – a humpback – which we had not seen here in decades.' We too had noticed these baleen whales, whose large, heart-shaped blows are very different from the short, stocky blows of orcas. On the hydrophones we would suddenly hear strange 'grunt' calls followed by a deep howling that was almost wolf-like, but underwater. This foreign sound was new to both of us and instinctively we knew that something huge was happening. Then one evening, just after sunset, the most beautiful calls we had ever heard filled our cabin. They were followed by another long, deep call that brought my hand to my heart. It was a male humpback and he was singing his famous song right here along the north coast of British Columbia.

Between 1905 and 1967 humpback and fin whales were hunted to the brink of

Technological advances and the ability to observe humpback whales bubble-net feeding from an 'eagle's-eye' perspective will help us to understand this incredible feat of cooperation by so many individuals. This photograph shows 13 humpbacks feeding as a team. As they surface, you can see that each whale has a strategic place beside its neighbour.

Photo by Janie Wray

Humpback whale *Megaptera novaeangliae*. The '*Megaptera*' part of the humpback's scientific name means 'large-winged' and refers to its long, white, wing-like pectoral fins. When these whales breach, you can see why they are sometimes referred to as 'the white-winged angels of the sea'.

extinction off British Columbia's coast. By the time this commercial slaughter ended in 1968, only 10% of the populations had survived. We soon realised that our arrival at this rugged coastal rainforest had coincided with the return of the humpback and fin whales, and a gradual increase in their populations.

Pacific humpbacks spend the winter months in Hawaii or Mexico, where they give birth to calves. Food is scarce in these tropical waters and a female humpback depends on fat stored in her body for survival and to nurse her calf for the first few months of its life. All humpbacks then migrate back to the nutrient-rich northern locations to feed. We often wonder what this epic journey would be like for a first-time mother and how she survives such an ordeal. Imagine giving birth and then nursing this little whale, which doubles in size in just a few months. After all this, she has to travel 4,800 kilometres (3,000 miles) just to find food! Young whales, too, making this journey on their own for the first time, need to be truly fit. Humpback whales do not stay in family groups as orcas do. The mother–calf bond lasts a little longer than a year and then the young whale is left to its own devices. This gives a mother just one year to teach her calf everything it needs to know to live a long life.

In the ecosystem of the Great Whale Sea, which borders the Great Bear Rainforest, whales play a vital role, often bringing nutrients from the deep to the surface for a multitude of coastal companions such as sea lions, seals, Dall's porpoises and seabirds to feed on. Even whale scat is a food source! Here we witness many different types of whale feeding displays, but the most spectacular of all is bubble-net feeding. In well-organised groups as small as two or as large as 14, the humpbacks dive as a team under a huge ball of schooling fish or krill. From the deep they blow bubbles around the bait ball, forming a net that forces the fish to the surface. Part way to the surface, a few of the whales begin to vocalise, using what we call a 'northern feeding call' that drives the fish into an even tighter, more compact ball – perfect for the whales as they break the surface with mouths wide open. It is this feeding call that stimulates the work of our underwater hydrophones. When we hear it, without even leaving the lab we can document the behaviour of the whales, how long they feed and where they are.

Other types of feeding include lunge feeding, tail flicking and pectoral feeding. The whales are also known to feed at depth, but this is more difficult for us to confirm. Whatever the method, feeding lessons are passed on from mother to calf and will be the most important aspect of the youngster's ability to survive.

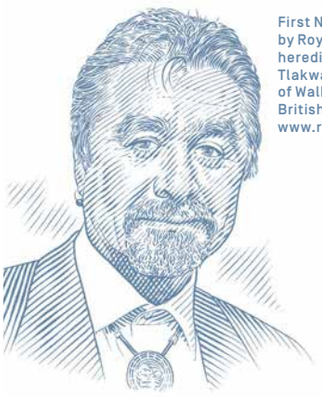
We have noticed in our particular area a huge increase in the number of mothers and that it is the females that seem to stay longest in our location. Our theory is that the females are the builders of humpback communities – their own version of a matriarchal society. We have not yet proven this, but our instinct and experience on the water suggest that it may well be the case. We have more than a decade's worth of data confirming that humpbacks have very strong bonds with each other. Like humans, they choose these bonds based on life experience and not necessarily on familial relationships.

In 2004 we began our marine surveys in a small 15-foot skiff with an unreliable outboard, which is why most of our survey routes were very close to home. Fortunately, location really is everything and many whales would come to us, attracted by the rich bounty of salmon, forage fish and krill. To identify individual whales, we photographed the giant tail flukes of the humpbacks and the dorsal fins and saddle patches of the orcas. Within a few years it became quite clear that we were in whale territory, with a community of three distinct resident orca clans and a growing population of humpbacks. By the end of 2004 we had catalogued 42 individual humpback whales. By 2006 this number had doubled and by the end of 2014 it was well past the 400 mark.

In 2006 we were in for an even bigger surprise. At that stage of our project

A young female transient orca learns to hunt with her family as they pursue a group of Dall's porpoises. They work like a pack of wolves during a chase, where position and speed are essential for success.

Photo by Jenn Dickie



First Nations artwork by Roy Henry Vickers, hereditary chieftain, Tlakwagila from the House of Walkus in Owikeeno, British Columbia. www.royhenryvickers.com

all our lab equipment was right in our cabin, hidden among trees. We ate, slept and lived for the moment a whale would arrive. When we saw or heard a whale, one of us would run to the lookout to get photographs while the other remained in the cabin to record any calls.

On one particular day it was our dog Neekas that drew our attention to the fact that there was a whale close by. Her hearing is much better than ours and often she would hear blows or even calls and let us know with an excited bark as she ran to the door. On this day we knew something was different. Hermann ran outside as I pressed record and waited for a call. Hearing him yell, I decided that sitting inside was out of the question, so out the door I went – just in time to see a very large whale actually porpoising through Taylor Bight!

It was a fin whale, with a small calf by her side trying to keep up, and they were being chased by five transient orcas. Fin whales are the fastest baleen whales, and now I understand why. Their bodies can be 18–21 metres (60–70 feet) long, but as well as being long they are slender, perfectly shaped to move at great speed if necessary – and now it was definitely necessary! So, not only was this the first time fin whales had been documented in these waters for close to half a century, but they were also being chased by killer whales! The transients soon gave up the hunt; perhaps it was just a test. The mother and calf were already at Ashdown Island and then gone. It was only then that I realised I had been holding my breath, and slowly I let it go.

Between 2006 and 2008 we had a few more fin whale sightings. Then in the following years the fin population in these fjords took a huge leap, just as the humpback population had done. We photographed each individual fin whale as it arrived in the area and started an identification catalogue. A population of five has now grown to 40 resident fin whales that share these marine channels with orcas and humpbacks.

The relationship between the three species is a perfect example of how, with unspoken cooperation, a food source and habitat can be shared. There are many days when we see humpback and fin whales spread out, foraging in the nutrient-rich waters of Squally Channel. Fins and humpbacks feed on the same prey and often it is hard to tell which species is feeding with which. The most surprising sight has been watching young fin whales join a group of resident orcas. You will remember that transient orcas will hunt fins if the opportunity presents itself. We wonder if the fins join resident orcas and travel with them, knowing they are safe from attack by transients while surrounded by a different kind of orca.

Now, in 2015, we look back at the decade we have spent where the Great Bear Rainforest meets the Great Whale Sea and recognise that no matter where you are, change will come. Our relationship with the Hartley Bay community has strengthened over the years. Hermann has been adopted into the Raven Clan, and I into the Killer Whale Clan. This is one of the highest honours that can be bestowed in Gitga'at culture. Johnny has since passed away, a great loss to the community and this region. When his wife Helen visited us recently her words were perhaps the greatest gift of all. She looked at us both and said 'Johnny would be so proud. You have helped this community to remember the ways of the whale and how as a people we are bonded to the blackfish.'

We have also developed a strong working relationship with the conservation group Pacific Wild, which does amazing work. It and the supportive Save Our Seas Foundation share our vision to protect this majestic coast and all its inhabitants. Here, you watch bears and wolves feeding on the salmon that will travel upstream one last time; listen to eagles and ravens calling while perched high in an ancient forest; and look outward to where whales gather to forage and sing in a quiet ocean. There is truly no other place like this on earth.

Artwork by Roy Henry Vickers

The tail of a humpback whale is as unique as our own fingerprints. By comparing patterns and the trailing edge of the tail, we can identify individual humpback whales in the area.

Photo by Janie Wray

Humpback whales bubble-net feed in groups of two up to 20. They work as a team, diving below a ball of small, schooling fish. Then they begin spiralling while blowing bubbles that form a net; as the bubbles rise, the net forces the fish upward. Massive gaping mouths then break the surface as the whales feed, side by side.

Photo by Janie Wray

As the summer comes to an end, we see more and more calf acrobatics such as multiple breaches – up to 30 times in one encounter! This may indicate to the mother that her calf is healthy and ready for the long migration south and starting a life on its own.

Photo by Jenn Dickie

Resident orcas will spend their entire lives in the vicinity of their mother. Since these families are so close, a shared dialect unique to each pod is passed on from one generation to the next.


Photo by Jeff Dickey

Photo by Thomas Peschak

The fin whale is the second largest mammal on the planet, after the blue whale. Long and sleek, it is able to travel at great speeds. The species' recent return to the Great Bear coast after decades of industrial whaling in the 20th century is an indication of the diversity of this nutrient-rich ecosystem.

Artwork by Roy Henry Vickers


Roy H. Vickers

SCIENCE WITH THE GIANTS

Ningaloo Reef on the north-western coast of Australia is one of the few coastal locations where whale sharks gather seasonally. Tourists and researchers come too to see and study these massive fish.

Photo by Ed Cardwell | Migration Media

As creatures of the open ocean, whale sharks give biologists little opportunity for research. They do aggregate at certain coastal locations, though, and at Australia's Ningaloo Reef Lara Marcus Zamora is helping to solve some of the mysteries surrounding them.

Words by Lara Marcus Zamora

The whale shark is the biggest fish in the world. Its massive size (a large specimen can reach up to 18 metres long) and harmless disposition have fascinated us since the species was first discovered off the coast of South Africa in 1828 – and these two attributes have led to its popular tag of 'gentle giant of the ocean'.

Mystery still surrounds this free-ranging animal that spends most of its time in open waters and out of our reach; studying it is not without its challenges! Luckily for us, though, whale sharks appear out of the blue every year and aggregate for several months at different coastal locations around the world, including Belize, Mexico, Australia, Philippines, Mozambique and the Red Sea. These seasonal gatherings are our only opportunity to approach the giants and learn more about them. My story with whale sharks started 10 years ago in the Seychelles where, in the waters of the Western Indian Ocean, I first encountered this unique creature. Swimming with a whale shark is a magical experience that no-one can ever forget, and from that very first moment the species has captivated me. With the encounter still fresh in my memory, years later I dedicated my PhD research to helping to unravel the mysteries of this giant. My main goal was to contribute any useful knowledge that I gained during my years as a PhD student to the effective conservation of whale sharks. Where do they come from? What do they eat? Why do they aggregate?

Ningaloo Reef on the north-western coast of Australia is one of the special places where whale sharks gather every year between March and July. It is characterised by two notable features: slopes that fall abruptly into the depths and a system of currents that makes the area very productive. Extending 260 kilometres along the coast, Ningaloo is the largest fringing reef in Australia and hosts a wide range of marine life, from reef fishes of all shapes and colours to mega-fauna such as turtles, manta rays, sharks and occasionally whales. Inland, Australia's red desert, with its endemic species and jumping kangaroos, stretches to the horizon and far beyond. In this scenario the reef is the main attraction and diving, snorkelling and fishing are the most popular activities, bringing national and international tourists to the area all year round. A prosperous and well-regulated ecotourism industry has developed around whale sharks at Ningaloo, generating a yearly revenue of about A$4-million (in 2006) that helps to support the local community.

Ecotourism operators have been working on Ningaloo Reef for several decades and provide researchers with first-hand information about the comings and goings of its marine inhabitants. From them we have learnt that whale sharks are no longer as gigantic as they used to be, and there are fewer of them too. These observations have raised some alarm in the scientific community, as shrinking size and decreasing numbers could well be signs that the species is being over-exploited.

Although the whale shark is protected in many countries, including Australia, and is classified as Vulnerable on the IUCN Red List of Threatened Species™, it is still hunted for food in South-East Asia, its white meat prized as a delicacy in Taiwan and its fins as an ingredient in soup by the Chinese. Its long life span – approximately 150 years – and low reproductive rate make it especially vulnerable to exploitation. The Ningaloo Reef population of this highly migratory species is very likely to be shared with some Asian countries, where strong regulations to protect the whale shark are not yet in place.

For the past 10 years Dr Mark Meekan, a shark expert at the Australian Institute of Marine Science, has led expeditions to Ningaloo Reef that have been a source of invaluable information about the numbers and structure of whale shark populations. Many scientists and students from different academic areas have participated in these field trips and for the past three years I have been one of them. Our field base is located in a remote area with expansive views over the ocean. An aluminium shed, struck by cyclones on several different occasions, serves as laboratory, living area and kitchen, and bats, birds and the usual snakes are our roommates. There are no luxuries there, but at day's end the outstanding background of Ningaloo's sunsets makes you forget about fresh water and a comfortable bed.

The spot and line patterns of a whale shark are easy to recognise from above, so we use a small plane in conjunction with a boat when we go out looking for our target animals. When a whale shark has been located by the team in the plane, for those aboard the boat it's a time of excitement and nerves. Once in the water, we try to disturb the whale shark as little as possible, but there are many tasks to be completed. We photograph each animal for identification purposes and record its sex, size and any distinct markings that will also help to distinguish it. In this way, we have been able to recognise the same sharks year after year, including 'Stumpy', an old acquaintance of ours that has been sighted on and off since 1989!

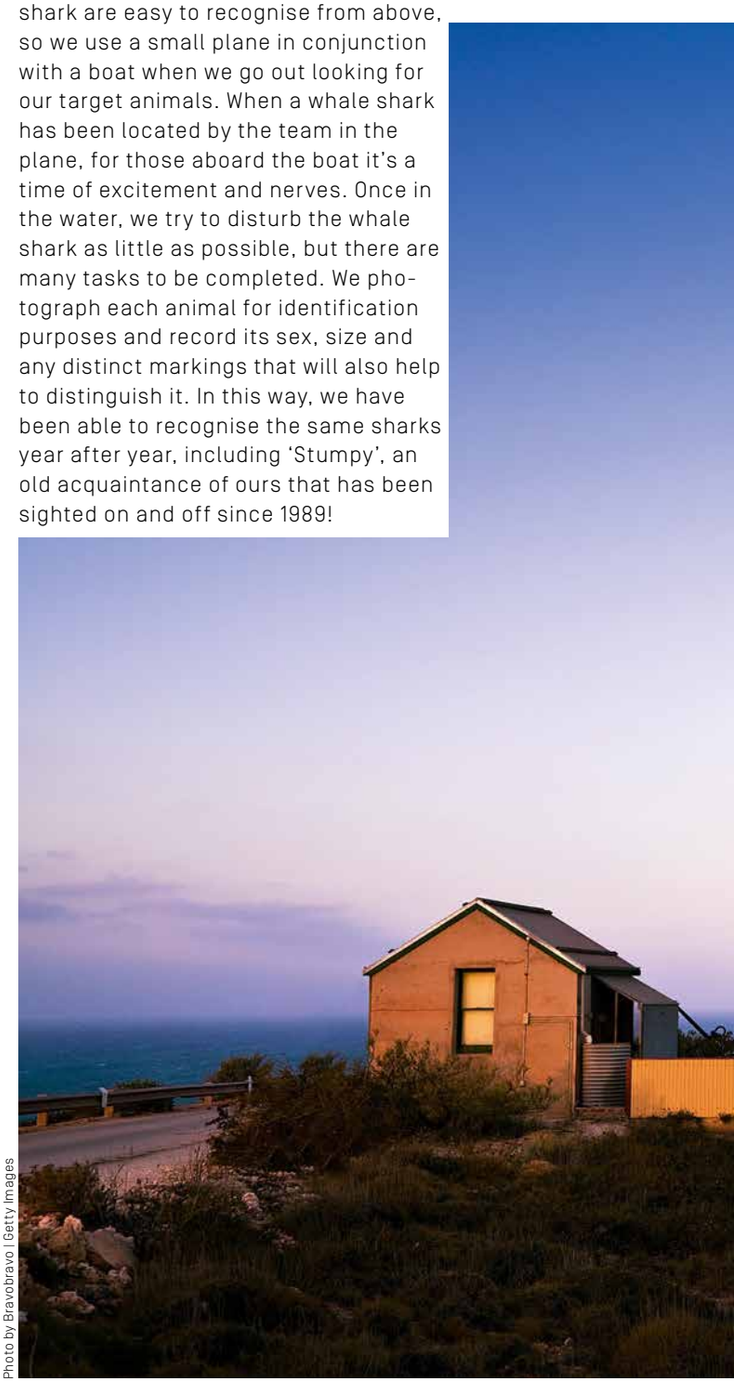


Photo by Bravobravo | Getty Images

From the data gathered over all those years we have learnt that the number of whale sharks visiting Ningaloo is between 200 and 500, and that most of them are males and immature (3–8 metres long). On average we encounter four or five individuals per day, with a record tally of more than 20 in a single day.

Interestingly, sightings of whale sharks less than three metres long or of females are scarce at the reef, as is the case for most of the aggregations in the Indian Ocean. So where are the whale shark females and pups? It is believed that nursery grounds, where the females give birth and the young spend the first few years of their life, may be found in the open ocean. When whale sharks are born, they are no bigger than 50 centimetres, which makes them vulnerable to all kinds of predators. So staying in open waters until they are bigger and stronger seems like a very smart way to avoid the sharks and other possible predators that frequent coastal areas.

Whale sharks are not sexually mature until they reach seven to eight metres, so our contact with the species at Ningaloo is mostly with 'teenage' males. From a conservation point of view, it is important to obtain information about their likes and dislikes and where on the reef they spend most of their time, as these animals constitute the younger generation. Specifically, I am looking at their diet, which will drive their movement patterns.

In order to find out what whale sharks are eating and where they are feeding, we look at the animal itself. Surprisingly, a small piece of it, in this case a skin biopsy, can tell us a lot of things. We base our research on the principle 'you are what you eat', a concept that has been used repeatedly in the past and stems from the fact that every time you eat something, the food leaves chemical traces (such as lipids) in your tissue. By looking at these traces in the skin tissue of a whale shark, we can track down the food source.

A whale shark biopsy is a piece of connective tissue no more than two centimetres long that is taken from the skin. To get a sample, an experienced free-diver swims with the animal and, using a modified spear gun, takes the biopsy. Many dietary studies require that the animal dies so that researchers can examine the contents of its stomach or sample other organs. Our method is less invasive while still providing very useful information, an important consideration when studying threatened species such as the whale shark, as we don't want to kill or harm any individuals. Over the years, we have been building up a significant collection of biopsies by this method and they are now producing some interesting results.

We are noticing that groups of whale sharks showing different diets visit Ningaloo Reef each year, which makes us think they come from different locations. It is likely that these findings reflect the different migratory routes – and different prey – taken by the whale sharks that come to the reef. When our results are coupled with tag data, this idea seems increasingly probable, as there is evidence that some Ningaloo whale sharks travel as far as South-East Asia, for example to the Timor Sea and Indonesia, whereas others prefer to stay around the Australian coast. We like to think of Ningaloo being a whale shark 'meeting point', although we don't yet know why they aggregate here.

Whale sharks are widely known to be pelagic filter feeders as they have often been observed in surface waters feeding on red crab larvae at Christmas Island in the Indian Ocean, fish spawn on Belize's reefs or tuna eggs in the Red Sea. For many years local fishermen at Ningaloo have seen them feeding in a similar fashion on swarms of krill. This leads us to believe that these tiny shrimps are the main reason that whale sharks approach the coast of Australia. However, even our earliest findings indicate that whale sharks are not just pelagic filter feeders and that their diet is far more complex than we previously thought. It seems that they also feed on prey that lives in deeper waters, such as mysids, fish and zooplankton.

We are at a very exciting stage in whale shark research, as more and more effort is going into it. We hope to gain a better understanding of the species' diet, which in turn will give us insight into why it forms aggregations. From the little that we know so far, it appears that whale sharks tend to approach coastal areas as they grow, and sometimes undertake long migrations between aggregations. Movements such as these could make them vulnerable to exploitation, as they are likely to cross into national territories where they are not protected. If that is the case, the negative effects of whale shark fishing thousands of kilometres from Australia may be reflected in Ningaloo's population. In this context, it is essential that countries with whale sharks in their coastal waters cooperate to develop adequate conservation programmes.

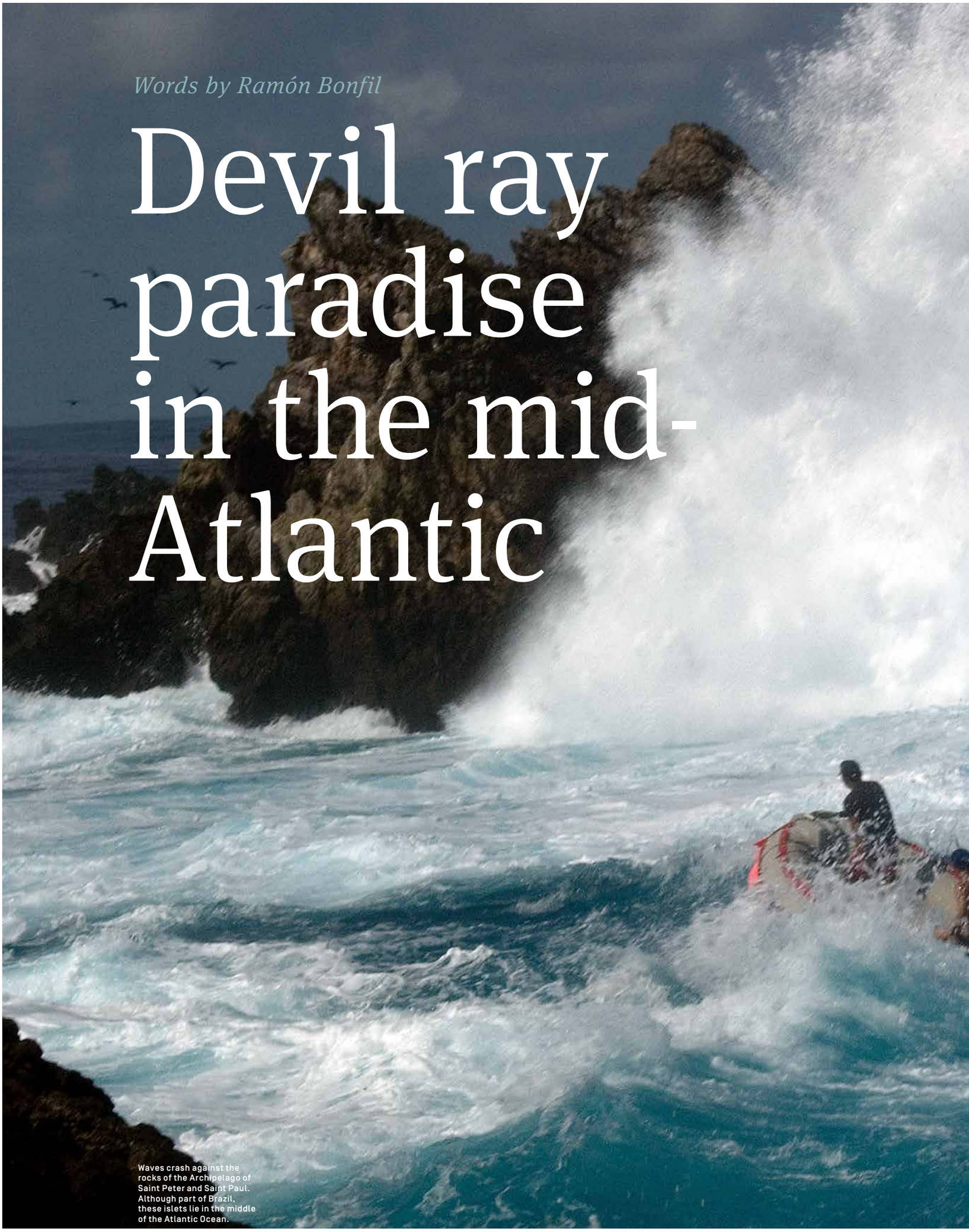
At Ningaloo Reef and many other places around the world it has been shown that an ecotourism industry based on whale sharks can be very lucrative, bringing in good revenue for local communities as well as being beneficial to whale shark research. We still have a long way to go, but step by step we will unravel the mysteries of these giants.

Vlamingh Head Lighthouse sits atop a hill on the Exmouth Peninsula in Australia, overlooking Ningaloo Reef.

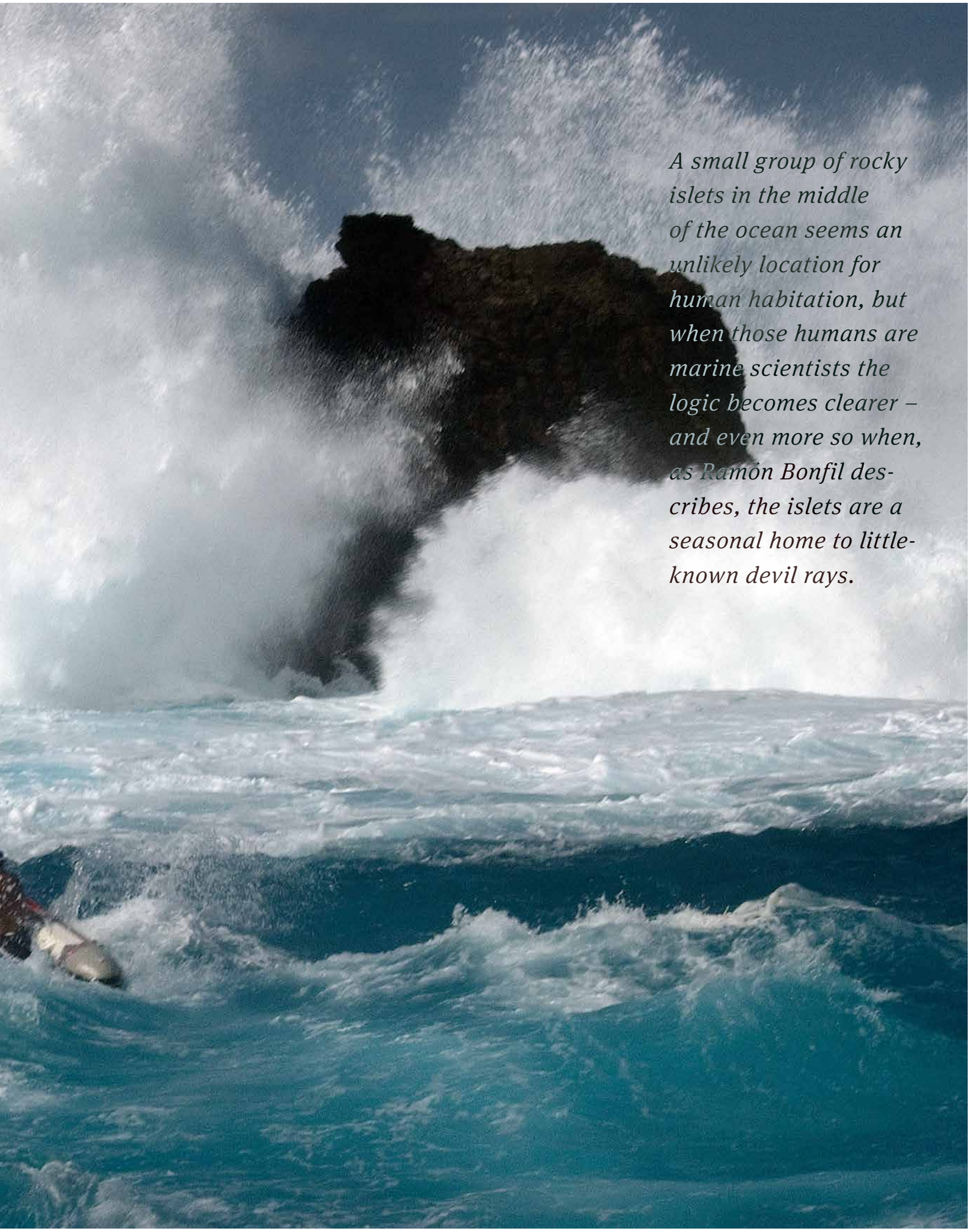
Photo by Andre Seale | ArteSub

Words by Ramón Bonfil

Devil ray paradise in the mid-Atlantic



Waves crash against the rocks of the Archipelago of Saint Peter and Saint Paul. Although part of Brazil, these islets lie in the middle of the Atlantic Ocean.



A small group of rocky islets in the middle of the ocean seems an unlikely location for human habitation, but when those humans are marine scientists the logic becomes clearer – and even more so when, as Ramón Bonfil describes, the islets are a seasonal home to little-known devil rays.

A few hours after darkness recedes and morning light fills the entire sky, we begin to distinguish the low silhouette of the rocky outcrop on the horizon just in front of us. It has been a long and tedious voyage from the Brazilian island of Fernando de Noronha: two days and two nights in a 20-metre (65-foot) fishing boat, with not much to do but look at the sea and sky for endless hours or lie in our tiny bunk beds to avoid seasickness and keep some food in our stomachs. But now, finally, we are closing in on our destination and excitement replaces boredom. Soon we will arrive at one of the most remote and inhospitable marine paradises on earth, a place of rough beauty where a few rocks are surrounded by deep blue seas full of marine life.

We are heading to the Archipelago of Saint Peter and Saint Paul, known in shorthand as the ASPSP. These distant islets lie in the middle of the Atlantic Ocean between Brazil and Africa, nearly 1,100 kilometres (700 miles) from Natal at the eastern corner of Brazil and 800 kilometres (500 miles) from Fernando de Noronha. Spearing out of the sea surface from depths of 4,000 metres (13,000 feet), they are one of the few outcrops of the submarine mountain chain of the mid-Atlantic Ridge, a place where the sea floor is continually spreading as the earth's crust gives way to new material from the planet's core. There are only nine places in the Atlantic Ocean where this mountain chain emerges from the sea to form landmasses with enough area to offer refuge for marine birds and sailors. But what makes the ASPSP unique is the fact that, of all the mid-Atlantic outcrops, it is closest to the equator and by far the smallest. The archipelago comprises just four small and six larger islets, as well as various rock points, and the longest distance between two points is just 420 metres (460 yards). In addition, it sits in an enviable location, between the northern and southern hemispheres and halfway between the American and African continents.

Discovered by Portuguese sailors in the early 16th century, the ASPSP was often used as a place where humans could find food (brown boobies and their eggs, fish, sea turtles) on the voyage between South America and Europe. However, it also represented a threat to sailors. Due to their low altitude (the highest point is a mere 18 metres, or 60 feet, above sea level) and small size, the rocky outcrops were difficult to locate before a lighthouse was installed, as several shipwrecks around the archipelago attest. The first of these, and probably the one that marked the discovery of the ASPSP, was the shipwreck of the Portuguese vessel *São Pedro*, which struck the rocks and sank here in 1511 on its way to Mozambique. Another ship in the same fleet, the *São Paulo*, rescued the survivors. (Ever wondered where the archipelago's name comes from?)

The first recorded landing on the ASPSP was by the Frenchman Bouvet du Losier in 1738. Several other explorers followed, including notable visitors such as Charles Darwin, who landed here in February 1832 during the HMS *Beagle* expedition, and Ernest Shackleton in 1921 aboard *Quest*. Numerous scientific and trade voyages set foot here, including the HMS *Challenger* marine research expedition in the 1870s, but the place remained of little interest to colonising nations and maritime empires due to its perceived poor value when compared to other treasured prizes that could be claimed and exploited. Brazil's possession of the archipelago was a *de facto* inheritance when it gained independence from Portugal. The islets remained largely in oblivion for a very long time, until the first lighthouse was erected in the 1930s. Later, in 1960, they had a claim to fame as the starting and end point for the first submerged circumnavigation of the world, made by the nuclear submarine USS *Triton*.

This tiny place is a jewel of marine life. Although the only permanent inhabitants of the dry rocks are brown boobies, noddies of two species and red rock crabs (and four human researchers at a time!), the waters around them hold several species of algae, invertebrates, cartilaginous and bony fishes, and marine mammals and reptiles. The known diversity of species is modest, due partly to the small size of the archipelago and partly to the difficulty of exploring its deep-water fauna, but the abundance and beauty of some species is great. The current biodiversity list runs to at least 107 phytoplanktonic and 205 zooplanktonic taxa, 32 sponges, 81 taxa of molluscs and 123 fish species. Common inhabitants of and visitors to the ASPSP are yellowfin and bigeye tuna, white and blue marlins, several species of jacks, flying fish, silky, Galapagos, dusky and whale sharks, giant manta rays and two species of devil rays. In addition, there are plenty of green and hawksbill turtles, and the always-thrilling bottlenose dolphins.

For several decades the waters around the archipelago were heavily fished for pelagic species, which led to some becoming less abundant and the unfortunate mistaken perception that the Galapagos shark *Carcharhinus galapagensis* was 'locally extinct'. Indeed, sharks had been extremely plentiful here before fisheries exploitation expanded to the high seas and they have certainly decreased in abundance (as they have everywhere else in the world because of overfishing). However, the claim that the Galapagos shark was extinct here has proved to be erroneous. A team of scientists from the Universidade Federal Rural de Pernambuco (UFRPE) in Recife, Brazil, has been working with sharks and rays at the ASPSP for the past 10 years and they have captured and tagged several Galapagos sharks during that period. I was fortunate to participate in their research during this trip and I personally saw and helped tag two Galapagos sharks. This species clearly has not been extirpated from the area and is still as abundant as the silky shark.

Important not only for its biodiversity and ecology, the ASPSP also holds a huge strategic value for Brazil. The nation has made a concerted effort to keep a permanent human presence in the archipelago by establishing in the late 1990s an impressive research station specially designed with innovative technology to be able to withstand the harsh environment of its location.

It is because of this research station that I was able to come to the ASPSP on what is my second adventure to this magnificent place. We came to look for Chilean *Mobula tarapacana* and bentfin *M. thurstoni* devil rays, species that are seasonally abundant in the archipelago. A team from UFRPE, led by Professor Fábio Hazin and PhD students Sibele Mendonça and Bruno Macena, has been studying them for the past few years. While I was a visiting professor at UFRPE in 2013–2014, I decided to contribute to this conservation research by joining the study, and was lucky to come here for the first time in 2014. By now we have strengthened our collaboration and have teamed up to continue researching the ecology of these mysterious 'sea birds'. Devil rays and their larger cousins, manta rays, are facing increasing threats in several parts of the world due to a huge demand for their gill plates in the Chinese 'traditional' medicine market. There is, however, nothing traditional about this trade. The use of the gill plates of devil and manta rays in Chinese medicine is very recent, having been successfully introduced by some canny traders without any scientific proof of the plates' curative efficacy.

The problem is that devil and manta rays cannot sustain heavy fishing because, like many other sharks and rays, they are slow growing and have only one offspring per reproductive cycle. This means that their populations cannot recover quickly from losses due to fishing. To make things more complicated, we know relatively little about the biology and ecology of devil and manta rays. So, we have come to the ASPSP to find out how the rays use this oceanic oasis; what other areas are key to them during their life cycle; what their migratory routes are; and how these might take them to areas where they are more likely to be caught and killed by fishers. Fortunately for the rays, they are fully protected by law in Brazilian waters, so

this mid-Atlantic archipelago is a haven for them. The information gathered during our studies will help to set up specific conservation strategies that are based on the best available scientific information, and hopefully they will contribute to the rays' eventual listing in Appendix II of CITES. This would help control the unrestricted international trade in their gill plates, which constitutes the major threat to the survival of populations into the future.

The work we do here with Chilean and, to a lesser extent, bentfin devil rays is some of the most rewarding I have had the fortune to carry out in my 30 years as a shark and ray researcher and conservationist (although my research into great white sharks in South Africa, New Zealand and Mexico also rates very highly). The 15 days we spend here during each expedition are among the most relaxing yet thrilling experiences I can remember. Meaningful and cutting-edge conservation research, adventure and pleasure all at the same time – what more could I wish for? The weather is enviable, a nice 25 ˚C (77 ˚F) , and the sun, breeze and warm blue waters entice us into free-diving for as long as we want. And the wonderful devil rays, with their regal underwater flight, are exquisite as the sun's rays fade quietly into the deep blue sea.

We spend hours on the leeward side of the islets, either swimming around the boat that serves as the main support for our research activities or sitting on its deck looking out into the blue surface and waiting to see the unmistakable diamond shadow of the devil rays. When Chilean devil rays approach, we swim towards them and our hearts immediately begin to race. Our aims are to tag them with the satellite-linked electronic tags that enable us to follow their movements for up to a year or to take very small samples of their skin and muscle. We use specially designed tips for both of these tasks, mounted on a pole-spear. Fortunately for us, Chilean devil rays are curious and tame, normally circling around us several times, going away and coming back a few seconds later. They're checking us out inquisitively and sometimes even approach us directly and almost bump into us. This facilitates our work and enables us to calmly and precisely insert the dart holding the tag towards the rear of the ray's back and just a little off the midline, so as to secure it on its muscle mass without touching any internal organs. The Chilean devil rays here reach a disc width of up to 3.5 metres (11 feet) and usually travel in groups of two to five individuals. During this trip, however, we encountered for the first time enormous aggregations of up to 30 individuals in deeper water, out of our free-diving reach, in what might be a gathering with a specific purpose.

In contrast to Chilean devil rays, we seldom see bentfin devil rays. This smaller ray reaches a disc width of only about 1.5 metres (five feet), swims extremely fast and is very elusive. We only see the bentfins at a distance; they never approach us or let us get close to them. The only opportunities we have to examine them at close range and obtain tissue samples is when they get caught in the research long-lines that the team from UFRPE uses to catch dusky, Galapagos, hammerhead and silky sharks for other tagging studies.

During this expedition, however, we managed to film from an airborne drone a group of four bentfin devil rays. They passed our boat quickly, swimming at the surface and appearing to chase one another. After filming and photographing them for a while, we analysed the video and realised that this was probably a courtship 'train' of three males chasing a female and trying to copulate with her. This is probably the first time such behaviour had been captured on film for this species!

The efforts of our joint research have started to yield some interesting results. Two of the four Chilean devil rays we tagged last year spent a few months at the ASPSP and then travelled towards West Africa. With the three additional tags we deployed during this trip we hope to continue to unveil their migratory routes and complete their movement cycles. The tissue samples we have obtained from both species will be key to a collaborative effort with The Manta Trust to develop an identification kit that will facilitate better documentation, and eventually control, of the trade in devil and manta ray gill plates around the world.

Very soon I will start similar research with Océanos Vivientes AC off the north-eastern Yucatan Peninsula in Mexico, studying Atlantic devil rays *Mobula hypostoma* with partial funding from the Save Our Seas Foundation. We hope to be able to continue working here and in Mexico for several years to unveil the complete biology and ecology of these majestic, but poorly understood rays and to contribute to their conservation and continued presence in our oceans for future generations to enjoy.

The field station at the Archipelago of Saint Peter and Saint Paul sits only a few metres above sea level and is buffeted by the region's storms.

Photos by Andre Seale | ArteSub

Mobula rays visit the archipelago seasonally and then leave again. Researchers are looking into how and why they use these islets.

Illustration by Gregory Gilbert-Lodge

SHARKS AND THE CITY

Yes, there are sharks in the downtown waterways of Miami, Florida – and their presence provides researchers from the University of Miami with a golden opportunity to study how they are affected by urbanised coastlines.

Words by David Shiffman

The news is full of stories about wild animals that are apparently invading our cities. A group of tourists had their Florida golf vacation delayed by an enormous alligator walking on the 7th hole. A fox was spotted waiting in line for an ATM outside a London bank. A mountain lion tried to move into a basement in California. What's going on?

Human settlements are expanding into areas that were once wilderness. As this continues, it's going to get more and more likely that we will see animals other than pigeons and squirrels downtown. Dr Neil Hammerschlag and his team are studying how coastal development in Florida is affecting animals that few city dwellers think of as neighbours: large sharks!

'To study or dive with sharks, we usually have to travel long distances to the relatively remote or pristine places where healthy shark populations occur,' says Dr Hammerschlag. 'However, when Dr Austin Gallagher and I were talking this over, we realised that we were probably missing an important aspect of shark biology and ecology. The trials and tribulations of sharks having to make it in human-dominated areas have to date been overlooked, yet this is becoming the new normal.'

Many shark species use shallow coastal waters, including bays and the rivers that feed into them, as nursery areas or feeding grounds. Miami is full of these waterways: man-made canals crisscross South Florida and the Miami River flows through downtown into Biscayne Bay. Coastal South Florida is an ideal place to study how urbanisation and development affect sharks, Dr Hammerschlag points out. 'Austin and I were flying over Miami on our way to a conference and we remarked about how human-dominated the landscape is. We could not make out any area from our bird's-eye view that did not show signs of human influence,' he adds.

Even though some sharks use the highly urbanised waterways around Miami, according to Dr Hammerschlag these channels aren't an ideal habitat. He continues, 'Human-dominated and highly disturbed areas tend to have poor water quality, are highly polluted and carry lots of boat traffic, which is not exactly great habitat for animals. We don't necessarily expect to find the density and diversity of sharks that would be in healthy, productive waters.' Although many species of fish eaten by sharks can be found in Miami waterways, they often occur in smaller numbers than in a pristine habitat.

Indeed, coastal habitats are being destroyed or modified around the world. The WWF estimates that more than one-third of the world's mangroves have been eradicated. A 2005 scientific study attributed up to one-quarter of coral reef loss in the Caribbean to run-off and sedimentation issues associated with urbanisation. Much of the coastline around Miami used to comprise mangroves; now it features mostly the high-rise luxury apartment blocks and skyscrapers that characterise the world's large cities. What this means for the animals that live there is not clear. 'There has been an increase in research looking into how terrestrial or avian animals like squirrels and pigeons are using urban landscapes, as well as the associated impacts on their health,' points out Dr Hammerschlag. 'Comparable studies from aquatic habitats are lacking, especially for large animals like sharks.'

To close this gap, this project funded by the Save Our Seas Foundation will use various research methods to study how coastal development affects sharks. The first step is to catch the sharks, and to do that Dr Hammerschlag and his team have been deploying shark fishing gear in the Miami River, in Biscayne Bay and even right off South Beach. 'It is a surreal experience to be tagging sharks among skyscrapers, neon lights, trains and used-car dealerships,' laughs Dr Hammerschlag. 'Once we were able to get to Hard Rock Café for lunch during the hour that the fishing gear was soaking.'

Every aspect of fishing and sampling is carefully planned to be minimally invasive to the sharks. The use of circle hooks instead of the more common J-style hooks greatly reduces the chance of 'foul hooking', which can damage a fish's internal organs. The design of the drum lines enables sharks to swim in large circles once they have been caught, which is important for animals that need to swim to breathe. And the entire research work-up is meticulously rehearsed so that it takes place as quickly and efficiently as possible.

Sharks caught in these urbanised waterways are fitted with acoustic telemetry tags, which are electronic devices that broadcast their location when the tagged shark passes near one of the receivers that have been set up in and around Miami. The data from the tags will enable the research team to track exactly where the sharks go and how they use their environment. With this information, Dr Hammerschlag and his team will be able to compare the movements and habitat use of 'urban' sharks with those of sharks in more pristine environments.

The team also takes various tissue samples from sharks they catch. Analysing serotonin in a shark's blood can reveal how chronically stressed it is. A triglyceride test shows whether the shark is getting enough food to build up the energy stores it needs for migrations, while detailed body measurements can tell scientists if the shark is unhealthily skinny. A technique called stable isotope analysis can even reveal what the shark has been eating.

Even though urbanised waterways like those in Miami don't make for great shark habitat, Dr Hammerschlag and his team have caught individuals of five species so far: nurse, blacknose and blacktip, as well as a great hammerhead and even several large bull sharks. 'Surprisingly, we are finding sharks right in downtown Miami, in some places that you would not expect,' says Dr Hammerschlag. 'However, we are not finding large numbers of them.' Why the sharks haven't moved on from this area, which in the relatively recent past was good shark habitat, is one of the questions we hope to find the answer to.

This research project is just beginning, and sampling will continue to next summer. In the meantime, early results have already revealed something important, something that anyone who lives in a coastal city should keep in mind. 'The take-home message here is that if there is a waterway linked to the ocean, there is a possibility of finding a shark, no matter how close to shore you are,' explains Dr Hammerschlag. 'This means that we have to be careful how we treat our waterways and the life occupying them.'

Photo by Frank Gibson | University of Miami | www.sharktagging.com

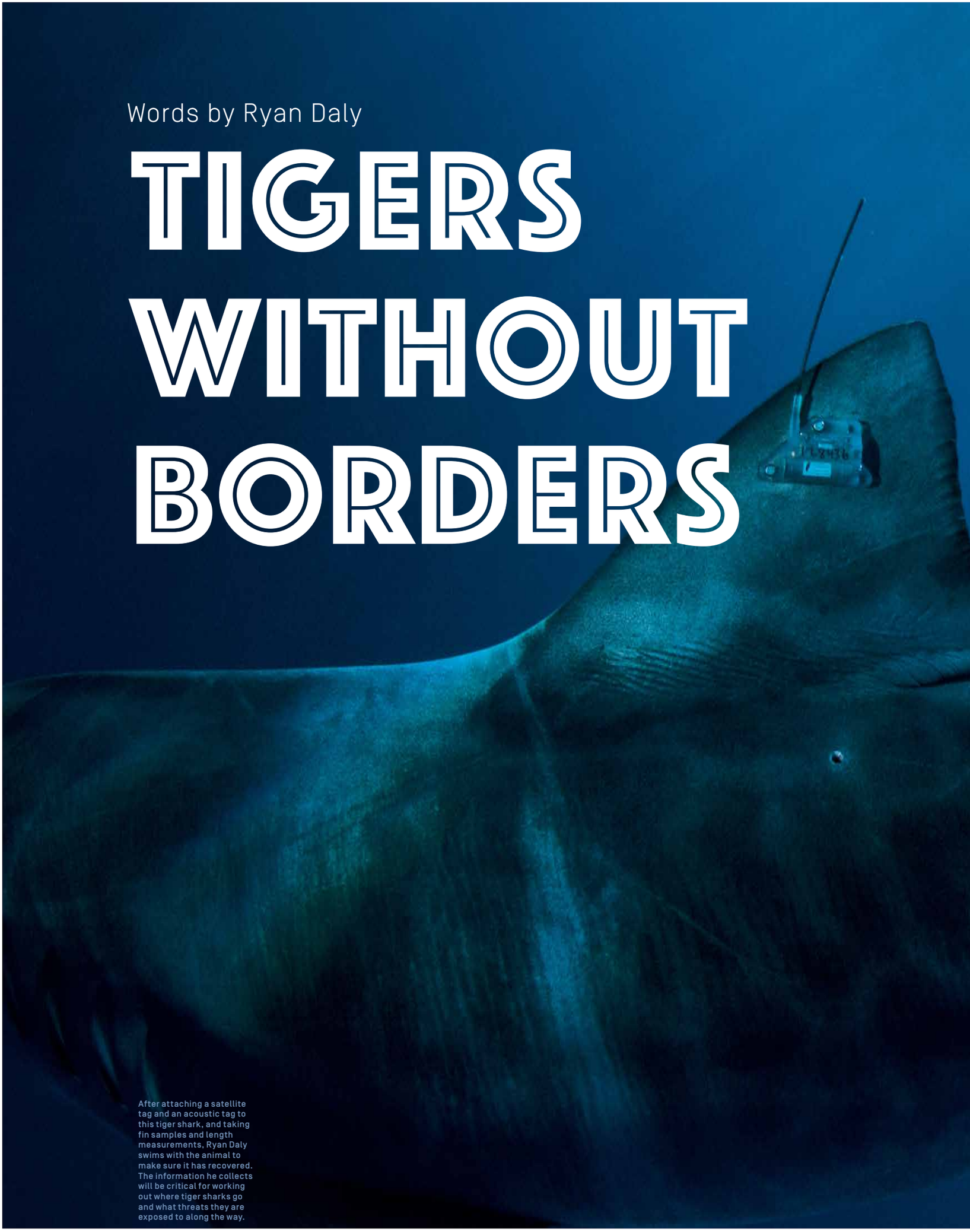
Carefully attaching this bull shark *Carcharhinus leucas* to a special platform allows researchers to quickly sample and tag the shark while promoting animal welfare. The bull shark is a coastal species that can be found close to shore, including in inland rivers surrounded by cities where they are vulnerable to human threats.

A nurse shark *Ginglymostoma cirratum* is gently secured and tagged before being sampled and released back into the ocean. The data gathered will be used to track the movements and health of sharks in relation to human disturbance.

Photo by Christine De Silva | University of Miami | www.sharktagging.com

Words by Ryan Daly

TIGERS WITHOUT BORDERS



After attaching a satellite tag and an acoustic tag to this tiger shark, and taking fin samples and length measurements, Ryan Daly swims with the animal to make sure it has recovered. The information he collects will be critical for working out where tiger sharks go and what threats they are exposed to along the way.

Photo by Steve Benjamin | Animal Ocean

Recent technological advances have opened a window on shark movements, including those of tiger sharks, and are helping researchers like Ryan Daly to understand how the sharks use their environment – and how best they can be protected.

Humans have recorded the migration patterns and seasonal presence of animals for millennia. Being able to observe large and conspicuous herds of animals, such as the wildebeest migration of the Serengeti, hunter-gatherer societies learned how to predict animal movements. As the seasons change, thousands of wildebeest still traverse the vast Serengeti plains in search of optimal areas for foraging and breeding. However, as migratory animals typically require enormous tracts of land that are free of barriers to movement, they are under increasing pressure from encroaching human development.

Today, the ocean is one of the last places on earth that remain free of barriers, and many species may roam over areas that encompass multiple countries and even continents and entire ocean basins. In the marine environment, though, the animals, unlike wildebeest herds, are not conspicuous and it is difficult to track their movements. This is especially true for species that cannot be observed from the surface or are highly mobile and cryptic. Only recently – within the past decade – have technological advancements enabled us to record the continuous movements of species such as tuna and sharks. This capability has completely transformed our understanding of the movements of marine animals and has provided insight into the global scale over which these animals travel.

Knowing how top marine predators such as sharks use their habitats is essential for predicting how and when they interact with their prey. This information is critical, as sharks, the top predators of the ocean, play an irreplaceable ecological role in an environment that is under increasing pressure. Additionally, as the number of people using the ocean for recreation grows, there is a need to understand how we can safely interact with potentially dangerous sharks. Finding the balance between keeping people safe and keeping shark populations healthy is critical both ecologically and economically. Shark tourism is becoming more and more popular around the world and contributes approximately US$314-million every year to the global economy. Iconic species, such as the tiger shark, are a crucial part of growing shark tourism, and learning to appreciate and interact with them is important.

The tiger shark is one of the largest of the shark species, growing to a length of 5.5 metres (18 feet), and it feeds on an exceptionally wide variety of prey, including birds, turtles, marine mammals and fish, throughout the world's warm-temperate and tropical oceans. The species thus plays a key ecological role in shaping the population dynamics of its prey within and between marine ecosystems.

Although we know that tiger sharks occur in many different parts of the planet's oceans, we still do not know when, why and how they travel between different areas. We have only recently discovered that adult tiger sharks can traverse an area of 6.7 million square kilometres (2.6 million square miles) in the Atlantic Ocean within a single year – an area about 223 times larger than the Serengeti, the location of the largest terrestrial migration on earth. This highlights the massive scale of tiger shark movements and suggests that our current understanding of their role within ocean ecosystems needs further exploration.

Considering that tiger sharks may cover vast distances, crossing oceans and navigating coastal regions, it is also important to take into account the wide range of threats that they may face. Currently tiger sharks are classified as Near Threatened on the IUCN's Red List of Threatened Species™ and they are killed throughout their range by commercial, artisanal and recreational fisheries. It is estimated that 100 million sharks are fished out of our oceans each year, primarily for the lucrative shark-fin trade, and tiger sharks are likely to be targeted for their large and valuable fins.

However, fishing is not the only threat to tiger sharks; habitat degradation, pollution and shark nets also contribute directly and indirectly to their mortality. As tiger sharks are relatively long-lived (up to 50 years) and reproduce slowly (gestating for 13–16 months), they are not adapted to deal with the current level of exploitation. Thus, the inevitable reduction in the size and numbers of tiger sharks could have negative consequences for marine ecosystems that depend on healthy populations of these top predators.

So, how do we find a balance for tiger sharks, humans and marine ecosystems? Marine protected areas (MPAs) can provide refuges free from fishing and may promote healthy ecosystems if managed properly. However, how do we know whether existing MPAs actually provide any benefit for tiger sharks? Typically, the delineation of an MPA does not take into account important tiger shark habitat that may be critical for mating, pupping and foraging. Furthermore, it is unlikely that MPAs will ever be large enough to encompass the entire range of an adult tiger shark. How can a patchwork of protected areas that only incorporates a small proportion of a shark's coastal range provide relief to a species that undertakes migrations on an oceanic scale? To begin answering these complex questions we need to find out where and when adult tiger sharks move. This will enable us to estimate the level of exposure to risks that these sharks face and find out whether MPAs offer any protection to them.

Currently, we know very little about tiger sharks in the Indian Ocean. Previous studies have focused on tiger shark populations in the Atlantic and Pacific, but we don't know whether tiger sharks in the Indian Ocean behave similarly or if they undertake similar large-scale migrations. So to investigate the balance between risks and refuges that tiger sharks face, we chose the largest trans-boundary MPA in the Indian Ocean as our study site. The iSimangaliso Wetland Park in South Africa and the adjacent Ponta do Ouro Partial Marine Reserve in Mozambique encompass 300 kilometres (190 miles) of some of southern Africa's most pristine coastline. This region is thought to be a critical habitat for tiger sharks. However, there are also many potential threats for the species in the waters surrounding these protected areas, including shark nets, illegal and unregulated fishing, and a shark-culling programme.

In 2014, we started tagging tiger sharks in this area to find out more about their presence and use of habitats. To track the movements of tiger sharks, we rely on two types of technology. The one is a tag that uses satellites to record its position, enabling us to follow where the tagged shark goes anywhere in the world, but it does come with some disadvantages. A satellite tag needs to break the ocean surface to be able to transmit its location, so its success depends on the tiger shark surfacing often enough. Additionally, a satellite tag has a relatively short lifespan of between six months and two years, so although it is able to provide short-term, fine-scale information about the movements of a shark, we need another type of tag that can record underwater movement over considerably longer periods, of up to 10 years.

Underwater tags, the second type of technology we rely on, use acoustic technology to transmit a unique identification code for each tagged shark that is detected by underwater receivers. These receivers are maintained in partnership with the Save Our Seas Foundation and the Acoustic Tracking Array Platform and enable us to 'listen' for tagged sharks along the entire coast of South Africa. We also maintain a border patrol with a row of receivers between South Africa and Mozambique to investigate any trans-boundary movements.

So far our tagging results have shown that the trans-boundary protected area we're studying is a critical part of the tiger sharks' habitat in the region, highlighting the importance of this as a refuge area. We've also seen that tiger sharks regularly cross the border between South Africa and Mozambique. Although these movements are not on the same scale as those of tiger sharks in the North Atlantic, they highlight the fact that the tiger sharks are moving between two countries with a range of different threats and conservation policies. In Mozambique, tiger sharks are exposed to increasing illegal shark fishing, both commercial and artisanal; in South Africa, legal bather protection nets cull tiger sharks. Although the sharks appear to regularly run the gauntlet of these hazards, they may also hop between protected areas that incorporate important foraging or refuge areas. While we still don't know if the refuges provided by protected areas are enough to alleviate the risks, it is critical that we find a balance.

Part of the challenge to finding a balance for tiger sharks in the Indian Ocean is the current disparity between conservation policies of the various countries that share the same tiger shark population. One example is the situation at Reunion Island, where recent incidents involving humans and sharks have led to a decision to cull tiger sharks there. Although seen by some as a rational approach to reduce the number of potentially dangerous encounters between surfers and sharks, it is a policy that could have far-reaching consequences beyond the island's borders. There is recent evidence to indicate that tiger sharks tagged in Reunion have swum to southern Mozambique and the east coast of South Africa. This is an important consideration, as the same tiger sharks being culled in Reunion may be part of the US$1-million tiger shark diving tourism industry in South Africa. Such conflicts are important to recognise and address as part of a larger-scale regional approach to the conservation management of these ecologically and economically important sharks.

Finding the balance between humans and top predators in a shared environment is nothing new. Our ancestors have been in conflict with predators for generations and typically the only solution they recognised was to exterminate their adversaries. However, ground-breaking research in Yellowstone National Park has enabled scientists to determine the massive ecological benefits of preserving just a handful of top predators, such as wolves. Seeing the same ecological benefits from predators in the oceans is more difficult, especially for highly mobile animals like tiger sharks. This doesn't make their ecological role any less important; it just requires scaling up our understanding of marine processes. As we continue to discover more about the habitat use of tiger sharks, we will be able to come to a more complete understanding of their movements between countries and within regions. We hope this will enable us to improve current conservation management policies for the species that take into account the balance between human-imposed risks and refuge areas in the Indian Ocean.

We know that tiger sharks travel great distances, crossing international and protected area boundaries. The threats they are exposed to can therefore vary considerably as they move.

Photo by Ryan Daly

Photo by Avlana | ShutterStock.com

RIES

E MINE

Are jellyfish taking over the world? Recent reports of havoc caused by proliferations of these gooey, brainless creatures indicate that the suggestion is not as unlikely as it sounds. Lisa-ann Gershwin explains why jellyfish are thriving.

Words by Lisa-ann Gershwin

Pages 112-113. The world's worst pest: accidentally introduced into the Black Sea via ballast water, the sea walnut *Mnemiopsis leidyi* spread rapidly and within just a few years its population comprised 95% of the Black Sea's total biomass, causing fisheries and the local ecosystem to collapse. Now the species has spread to the Mediterranean and Baltic seas.

When we think of the ocean, many of us think of romantic walks with the one we love, or of making sandcastles on the beach as a child, or of scuba diving a coral reef where the only sounds we hear are those of our own breathing and heartbeat. Or we may think of bountiful seafood: lobster dipped in lemon and butter, salmon on the grill, a clam bake with friends.

The ocean is a place of celebration, adventure, discovery, industry and solace. Writers write about it. Painters paint. Singers croon. Poets wax lyrical. Hundreds of millions of people around the world depend on the ocean for their primary source of protein. Many more make their living from it. And all of us, 7.3 billion and counting, still carry the ocean's salty signature in the blood that courses through our veins.

We love the ocean. We need the ocean. We are made of ocean. But many of us are unclear about what is happening to the ocean, where it will lead and, more to the point, what – in plain English – does it mean for our future?

There is a stark reality in many places around the world that makes the state of the ocean a far cry from our romantic vision. Waterways stagnate with putrid, foamy brown bubbles. Beaches are littered with plastic drink bottles and used syringes, and tiny pieces of plastic now mix with sand. Fish have tumours. Reefs are bleaching. And vast stretches of coastline have become dead zones, where even the worms are struggling for oxygen.

One organism, however, is thriving in these impacted oceans: jellyfish.

The word makes some of us recoil a bit, either frightened by the recollection of stings or put off by the 'goo' factor. Others go all melty in the heart, remembering beautiful jellies in an aquarium exhibition or in a fascinating documentary on television or from photos online. A few perk up with curiosity, as jellies have inspired artists and compelled nature-lovers since time immemorial. Jellyfish are different things to different people, but one thing is certain: they are commanding attention.

Jellyfish blooms are causing all kinds of havoc around the world. We normally think of stings when we think of jellyfish, but stings are often the least of our worries. Seawater-cooled power plants the world over undergo emergency shutdowns when swarms of jellyfish are sucked into the cooling intake pipes – and that happens more often than one might think. This is not only disruptive and expensive but, in the case of nuclear plants, can be dangerous. So too, desalination plants, water-cooled data centres and even cruise and cargo ships are suffering this fate. Take for example the USS *Ronald Reagan*, in 2006 the newest, largest and most expensive super-carrier ever built in the USA. On its maiden voyage, its first port of call was Brisbane in Queensland, Australia. This ship was designed to stay at sea for 20 years without refuelling and to take on any country's might or nature's most furious wrath. But it wasn't prepared for jellyfish. Thousands of sea blubbers *Catostylus mosaicus* disabled the engine's cooling system, triggering an emergency evacuation and system shutdown. This was not only embarrassing to the US Navy, it was also a rather colourful example of an all-too-frequent occurrence.

Consider also the case of the giant jellyfish in China and Japan. Nomura's jelly *Nemopilema nomurai* is an incredible beast, reaching some two metres (six feet) across the body and weighing in at some 200 kilograms (450 pounds). It is easy to track, because you can't miss it. Throughout the 20th century it had been reported only a few times. Then something changed in 2000: this sleeping giant awoke, and it has bloomed in truly massive numbers nearly every year since then. It has been estimated that in full bloom, half a billion of these giant jellies drift into the Sea of Japan every day. Half a billion! It appears that the highly impacted seas around China provide a perfect breeding ground for these refrigerator-sized behemoths. Most of the fish have been fished out, so there are fewer predators and competitors. Very high levels of toxic chemicals and nutrients draining into the coastal waters from the cities and farmlands are killing what's left and triggering microbes and harmful algal blooms. The seabed has been trawled so many times that the original three-dimensional habitat that supported other species is now gone, with the rubble providing new growing space for jelly polyps. And intense coastal construction offers even more growing space. Without meaning to, China has created the perfect habitat for jellyfish.

Although most of the ecological and industrial havoc that jellyfish cause involves non-stinging or mildly stinging species, there are a few life-threatening species that are worth keeping an eye on, particularly in tropical regions like Australia, Hawaii, Thailand and the Caribbean. These highly dangerous types fall into two main categories: deadly box jellyfish and Irukandji jellyfish. At least two species of deadly box jellies are known, one from northern Australia and the other off East Asia. The venom acts on the heart by locking it in a contracted state. A typical adult box jelly has a total of 120–180 metres (360–540 feet) of tentacle capacity and needs only 1.4 metres (about 4 feet) to kill a child, or 3–5 metres (9–15 feet) to kill an adult in as little as two minutes (typical time to death is just four minutes).

The other highly dangerous group of jellies is the Irukandjis, named after an Australian Aboriginal tribe in the 1950s and comprising roughly 15 species known to date. The initial sting of most of them is mild, but after a characteristic delay of about half an hour a constellation of systemic symptoms kicks in. These symptoms are fully debilitating: severe lower back pain, chest and abdominal cramping, nausea and vomiting, difficulty breathing, drenching sweating and a feeling of 'impending doom'. Some species also cause severe hypertension (high blood pressure), which can result in a stroke or heart failure. Species that cause Irukandji syndrome are currently known from as far north as Boston and Dublin and as far south as Sydney and Melbourne, and may become more numerous or more venomous as the oceans warm.

So let's take stock: dangerous jellyfish already occur throughout the usable oceans and seas of the world, and non-dangerous species are threatening our fishing, power and shipping industries, as well as the military. As tempting as it may be to blame it on the

jellyfish, like the proverbial canary in the coal mine, it's not the canary's fault. Jellyfish are merely responding to the conditions that we are creating. In some cases, jellies are a visible indicator that the oceans are out of balance; in others, they act more like an angel of death, hastening ecosystem decline.

Another unexpected aspect of jellyfish has recently come to light: it now looks like they may exacerbate climate change and ocean acidification. There is a peculiar property of jellyfish mucus and dissolved organic matter (or jellyfish goo and poo) that favours certain types of bacteria over others. The types of bacteria that flourish here are those that shunt energy away from the food chain and towards the production of carbon dioxide instead. Jellyfish in large numbers, therefore, act like carbon dioxide factories.

Jellyfish seem impervious to many of the stressors that affect other species. In fact, some stressors even spur them on. For example, one stressor that is particularly favourable for jellyfish is overfishing. For each fish that is removed, the food that it would have eaten becomes available for others. At first, other fish benefit from this bounty, but as more and more fish are removed, eventually that extra food becomes available for species that are normally outcompeted, like jellyfish.

Another example of a stressor that favours jellyfish is warming. Even a nearly imperceptible increase in temperature reduces the amount of oxygen dissolved in water, so fish and crustaceans must exert more energy to extract enough oxygen to survive. This in turn means that they must find and catch more food just to break even with their increased energy output, which in turn requires more energy. Compared with fish and crustaceans, jellyfish have an incredibly low metabolism – so low that while other species are struggling, they are under no threat at all. Moreover, warmer water acts like steroids for many types of jellyfish, revving up their growth and breeding rates and lengthening their growing season.

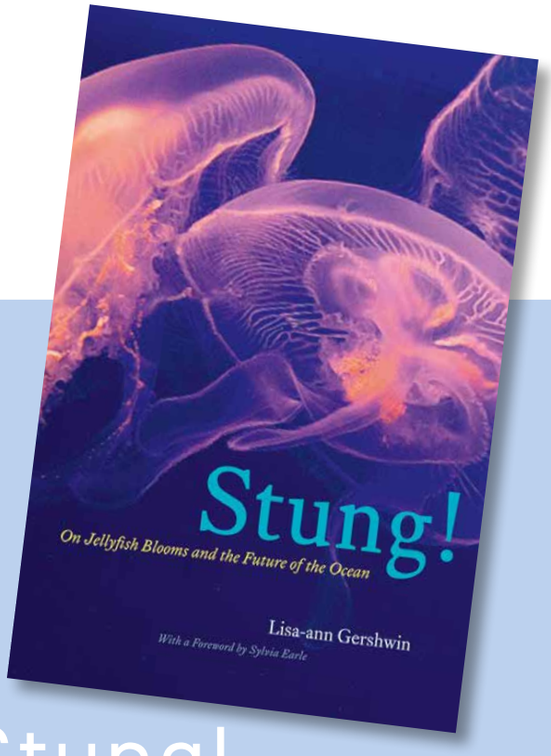
Even other stressors like pesticide run-off that have little direct effect on jellyfish can nonetheless help boost their numbers simply by making it more difficult for other animals like fish to survive. Thus, as other species struggle, jellyfish find opportunity.

It may seem hard to believe that a creature as primitive and mucousy as a jellyfish could somehow be taking over. Fish are faster, smarter and often bigger. And fish are visual predators that can target their prey, whereas jellyfish merely blunder into it. Indeed, in healthy ecosystems fish have a strong advantage over jellies. But as ecosystems falter, they don't just come to a stop – they transform. Species' relationships shuffle and new winners and losers emerge.

Jellyfish have several key features of their biology that make them particularly well suited to picking up the slack of disturbed ecosystems. Like dandelions and cockroaches, jellyfish have a weedy lifestyle that enables them to flourish. Many have broad tolerances for fluctuations in temperature and salinity. Most are opportunists and are able to breed and grow quickly and eat just about anything. Some don't need to eat: when food is scarce they just slowly 'degrow', or get smaller, then regrow when food becomes available again. But perhaps the most important feature that makes them so tenacious is their life cycle.

The jellyfish life cycle is completely different from that of any other animal we are familiar with. The jellyfish (or medusa) is only part of the life cycle. Male and female medusae release sperm and eggs into the water or fertilise internally. The resulting embryos develop into tiny larvae that settle on hard surfaces like rocks or shells, and grow into polyps. These polyps resemble minute hydras or sea anemones. The polyps clone many replicas of themselves, creating colonies. When the conditions are right, these polyps undergo a transformative process, triggering them to release baby jellyfish, which then grow quickly into adult medusae.

While medusae may live for only a few months, polyps can survive indefinitely by cloning. These polyps act as a seed bank, just waiting for the right conditions. And then whammo – jellyfish appear almost overnight, as if out of nowhere.



Stung!

Combining powerful scientific data about human-caused change with surprising vignettes about jellyfish super-abundances, Gershwin's first book *Stung! On Jellyfish Blooms and the Future of the Ocean* weaves a compelling story about our effect on the ocean. The collapse of cod populations due to overfishing, the vanishing of the Great Barrier Reef because of ocean acidification, and the Great Ocean Garbage Patches where plastic outnumbers plankton and chokes seabirds – *Stung!* explains all these phenomena and more, and shows synergies between many of the stressors that are impacting our oceans today.

From herbivorous jellyfish starving out penguins in Antarctica to carnivorous jellyfish taking over the seas of Europe, readers on this journey of intrigue will begin to see 'jellies' in a whole new light. There is even a remarkable coincidence between Gershwin's early anti-nuclear activism and her own scientific history. *Stung!* spent four months as number one in Amazon's catalogue of marine biology and ecology books for good reason!

Photo by Matty Smith

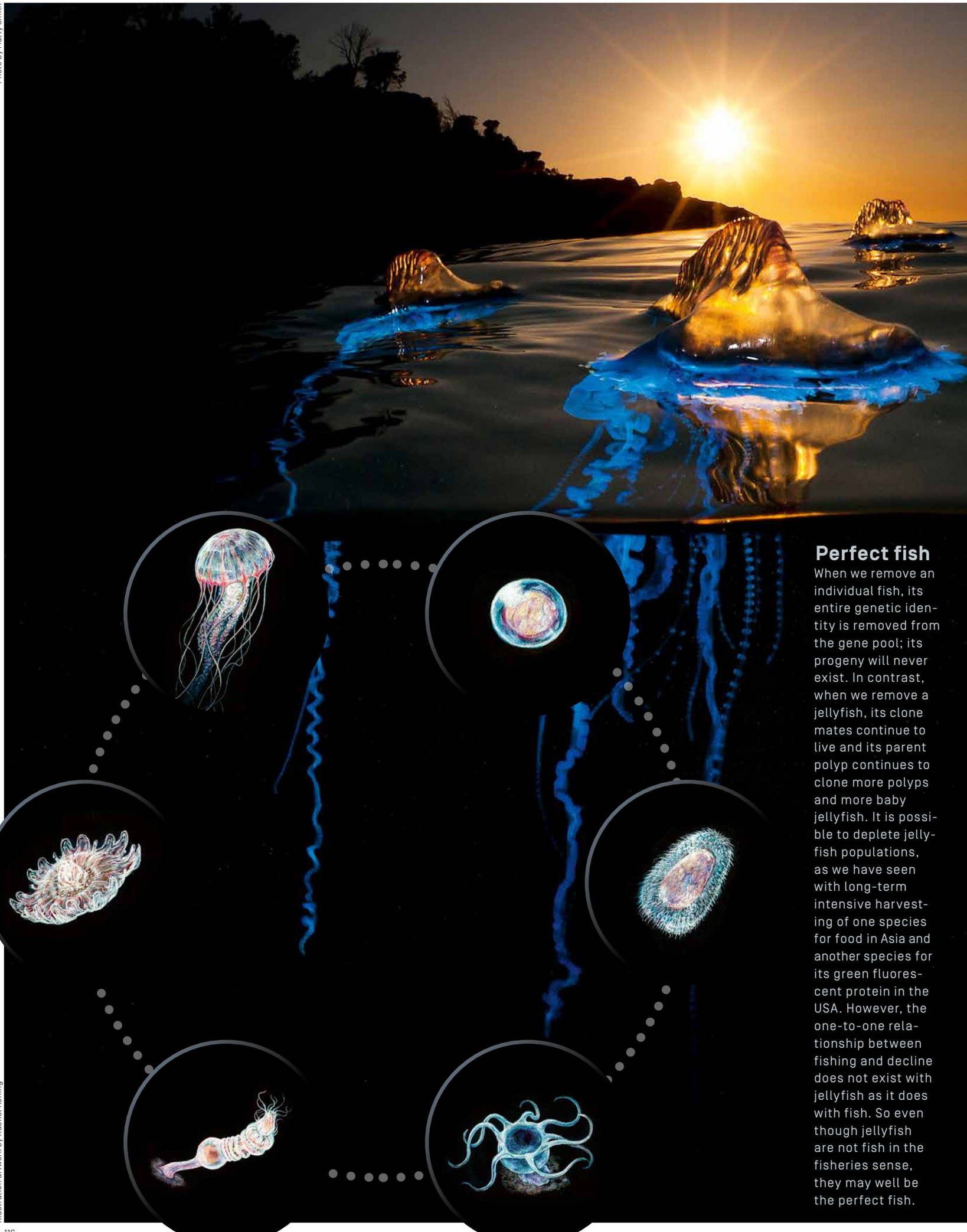


Illustration artwork by Rachel Koning

Perfect fish

When we remove an individual fish, its entire genetic identity is removed from the gene pool; its progeny will never exist. In contrast, when we remove a jellyfish, its clone mates continue to live and its parent polyp continues to clone more polyps and more baby jellyfish. It is possible to deplete jellyfish populations, as we have seen with long-term intensive harvesting of one species for food in Asia and another species for its green fluorescent protein in the USA. However, the one-to-one relationship between fishing and decline does not exist with jellyfish as it does with fish. So even though jellyfish are not fish in the fisheries sense, they may well be the perfect fish.

Beauty and the beast: the electric-blue coloration of the Portuguese man o' war *Physalia physalis* is a natural warning. When armadas of these strange jellyfish blow towards shore, run! It is estimated that they sting more than a million people a year, sometimes fatally.

From the growing number of media reports about jellyfish problems – some are even calling this the Age of the Jellies – the question naturally arises: are jellyfish blooming more, or are we simply more aware of them?

The fossil record tells us that jellyfish have been around for at least a half billion years; DNA modelling suggests perhaps twice that long. One particularly spectacular Cambrian fossil quarry in central Wisconsin contains seven consecutive bedding planes of ancient jellyfish blooms, preserved one after another like pages in a history book. This tells us that jellyfish have been blooming since the dawn of animal life – it is just what jellyfish do.

Even in the tiny slice of time since recorded history began, jellyfish blooms come and go. The sporadic nature of their occurrence, along with very patchy data collection, makes interpreting their trends difficult. Currently experts debate as to whether there is an overall increase in jellyfish globally, or whether global blooms are more cyclical in nature, or whether the increase in reports of jellyfish blooms is indicative of an increase in disturbed habitats. Many experts favour the last explanation, where jellyfish are merely responding to the conditions that we are giving them.

In fact, a couple of recent events suggest that this may be truer even than it seems at face value. For example, jellyfish disappeared almost immediately from a bay previously infested with them as soon as aquaculture installations were removed. It seems that the structures slowed the flow of water and provided settling areas for the jellyfish polyps. Without these two features, the jellies simply died off.

Another example is from the King Daddy of all jellyfish problems: *Mnemiopsis leidyi* in the Black Sea. This American species of comb jellyfish was accidentally introduced in ballast water in about 1982 and within just a few years the population had exploded to become about 95% of the biomass. The unlikely simultaneous timing of three unanticipated events led to its decline. First, as fisheries collapsed, fishing pressure stopped, allowing the fish to begin to recover. Second, when the Soviet Union broke apart, farming subsidies ended, so farmers used fertilisers more sparingly, resulting in less run-off and less hypoxia. Third, a native predator of *Mnemiopsis* was accidentally introduced into the same area, resulting in natural control. While we can look to both of these examples as encouraging news that jellies can be controlled, the reality is that both required extraordinary disruption that would be unlikely to occur in the Western world.

When confronted with the problem of jellyfish, one naturally asks, 'What can be done?' The answer, however, is less than straightforward. There is no shortage of uses for jellyfish. For thousands of years jellyfish have been considered a delicacy in Asian cuisines and increasing demand has led to jellyfish harvesting as a lucrative export industry for many nations. So too, numerous intriguing commercial uses for jellyfish have been developed in recent years, including a hyper-growth fertiliser for rice; super-absorbent products like paper towels, baby diapers and sanitary products; and a low-calorie, fat-free thickener for sweets or egg substitute for baked goods. These and many other uses show great promise for the removal of large quantities of pesky jellies from the ocean. So that could be a good thing because, in theory, it will give fish a chance. But will it?

There is also a less clear and more variable side to the story: removing jellies may simply open up more ecospace for the next pest in line, probably algae and microbes. Nature doesn't hold a vacuum until its original inhabitant returns. Nature moves on. Nature adopts a new normal. So as we continue to deplete, poison and warm our oceans and seas, it appears that we are conducting a grand experiment – and nobody really knows the outcome.

The actions necessary to budge jellyfish out of dominance seem to be fairly drastic, and in some cases may not be fully effective. A much more sensible approach would seem to be to keep jellies from reaching that tipping point in the first place – and the bountiful seafood, romantic walks on pristine beaches and bustling coral reefs will be a more enduring legacy.

Jellyfish mechanisms

Jellyfish have a couple of surprisingly simple but stunningly effective means of taking control of ecosystems. Not on purpose, of course, since they have no brain.

Double whammy

One of the most effective mechanisms lies in the jellyfish's generalist feeding habits. Jellyfish eat not only the eggs and larvae of fish, but also the planktonic food that the larvae prey on. This 'double whammy' of predation and competition can cripple the food chain at its base, thus impacting the species higher up. This mechanism is particularly relevant for krill and smaller schooling fish species like sardines, where the ecological overlap with jellyfish is very high.

Energy transfer

Another mechanism that favours jellies is in how they affect energy flow through the food chain. Normally we think of the food chain in more or less linear terms: big things eat little things, fast things eat slow things, and smart things eat less intelligent things. But jellyfish muddle this up. Jellyfish, which are slow and brainless and often small, eat fast fish that are smarter – and often larger – than they are. They don't eat an adult fish, of course, but they eat its eggs and larvae. In this way, jellies take higher quality food from higher up the food chain and convert it to lower quality food in their own bodies, lower down the food chain. Not many other species routinely prey on jellies, so they are considered a dead-end branch of the food chain.

Full moon rising: moon jellyfish *Aurelia* spp. are increasing in many bays and harbours around the world. They have been responsible for clogging the intake pipes of power plants and the mass deaths of farmed salmon.

Photo by Optimarc | ShutterStock.com

Words by Dean Grubbs and Charles Cotton

Sharks of the twilight zone

What is a 'typical' shark? A large, toothy, familiar predator or a small, dark creature of the deep? Dean Grubbs and Charles Cotton reveal some surprises about sharks that are little known, poorly researched and increasingly overfished.

The sharpnose sevengill shark *Heptranchias perlo* is a deep-sea shark we know little about, even though it is caught as incidental by-catch in bottom-trawl and long-line fisheries.

Photo by Kelvin Aitken | MarineThemes.com

Ask a child to describe a shark and he or she will often respond with something like 'a big fish with big sharp teeth'. Perhaps an adjective like 'scary' or 'man-eating' will be added. Asked to name a shark, the child will typically reply 'great white shark', 'bull shark', 'hammerhead' or 'tiger shark'. These responses reflect the species made most familiar to the public by books, television documentaries and films.

Few people realise how diverse sharks are or that there are close to 500 living shark species – or, indeed, that there are 1,200 living chondrichthyan fishes, which include batoids (rays, skates and sawfishes) and chimaeras, as well as sharks. Why should they? Small, dark-hued sharks with tiny teeth that live their entire lives in the darkness of the deep sea are seldom encountered and, being also not particularly scary, they don't garner the media attention of their larger coastal and pelagic counterparts. But in reality, these small, deep-sea sharks are much more representative of a 'typical' shark than the familiar species featured in documentaries. In fact, two-thirds of all living shark species reach a maximum length of less than one metre, and fewer than 20% of living shark species reach lengths of more than 1.5 metres. In addition, 53% of all living shark species, and 48% of all chondrichthyans, live their entire lives more than 200 metres below the surface of the sea.

The bias favouring large, charismatic species of sharks and rays isn't particular to the public; it pervades the scientific domain too. A survey of nearly 50,000 peer-reviewed research papers about sharks, rays and chimaeras published since the year 1820 revealed that although deep-water taxa make up more than half of the living species diversity, they represent only 7% of the scientific literature. In fact, over the past 15 years there have been almost as many published studies on white sharks and tiger sharks alone as there have been on the nearly 600 species of deep-water chondrichthyans combined.

Sharks, rays and chimaeras occupy varied habitats in the deep ocean. As is the case for most predators, the biomass and diversity of deep demersal chondrichthyans is highest in variable or edge habitats – places like submarine canyons, sea mounts and the edge between the continental shelf and slope. Most deep-sea chondrichthyans are bottom-dwelling species that probably rarely venture more than a few metres from the sea floor. This diverse assemblage is dominated by skates, catsharks, lanternsharks, gulper sharks and dogfishes. However, certain species, such as cookiecutter sharks (*Isistius* spp.), some lanternsharks (Etmopteridae) and the pelagic stingray *Pteroplatytrygon violacea*, migrate vertically each day between deep and shallow water. During the day they are found in the mesopelagic zones, between 200 and 1,000 metres down, while at night they may penetrate the epipelagic zone, which is less than 200 metres deep.

Many deep-water sharks and skates previously thought to be 'rare' are actually quite common in the deep ocean. The abundance and diversity of deep-sea sharks and rays often peak at intermediate depths (400–800 metres), and recent research has shown that there appears to be a limit to the depth at which deep-sea sharks and their relatives can live. More than three kilometres below the ocean surface – or in the abyssal depths, as they are known – the ocean is almost entirely devoid of chondrichthyans, and there are three prevailing hypotheses to explain why this may be so. One posits that the limited food available below 3,000 metres makes it impossible for sharks, rays and chimaeras to generate enough liver oil to provide buoyancy. Thus, below 3,000 metres these animals would have to swim continuously to avoid sinking. Another hypothesis suggests that since food resources are so limited in the deep ocean, predators at the top of the food chain are unable to find enough food in this habitat and would essentially starve. Lastly, all chondrichthyans need a vital compound in their bodies – trimethylamine N-oxide (TMAO) – which helps to maintain osmotic balance and protects proteins from the destructive effects of extreme pressure; it's the molecular constraints of that compound that could be imposing this depth limit.

The relatively similar pressure, temperature, salinity and light levels across and between deep ocean basins mean that many deep-water shark species have very broad, often global distributions. Recent technological advances in telemetry have facilitated greater understanding of the distribution and movement patterns of some deep-water shark species. The limited studies that have been conducted reveal that many species make daily vertical migrations from depths of 600–1,000 metres to the edge of the thermocline (200–300 metres) at night and back to the depths during the day, following a massive migration of smaller fish and other marine organisms. As technology advances and logistical constraints are overcome, we predict telemetry studies will become more common for deep-water sharks in the near future, helping scientists to unravel some of the mysteries surrounding the ecology and behaviour of these little-known species of the deep.

Superficially, deep-water sharks may seem like small, drab or dark-coloured species that are not particularly charismatic, but some of them possess specialised adaptations for life in the deep sea that are anything but boring. Most people are probably unaware, for example, that some sharks glow in the dark by producing light, or bioluminescence (see 'A light in the dark', next page).

Bioluminescence occurs in three families of deep-sea sharks, which create a blue-green light from tiny photophores that are often arranged in very specific patterns. Visible light attenuates rapidly with ocean depth, to the extent that below 1,000 metres the sunlight filtering down from above is so limited that most fishes no longer rely on vision as a major sense. However, in the so-called 'twilight zone' between 200 and 1,000 metres very dim blue to blue-green light does filter through, and most fishes that live at these depths have visual systems adapted to use this light as effectively as possible. Sharks that live in the twilight zone often have large, green eyes capable of harvesting this dim light. Whereas this habitat would appear pitch-black to the human eye, to the eye of a deep-sea shark it is perfectly lit.

A LIGHT IN THE DARK

Bioluminescence – the production and emission of light by a living organism – has evolved independently many times in creatures ranging from bacteria to beetles. To create light, the animals rely on a chemical reaction that converts chemical energy to radiant energy: a chemical in a class of compounds known as luciferins reacts with oxygen in the presence of a luciferase enzyme, resulting in light emission. Whereas many people may be aware of luminescent creatures on land, like fireflies, the phenomenon is much more common and taxonomically widespread in the marine environment, where it is present in marine organisms ranging from single-celled dinoflagellates to fishes.

Although there are diverse examples of luminescing animals that live on or near the seabed, such as luminous worms, molluscs and echinoderms, marine bioluminescence is most widespread in the open ocean. Marine planktonic and pelagic communities are full of luminescent species. In chondrichthyan fishes, bioluminescence is known only from members of the squaliform sharks, and all are deep-water species. Among the bony fishes, however, there are bioluminescent species in at least 38 families from nine orders!

This light production can serve many functions. Across a range of taxa, particularly those whose photophores, or light producing organs, are arranged in very specific patterns, bioluminescence is used for communication for mutual recognition in schools or for identifying the opposite sex. This is probably the function of the distinctive photophore patterns in many lantern sharks (Etmopteridae).

The function of bioluminescence can also be to counter predation. Many small mesopelagic organisms use flashes of light or luminous secretions to repel or confuse predators. One major function of bioluminescence is camouflage. The community of animals that live in the 'twilight zone' includes a diverse assemblage of bioluminescent creatures, particularly small fish, shrimps and squids. At dusk every evening, this community migrates vertically from about 1,000 metres to the shallow edge of the thermocline (at about 200 metres) to feed under the cover of darkness. When dawn comes it makes the long return migration to depths where visible light barely penetrates. These animals produce light in the blue-green region of the visible spectrum, similar to the spectrum of remaining dim light at these depths. Their bioluminescence thus creates a counter-illumination that obliterates their silhouettes against very dim, down-welling light, making the animal more difficult to see. This camouflage through counter-illumination is likely to be the dominant function of bioluminescence in sharks.

Bioluminescence can also serve predatory functions. The 'headlight' photophores of some deep-sea fishes are used to illuminate small zooplankton prey. In the ceratioid anglerfishes, the luminous esca (Latin for 'bait') at the end of the illicium (essentially a fishing pole) is used to lure prey close enough to be captured in a gaping, large-toothed mouth. Similarly, cookiecutter sharks are thought to use their bioluminescence for predatory purposes. Photophores cover the shark's underside except for its fins and a small 'collar' below its gill slits. Against a dimly lit backdrop, this non-luminous collar would create a small silhouette that mimics the search image a pelagic predator would use to locate potential prey. The unsuspecting predator is thus lured to the cookiecutter shark, which then collects its 'pound of flesh'!

Photo by Espen Rekdal | SeaPics.com

Lanternsharks glow in the dark, thanks to luminous glands – photophores – that produce and focus light. A single shark can have hundreds of thousands of these glands. This species is the velvet belly lanternshark *Etmopterus spinax*.

In addition to having specialised eyes, deep-water sharks, rays and chimaeras have remarkably variable teeth. For example, sixgill and sevengill sharks have distinctive teeth in the lower jaw, each one shaped like a cock's comb. This is an adaptation for sawing pieces of soft tissue out of the carcasses of large animals such as whales, which the sharks may scavenge from the sea floor. Some kitefin sharks (Dalatiidae) have small, narrow-cusped upper teeth and very large, triangular lower teeth arranged like a picket fence. The best-known of these species, the cookiecutter sharks, use their specialised dentition in concert with fleshy lips to latch onto large marine mammals and fishes, create suction and, with the assistance of the momentum of their prey, rotate their bodies to carve out small chunks of flesh, leaving behind crater-type wounds resembling the indentations made by a melon-baller.

Often – and unfortunately – our knowledge of the biology of marine species lags behind the development of fisheries that exploit them. This information lag is especially severe among deep-sea fisheries, particularly for sharks, rays and chimaeras. Logistical challenges are among the primary constraints. With the exception of species associated with some oceanic islands whose slopes can be reached by small boats, studies of deep-sea chondrichthyans often require large vessels that cost tens of thousands of dollars per day. And even when the financial support is available, weather and sea conditions often limit the days available for research. In addition, it is not a trivial challenge to develop methods that effectively capture deep-water chondrichthyans, particularly the larger sharks, while minimising gear loss.

However, the challenges to accessing the deep sea have long been overcome by fisheries. As human populations have grown over the past century, many coastal fishery resources have become fully exploited or overfished. Technological advances in vessels and equipment have enabled fisheries to expand their access to deep-water resources. Although in some countries deep-water sharks and skates are targeted specifically for human consumption, for the most part these chondrichthyans are caught unintentionally as by-catch, particularly by large trawl fisheries. Whether targeted or taken as by-catch, the most valuable commodity from deep-sea squaliform sharks is usually their liver oil. Often the shark's liver is removed and the rest of the animal is discarded.

In countries where deep-water sharks have become an important food source – Portugal, Spain and India, for example – concerns about both sustainability and human health have been raised. Little or no information exists about contaminant loads or the need for consumption advisories in those countries, even though some studies have shown elevated levels of harmful chemicals such as mercury, PCBs, the pesticide DDT, the fungicide HCB, dioxins and flame-retardants in the tissue of deep-water sharks.

In theory, the technological advances that have made the development of deep-sea fisheries possible should facilitate scientific study; in fact, data suggest that science still lags far behind. From 1940 to 2010, studies of deep-water chondrichthyans contributed to a maximum of 8% of the total studies on sharks and their relatives. As a result, we know very little about even their basic biology, such as distribution patterns, habitat use and life histories, and this limits our ability to manage the deep-sea fisheries that capture these species. There is, however, some good news: in recent years there has been a marked increase in the number of studies of deep-sea chondrichthyans. This is reflected in the fact that of the nearly 250 new species of chondrichthyans described over the past 15 years, almost two-thirds were from the deep sea.

In places where deep-water fisheries operate, deep-sea sharks often become quickly depleted. In a 2014 study assessing the conservation status of chondrichthyan fishes, Nick Dulvy and his colleagues highlighted three regions of the world where the status of deep-water chondrichthyans is of most concern: the eastern Atlantic Ocean from Norway to southern Africa (including the Mediterranean Sea); the south-western Atlantic (primarily off Argentina); and the south-eastern coast of Australia. These areas reflect the places where industrial-scale, deep-water long-line and trawl fisheries have developed. One study in New South Wales, Australia, revealed declines of more than 90% in a large suite of deep-water sharks between the late 1970s and the late 1990s as the result of by-catch in a deep-water trawl fishery. Even though the fishery aimed to catch primarily redfish and gemfish, it also caught substantial numbers of sharks, many of which were marketed. But these regions are not the only areas that we need to watch. For example, in the Maldives during the early 1980s, a deep-sea fishery targeting gulper sharks for liver oil developed and by the early 1990s landings had declined dramatically. Concerns have also been raised over the rapid development of deep-water fisheries targeting sharks in the Arabian Sea off south-western India.

In their review, Dulvy and his colleagues also reported that 17% of sharks, rays and chimaeras were threatened, as determined using information collated from the IUCN Red List of Threatened Species™, but that only 5% of the deep-water species they assessed were threatened. This, however, is biased by the fact that deep-water species are severely understudied. Data Deficient species – those for which information is too scant to establish the threat status – made up 58% of the deep-water species assessed, but only 39% of the coastal species.

Although it was determined that, in general, deep-water chondrichthyans are less likely to be threatened than coastal or pelagic taxa, this is probably because most of the deep-sea species that were assessed belong to two large families of small, egg-laying chondrichthyans with high fecundity (softnose skates and catsharks). Life history data are available for only a very small percentage of deep-sea sharks, rays and chimaeras. What information there is, however, suggests that many of the live-bearing deep-sea taxa (such as gulper sharks, dogfishes, sleeper sharks and some lanternsharks) have extremely conservative life histories. Females reach sexual maturity between 15 years and more than 30 years of age, produce litters of fewer than 10 pups and, with gestation periods that are among the longest of any vertebrate, are able to reproduce at a minimum of every two years. As a result, these species have some of the longest population doubling times of any chondrichthyan and therefore the lowest rebound potentials if overfished. Unfortunately, most of the species with such conservative life histories have not been assessed for the IUCN Red List.

Concerns over the extremely long recovery trajectories for deep-sea sharks have resulted in some efforts to manage their stocks and limit harvest in certain regions. In the Maldives, for example, all shark fisheries – including the deep-sea demersal fishery targeting gulper sharks – have been closed. However, the closure of targeted shark fisheries is likely to have an insignificant effect on deep-sea chondrichthyan stocks as long as there are deep-trawl fisheries that capture and discard these fish as incidental by-catch. We know very little about the survival rates of deep-sea sharks that are released after capture, but the evidence suggests that very few survive, even if they are released relatively unharmed.

Closing areas of deep sea to trawling may offer the only effective management

The frilled shark *Chlamydoselachus anguineus* is a rare deep-water shark with a patchy distribution around the world. Its mouth has rows of needle-like teeth that stop prey from escaping its grasp.

mechanism for limiting mortality in these inherently vulnerable species. In recent years, some areas have been closed to deep-sea trawling and other fishing around the world, particularly off the coasts of Australia, New Zealand, the USA and Europe. The USA closed much of its Pacific coastline to trawling, including deep-sea habitats, in 2006. Four sea mounts along the mid-Atlantic Ridge have been closed to all fishing. Australia and New Zealand have established relatively large deep-sea closures to bottom trawling, primarily to protect vulnerable sea mounts. Bottom-trawling is banned in one-third of New Zealand's territorial waters. The European Union has also closed certain sensitive deep-sea habitats to trawling and is considering a moratorium on fishing at depths greater than 1,000 metres in the Mediterranean. However, since most deep-water sharks are concentrated at bottom depths of between 400 and 800 metres, such a regulation could either have little effect on catches of these animals or could result in higher catch rates as fisheries targeting deeper species are forced to fish at other depths. Nevertheless, these are positive, albeit small, steps forward in the management of deep-sea fisheries.

Research on deep-sea sharks and rays is wide open to exploration and may represent the last frontier of chondrichthyan ecology. Studies on deep-water sharks have flourished in the past decade and threats posed by escalating and often unregulated deep-water fisheries promise to elevate the need and demand for such research. Although great strides have been made, we are at least half a century behind the current state of knowledge for coastal shark species. Fishery managers and the conservation community desperately need biological information for deep-water chondrichthyans, particularly the skates and squaliform sharks, to ensure that wise management practices are implemented. Therefore, it is imperative that more resources are dedicated and research efforts initiated to study the biology of deep-sea chondrichthyans and the community ecology in the habitats where they exist.

Photo by Kelvin Aitken | MarineThemes.com

A number of things make whales fascinating: their size, their mammoth migrations, their inscrutability… South Africa's south-western coast is a good place to catch up with them – and with Katja Vinding Petersen as she studies them. Philippa Ehrlich spoke to Katja about the fascination southern right whales hold for her.

Originally from Denmark, Katja Vinding Petersen has lived in South Africa for almost six years studying the country's population of southern right whales. These enormous cetaceans were almost hunted to extinction in the first half of the 20th century, but today they are thriving along the coast between Cape Town and Mossel Bay.

How did you come to study whales in South Africa?

In 2006 I was privileged to be on the Danish Galathea 3 expedition, an around-the-world scientific and educational project. My biggest passion has always been marine mammals, and cetaceans in particular. One of my good friends was on the ship as well, working on acoustics, so we decided to see if we could record some of the southern right whales in South Africa. We left the expedition in Cape Town and went out to the Overberg – and I fell in love with the area. It was like coming home. My soul felt at home in Gansbaai, of all places. We didn't get any recordings because the animals were silent, as cow–calf pairs are most of the time. But I definitely got my connection to the area.

What is it about marine mammals that fascinates you?

There's something intriguing about them. You see them, but you don't really see them. And all their adaptations are so fascinating. They're mammals, but they can survive in the ocean. They've got no legs. They've got thick blubber to protect them in that cold, cold environment. And they use sound to find their way around and locate each other.

Did you ever manage to record the sounds of the whales?

That's one of my biggest research passions: the acoustic part. I have loggers in the ocean recording the whales and I have been going through those recordings for most of this year. It's incredible to finally be eavesdropping on southern right whales communicating.

What is it about the Overberg coastline that the whales like so much?

They like gently sloping bay areas protected from the wind. Especially the cow–calf pairs because they want to spend as little energy as possible fighting waves. Also this seems to provide protection against killer whales. The southern rights can move into water as shallow as four metres, where a pod of killer whales cannot hunt them from underneath or breach out of the water and separate the calf from the cow.

Have you ever been in the water with a whale?

Once, here in South Africa. We were servicing my logger with a local dive team and one of the whales came up to us. It was amazing. It looked at us and it seemed to check us out, wondering 'Is this something dangerous? Is it another whale?' We were all just passively in the water together and then it swam off and we could see that massive tail disappearing into the abyss.

What are the main questions that you are trying to answer about South Africa's southern right whales?

We are trying to understand their behaviour. For example, I want to know how the animals behave in a 'surface active group', which is when you've got at least one female and up to 15 males around trying to mate with her. When we're looking at it from land, we can't really assess if there are five or 10 or 15 males. We use planes to get a better idea and we are also investigating the potential of using drones. I also want to see if we can get the interaction between the cows and their calves. It seems that as the calves get older, they get more adventurous – just like kids. They move further away from their mothers and then come back again. There've been cases where whales met up and kind of swopped calves, swimming off with the wrong one.

Do calves ever get lost?

Unfortunately, yes. It's hard to say what happens to their mothers. Maybe they were inexperienced and left their calf behind. Maybe they got separated in a major storm. Maybe she died. Maybe the calf just wandered off and got lost. We have seen two interactions between an orphaned calf that approached an adult female with her own calf. We observed these interactions in two different years, the first one in 2012 and the next in early to mid-December 2013. In each case, the cows reacted differently. The first was

In conversation with Katja Vinding Petersen

Photo by Peter Chadwick

Southern right whale *Eubalaena australis* cows and calves seek out calm, gently sloping bay areas protected from the wind. Their goal is to expend as little energy as possible fighting waves.

actively fighting the little calf because she knew she couldn't feed two calves. We could see from the aircraft how this calf just kept trying to get in there to drink and the mother would bang her tail and flippers and scare it off, while her own calf was waiting further away. It was heartbreaking to see how that little orphan was struggling. But it seemed that the orphan we saw in 2013 was accepted by a cow–calf pair. In that case, it was much bigger than the mother's own calf. I think there's a big chance that calf actually survived because we followed them throughout the month, until they left on 30 December.

How do you know which whale is which?

We take ID photos that show each whale's callosity pattern. A callosity is like the rough skin on your elbows. The calves are born with these rough patches on their face and these patches are colonised by a kind of sea lice. The calves inherit the lice from their mothers. Each louse is about the size of a bottle cap – massive!

How regularly do the same whales come back to the Overberg area?

We know from Peter Best's study, which covered the whole coastline, that the majority of the females return to give birth every third year. They have a three-year cycle. In the first year they come here to mate. They are very promiscuous and mate with countless males in a season. Then they swim back down to Antarctic waters to feed. After that they return and give birth to the calf, which they take back south with them at the end of the season. Then they'll take a year off and either stay down there and not come back or bring the calf back as a yearling and wean it up here.

How are these southern rights doing in terms of population health?

There are three main populations in the world and Africa's is the biggest. It's very healthy, and since we stopped hunting southern rights in 1975 it has been increasing by 7% every year. The last estimate was done in 2001. I'm always cautious about these estimates, but we can say that there are at least 6,000 southern right whales in the South African population. There might even be double that. Either way, the population is nowhere near what it used to be. I think it was 100,000! Can you imagine Walker Bay with a population that size? You could have walked on the backs of right whales…

inside stories

Photo by Michael Scholl

There is no shortage of work to be done in the areas of ocean research, conservation and education. In addition to the projects we fund around the world, the Save Our Seas Foundation (SOSF) is proud to directly manage four centres and hold long-term relationships with four NGO partners, all of which are leading vital work to protect our marine environment and wildlife. Of the SOSF centres, two concentrate on education – the Island School Seychelles and the Shark Education Centre – and two are dedicated to research – the D'Arros Research Centre and the Shark Research Center. Located in the Seychelles, South Africa and the USA, the centres extend the on-the-ground reach of the foundation to these countries and beyond. The partnerships we hold with independent NGOs, the Bimini Biological Field Station (also known as the Shark Lab), CetaceaLab, the Manta Trust and Shark Spotters are mutually supportive and closer in terms of funding and communication than our regular projects. Each partner has its own area of expertise and is conducting long-term research and conservation work that goes beyond the normal project cycle length. This is one of the reasons we partner with them; the other is the passionate people who lead and drive this work – and have inspired us. The following pages are dedicated to stories from these centres and partners, and from the great people working there who are leading the charge for marine conservation.

Save Our Seas Foundation project leader Ornella Weideli and Kennedy Warne, writer for *National Geographic* magazine, work together to take a blood sample from a young blacktip reef shark *Carcharhinus melanopterus* in St Joseph Atoll, Seychelles.

Going with

One of the first interesting facts that staff at the Save Our Seas Foundation D'Arros Research Centre told me about the adjacent St Joseph Atoll was that the whole atoll ecosystem is immensely affected by the continuous change of the tides. Before working at St Joseph, the study site for my PhD project, I didn't quite understand the full meaning of what they were saying. But now I've spent four months on the remote atoll, catching juvenile blacktip reef sharks *Carcharhinus melanopterus* and sicklefin lemon sharks *Negaprion acutidens* for my project, and I not only understand what they meant, but have even learned to use the changing tides in my favour.

St Joseph Atoll is subject to the patterns of a mixed semi-diurnal tidal cycle, which means that the magnitude of the high and low tides differs throughout the month, depending on the lunar cycle. Extreme high and low tides, called spring tides, occur around full and new moon, while moderate tides, called neap tides, occur around half moon. Therefore the appearance of St Joseph Atoll changes completely from one extreme to the other within a single month. At spring low tide, large sections of the reef flats are exposed to the heat of the day and transform into a hot, desert-like habitat. At spring high tide, the atoll fills completely with water and nearly disappears into the surrounding ocean. Also, the lagoon's colour changes with the large amount of water that enters from the surrounding ocean, transforming from bluish turquoise to a much darker greenish colour.

Animals that live at St Joseph Atoll have adapted to these extreme changes in their environment by using different feeding strategies and foraging grounds at different tidal stages. At low tide, while my field team and I are struggling to drag our kayaks through the atoll's shallow waters, we suddenly see seabirds all around us. They are feeding on worms and other

the tides

D'Arros Research Centre

Words by Ornella Weideli

Photo by Ryan Daly

creatures hidden in the freshly exposed and still-wet sand flats. However on an incoming spring high tide, the inflowing water quickly fills this exact same place and transforms it into a feeding ground for predatory fish and adult and sub-adult reef sharks. This hectic aggregation of foraging fish quickly turns the water into a murky soup to the extent that we are unable to see the substrate below us.

The juvenile shark population at St Joseph Atoll had never been assessed before, so one of my first tasks when I arrived at the atoll in November 2014 was to locate these animals. I quickly realised that it is not only the seabirds and large sharks that are influenced by the tides, but the new-born sharks too. With the help of my GPS device and precise tidal observations, I discovered that at specific tidal stages in certain areas, I am much more likely to find and catch juvenile sharks.

As my first study objective is to understand at a very localised level which habitats are used by these juvenile sharks and when, I'm tracking them manually to observe the behaviour of individuals. So far we have followed more than 20 individual sharks over several hours in kayaks, constantly recording GPS coordinates, temperature, depths, behaviour and potential encounters with other sharks. During these long days in the field, I wasn't surprised to discover that the movements of both of my study species are highly impacted by the dynamic changes of the tides. At low tide, while seabirds find buried food in the newly exposed sand banks, the extent of the young sharks' favoured habitat (shallow water 30 to 50 centimetres deep) decreases and they are forced to move to other parts of the atoll where water still covers the substrate. In contrast, at high tide, large areas of the atoll are now available to the young sharks, but these areas must be shared with other animals. Large predatory fish and adult and sub-adult sharks make use of the high tide to enter the atoll's flats to forage for prey. Every so often, we see the dorsal fin of a sub-adult lemon shark slicing elegantly through the water as the shark patrols the mangrove-fringed shoreline in search of food. Like the seabirds, these predators are benefiting from the newly available foraging habitats and they sometimes even enter small channels within the dense mangrove forests to look for hidden prey. While watching the lemon sharks foraging, we inwardly hope that they don't cross paths with our juveniles.

One of my favourite discoveries so far while actively tracking juvenile sharks is the existence of what I call 'secret' spots in the atoll. I wouldn't have been aware of these places if I hadn't personally followed the sharks' daily small-scale movements. These secret spots are specific elevations in the atoll that are normally exposed to air and only covered by water during extreme spring high tides, when the water level reaches its maximum height. I believe that under these extreme conditions these elevation spots serve as shallow-water refuges for juvenile sharks, an assumption that the large numbers of young sharks that I usually find in these places seem to confirm. As I always have my GPS with me, I quickly save the coordinates of a newly found spot and make a plan to return to this hidden sanctuary at spring high tide.

The combination of methodical field work and understanding the ecology of my study habitat has contributed immensely to the substantial progress of my study and has made me realise how important it is to observe carefully and interpret the surrounding environment. As marine biologists, we enjoy the privilege of working outside in nature; we need to also think outside of our scientific objectives and deadlines and learn to understand the surrounding world. Doing so can help us not only to answer our scientific questions, but also to open the public's eyes to the wonders of the marine realm.

Photo by Philippa Ehrlich

CHANGING ATTITU

Shark Education Centre
Words by Zanele Mayiya

DES

I grew up in the Eastern Cape, South Africa. Although the ocean is very close to us there, I didn't get a chance to connect with it because of the negative things that people, including my relatives, used to say about it, especially the sharks. They would warn us that sharks like to hide buried in the sand and lie in wait to attack people. When you go to the beach, they said, a shark will swallow you and once you're in its stomach you will find more dangerous animals, like big snakes, and they will kill you.

I started to work for the Save Our Seas Foundation (SOSF) in March 2008 as a housekeeper and in the shop, and at that time I had no idea about the ocean and its creatures. In June 2009 I got an opportunity to join Alison Kock on the research boat to Seal Island, where I saw great whites for the first time. Those sharks were so huge and beautiful, swimming around the boat – I'll never forget it. After that trip I started reading books from the Shark Education Centre's shop, looking for more information about the different shark species. One that I read was *End of the Line*, a book that I think can change the attitude of people who are afraid of sharks or have a negative view of them.

In 2010 I started to help Lesley Rochat, who was the centre's educator at the time, with school groups. By helping her I was trying to open up a way for me to tell young South Africans about what I had seen at Seal Island. While I was looking for information about sharks, I discovered that some of the books featured other animals, like starfish and anemones. Luckily, while I was helping with the school groups one day, the SOSF's former CEOs Georgina Wiersma and Peter Verhoog were visiting the centre. That morning educator Paul Millar and I were exploring the rock pools across the road with the children when Peter and Georgina came along to take photos. Peter listened as I was telling one of the little girls about a starfish – and that's when they 'discovered' me. At the beginning of 2012 I started to listen to Paul's talks and they inspired me. After about the fourth talk, each presented to a different age group, I said to myself, 'This is what I want to do.'

Fortunately in 2013 I was given a chance to prove myself when I was sent on a training course. It wasn't easy for me, as I don't have any experience or background in teaching. However, I told myself to just do it because it is important not only to me, but also to all South Africa's children, especially the ones from rural areas who don't know anything about ocean life. I started my assessment at the end of 2013. Although I was excited about my new position, I was also nervous because I was always asking myself, 'What if I don't make it? That will be the end of me and I will miss the opportunity to tell young South Africans about the amazing creatures that live in the oceans and why they should be protected.' Finally, in 2014, I finished my training and became an assistant educator. I'm so proud to be in this new role.

Most people in townships and rural areas are scared of sharks and even tell their children not to go into the sea because they'll be eaten by a shark. Any small connection to the ocean and its creatures that these children might have had is thus reduced even more. I believe that marine education can be a powerful tool to change attitudes. I noticed that when you talk to children in the school groups that we have had at the Shark Education Centre, for most of them the first animal that comes to mind is the shark; they don't know that the sea is full of different species. That's because the majority of these kids only go to the seaside during the festive season (at Christmas time), even though some of them live within walking distance of the beach. When they come to visit us, I always enjoy sharing their excitement as they learn about marine life, especially the little ones because they will know more about the ocean before they become adults – and that's a good thing for us as humans.

Photo by Cristin Fitzpatrick

Sharing samples and knowledge for global shark conservation

Words by Cassandra Ruck

International collaboration, such as this between researchers in the United States and Sudan, provides an opportunity to share ideas, knowledge and culture.

The day was Friday, 9 January 2015. After battling traffic for an hour, finding the correct parking garage and navigating to the terminal, it was time to find a place to 'chill out'. If you've ever driven in Miami on the infamously crowded I-95 freeway, you will understand that this is quite a feat for a native New Englander who had never been to Miami International Airport. Thankfully, I had a great co-pilot in Cristín Fitzpatrick, my lab mate at the Save Our Seas Shark Research Center (SOSSRC). We found a restaurant not too far from the terminal and plopped down at the bar. I sat there munching on chips and guacamole while awaiting the arrival of a woman, Igbal Elhassan, whom I had only met via e-mail. All I knew was that Igbal was from Sudan, was pursuing her PhD, had sampled thousands of sharks from the Arabian and Red seas in dozens of remote fishing villages, and was visiting the USA for the first time. She had been described to me as 'a remarkable woman'.

Finally, after a few flight delays and three hours at Chili's, Cristín and I were able to greet our new colleague. Igbal walked into the terminal with a huge smile and hugged us warmly. We located her belongings, which had arrived on an earlier flight without her, and ultimately made it back to her home away from home: Hollywood, Florida.

On Monday we got straight to work. With an MSc in fisheries, Igbal found herself in the completely new territory of conservation genetics. Like the spirited woman she is, she came to her new scientific environment with perseverance, enthusiasm and a keen interest to learn genetics lab and statistical methods. Our goal in this collaboration was to provide her with the experience and training that would enable her not only to pursue her PhD, but also to return home with knowledge she could pass on to students in her home institution, the University of Bahri in Sudan. Heavy sanctions limit the resources of Sudanese scientists and it is vital for them to travel internationally to gain skills and knowledge that they can bring home and share.

In order to give Igbal a fully immersive experience, the SOSSRC team of Dr Andrea Bernard, Cristín, Reggie Williams, Megan Earney and myself got started on the samples Igbal had painstakingly collected from fishery landing sites and began working on projects to train her in genetics and contribute to her PhD. We chose to conduct a population genetics study on the spinner shark *Carcharhinus brevipinna*. An important coastal species with a global distribution, the spinner shark is a target of both recreational and commercial fisheries. It takes its name from a peculiar behaviour: bursting from the water and spinning in the air one, two, even three times before falling back with a splash. The spinner shark closely resembles the blacktip shark *Carcharhinus limbatus*, the main visible difference being a black spot on the anal fin that the spinner has and the blacktip lacks. It's a small difference and the two species are often confused – spinner meat is often sold as blacktip meat – but thankfully genetics can always tell the difference, even if only from body parts!

Because of this easily mistaken identity, spinner shark catches are presumed to be vastly under-reported. Based on data currently available, the spinner shark is classified as Near Threatened on the IUCN Red List of Threatened Species™. It is also a commercially important and heavily fished species, so it is imperative that we determine its population structure and genetic health.

As many Florida residents are aware, spinner sharks are migrants: every March, thousands of them, together with blacktip sharks, swim north up the coast of Florida. But we don't know where they go or how far they travel. If spinner sharks undertake long migrations, it is possible that different populations may be genetically linked across broad geographic areas. Unfortunately, though, very little genetic assessment of spinner sharks has been done. In terms of population structure, only one scientific study has been published: in 2013 Pascal Geraghty and his colleagues investigated the genetic structure and demographic history of spinner sharks in the Southern Indo-Pacific Ocean. The results of the study suggest that there are at least two genetically distinct populations of spinner sharks that should be managed accordingly – one in Australian and one in South African waters.

Cue the SOSSRC and Igbal Elhassan. By combining new genetic analyses – of samples Igbal collected from fisheries in the Red Sea and Gulf of Aden and samples obtained by the SOSSRC from the Western Atlantic – with the published genetic data from the Southern Indo-Pacific Ocean spinners collected by Geraghty and his team, we are working to provide a global view of spinner shark population structure and dynamics. Are the spinner sharks in the Gulf of Mexico part of the same population of spinner sharks that migrate off the coast of Florida? Are the spinner sharks in South Africa somehow connected with those in the Red Sea? How does the genetic diversity of Atlantic spinners compare to that of spinners in the Middle East and Southern Indo-Pacific? These are all questions we aim to answer with this collaborative study.

International teamwork such as this provides an opportunity to share not only samples, but also ideas, knowledge and culture. Working together is critical if we are to expand the reach of shark conservation worldwide. It is especially gratifying that by the end of her visit here, Igbal will be adding the powerful tools of conservation genetics to her already impressive expertise in shark fisheries and taxonomy – and transferring these skills to her students in Sudan. Hosting Igbal has been an invaluable experience for the SOSSRC team and we look forward to long-term collaboration with her after she returns home.

Words by Abi March

LOST WORLD IN THE CLASS-ROOM

As I turned the pages of the book, gasps of amazement came from my audience; for each new page they saw, they squealed in delight at the photographs. The audience was a group of seven- and eight-year-olds from a local primary school and the book that made them so happy was *Lost World: The Marine Realm of the Seychelles* by Thomas P. Peschak.

Stunning images of ocean and coastal habitats in the Seychelles and the animals found there fill the book, with informative text alongside them. Words and pictures focus mainly on the Outer Island of Aldabra, a pristine atoll that, at 1,150 kilometres west of the Inner Islands, is far out of reach for most Seychellois. It is brilliant to see how *Lost World* brings the beauty of the Seychelles' marine life right into the students' classroom, making these distant islands and the underwater world around them far more accessible. For many of our future marine ambassadors, the book provides their first glimpse of the animals and habitats they will come to love and strive to protect.

Earlier this year we donated 25 copies of the book to all the public primary and secondary schools across the Seychelles. In February, SOSF CEO Michael Scholl and I formally presented the donation to the education minister, Macsuzy Mondon. Mrs Mondon expressed gratitude for the gift and for the commitment of the SOSF and Island School Seychelles to bringing quality marine awareness to the young people of her country.

The beauty of the granitic Inner Islands is on the doorstep for every Seychellois. Yet, even though the ocean covers 99% of the nation's territory, people know far more about the terrestrial environment. Some years ago I visited the Biodiversity Centre on Mahé with a group of school environment leaders. I was amazed at their knowledge of every tree and plant we came across. However, talking to the same teachers revealed that their knowledge of the marine environment is not at the same depth. At the SOSF Island School Seychelles we are committed to raising awareness of sea and coastal life throughout the community. To do so we work a great deal with local primary and secondary students. However, we recognise that to reach more students, we also need to raise awareness among the teachers.

We want *Lost World* to be used in every classroom and seen by every student. Quite often beautiful books are kept hidden away for fear of little hands damaging them. We do not want these books to be confined to a locked room in the library; we want them to be pored over, the wealth of knowledge they contain to fill young minds. We want to encourage the teachers to take advantage of this valuable resource and share ideas of how *Lost World* can be used across the curriculum. So this term, project assistant Fred Hypolite, project advisor Abbie Hine and I are conducting professional development sessions with all the teachers at all the 34 public schools in the Seychelles. Once we have shown the book to the teachers, they gather in their subject or year groups and brainstorm how they could use it in their lessons.

After each brainstorm session, we listen to the teachers' ideas and share our own suggestions for how *Lost World* can be brought into different subjects. In science lessons at both primary and secondary levels, much of its content lends itself directly to the curriculum: classifications of animals, how they move and reproduce, food chains – the ideas from the teachers were plentiful. Likewise in history and geography: the images and text can give information about the first settlers and how and where islands are formed. In languages and art the book can be used as a source of inspiration for poetry, stories and paintings. Though both Fred and I are teachers, maths is not one of our subjects and when we created the presentation we struggled to come up with ideas of how *Lost World* could be brought into these lessons. However, the maths teachers relished the challenge and we were elated listening to one of them describe the imaginative ways in which he could use the book. When he'd finished, Fred led the whole room in a round of applause!

Fred has loved his first sessions with the teachers, and so far the feedback we have received from them has been very encouraging. We hope they will be inspired to use the resource frequently with their students. As Fred says, 'It gives me satisfaction to know that they have become aware of how to conserve marine life and at some point they will share what they have learned during the session with their students.' In the foreword to *Lost World*, the president of the Seychelles, James Michel, echoes our sentiments: 'It is my hope that this book will instil a sense of wonder in the seas around Seychelles and awaken a sense of responsibility for caring about the unique life they sustain.'

As the teachers are the main contact the students have with environmental education, we feel it is important for them to be passionate about marine life so they will want to share their knowledge and experiences with their students. In order for them to immerse themselves in the underwater world, we are encouraging all teachers to join us for snorkelling sessions. Already they are signing up to participate, a decision no doubt influenced by spending a few hours with *Lost World*. We can't wait for these teachers to discover the marine realm with us.

The SOSF has also produced two workbooks aimed at secondary school students to accompany *Lost World*, one about Aldabra and one about the granitic islands. These can be downloaded from our website.

We would like to thank the Ministry of Education, especially the Environmental Education Unit, for supporting our work with teachers and schools.

The Island School Seychelles donated 25 copies of *Lost World* to all the public primary and secondary schools in the Seychelles earlier this year.

Photos by Abi March

Bimini Biological Field Station

Words by Tristan Guttridge

At the Bimini Biological Field Station, aka the Shark Lab, one of the highlights for most volunteers is checking our shallow-water long-lines. There is something special about getting up in the middle of the night and working against the elements – blustering winds, biting insects, rain, thunder and lightning – always in anticipation of working with a huge tiger shark! 'No matter what the conditions, we must check the lines,' Samuel 'Doc' Gruber's words echo around the lab.

In 1992, soon after Doc had established the Shark Lab at Bimini in The Bahamas, long-line surveys were begun with the initial objective of examining the assemblage of large sharks in the vicinity. To this day, our team sets five lines each month. As a former volunteer, PhD candidate and now the director of the Shark Lab, I have had the good fortune to participate in many checks, but few are more memorable than one night in September 2014. It was just one of those occasions when I had a sneaking feeling we were in for a busy time!

For some reason, tough conditions and lots of sharks seem to go hand in hand. It's as if the sharks are out to challenge us: 'Calm, flat seas – no bite tonight', whereas 'White caps, torrential rain and thunder – yes, that bait looks scrumptious!' And on this particular night, of course, it started to rain within minutes of our departure from the shelter of the lab. Despite the adverse conditions, our team was in great spirits and excited to accept the challenge set by Mother Nature. We located the first line, at the south end of the Bimini lagoon, and quickly illuminated the hook floats with our Q-beam, targeting them through the choppy waves. The count began. 'One, two... Oooh, can anyone see float number three? Wooohoooo, it's down.' Flash of a tail, a dorsal fin slicing through the water. 'It's a blacktip!' exclaimed Jack, the current lab manager.

For anyone who has not come across a blacktip shark before, this species epitomises what many people imagine a shark to be: powerful, sleek and streamlined, with the notorious torpedo-shaped body and a water-piercing, triangular dorsal fin. This particular individual must have just been hooked, as it was full of life. But, no matter how spiritedly the shark may fight, it was crucial for our team to work fast because unlike some species (such as nurse sharks) that can actively pump water over their gills, the blacktip must swim to breathe. This is called obligate ram ventilation and it makes these sharks sensitive to capture because they expend a lot of energy in their initial attempts to escape.

With this in mind, we worked quickly to secure this individual alongside the boat, nose to bow and tail to stern. One team member held the dorsal fin to stabilise the shark while others recorded length measurements (pre-caudal, fork and total lengths) and other biological information such as species and sex, took a tiny piece of fin for genetic and dietary analysis and, as this one was more than 1.2 metres long, attached a National Marine Fisheries Service dart tag for future identification. Additional comments about the shark (such as hook location and mating scars) and about environmental conditions (such as water depth and temperature) were also noted. After all the information had been recorded in the logbook, the shark was released with a strong push to start it swimming.

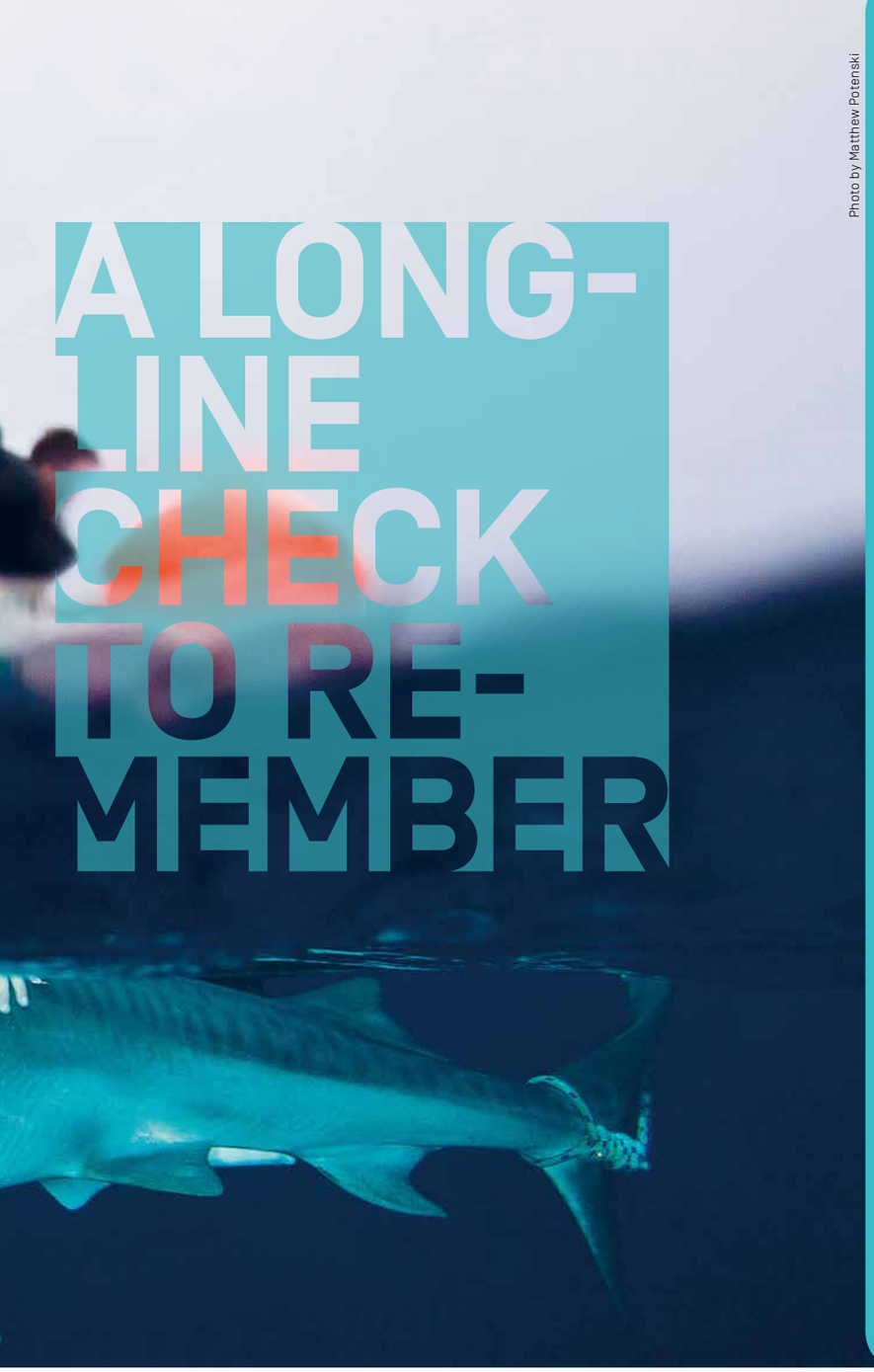


Photo by Matthew Potenski

A LONG-LINE CHECK TO RE-MEMBER

HOW LONG-LINING WORKS – BIMINI STYLE

From the 1960s onward, Dr Samuel 'Doc' Gruber, the founder of the Shark Lab, tested and utilised bottom-set long-lines in comparable habitats off Virginia Key, Florida. During the 1980s he expanded their use to his two-week research cruises to The Bahamas, and since the early 1990s the Shark Lab has been using a modified long-line technique adapted from the National Marine Fishery Service's pelagic set-up.

To this day, our team sets five lines monthly: four that run north to south down the east side of Bimini's main lagoon and a fifth 'roaming' or wild card line that is deployed in a new location each time. The lines are 500 metres long and have 15 gangions at 30-metre intervals, which are secured with anchors and marked with floats at each end. Circle hooks are used to avoid hooking the shark in the gut and reduce the by-catch of non-shark species. Lines are typically set in the early afternoon, allowed to soak for 24 hours and are then checked every three to five hours.

To get a feel for the sharks we catch on our shallow water long-lines, these are some results from our 2004–2014 surveys.

Summary: 132 long-lines set, totalling 9,900 circle hooks.

Species composition: 684 sharks representing nine species were captured. Most (95%) were tiger (30%), nurse (30%), blacktip (25%) or lemon sharks (10%), but other species included sharpnose and bull sharks. Interestingly, early analyses have revealed that the lemon shark was once the dominant species in Bimini, with a high capture rate in the 1980s. In the past few years, however, we have seen a real surge in the number of tiger sharks.

Smallest and cutest: 69-centimetre juvenile lemon shark.

Biggest and baddest: 3.85-metre tiger shark.

Preliminary capture patterns: Triple the numbers of blacktip, nurse and lemon sharks are caught during the wet season (summer). Tiger sharks are captured year-round.

Most extraordinary recapture: A juvenile tiger shark (measuring 2.2 metres total length) was captured at Bimini in July 2014 and recaptured east of Bermuda in February 2015 – a massive trip of 1,560 nautical miles in seven months.

We accomplished everything in a lightning-fast, five-minute work-up – like a racing car pit stop!

Excitingly, blacktip #2 was just a few hooks away, and so the process began again. This time we switched roles, allowing our international volunteers to gain valuable hands-on experience. It was at this point that the gentle drizzle turned into a torrential, tropical Bahamian downpour. Within a few minutes we were drenched and forced to come up with imaginative ways to record data in the logbook. A drink cooler that we call a 'dry box' doubled as a makeshift shelter.

We completed the 'pit stop' work-up on five more occasions that night, bringing our tally for the check to seven female blacktips that ranged in length from 1.2 to 1.82 metres. Happily, all these delicate sharks swam off vigorously when released and, despite our waterlogged exterior, the team was full of excited chatter on our return to the Shark Lab. 'We cheated death', 'My favourite experience at the Shark Lab so far' were just a few of the comments I heard as we tied up to the dock. Based on our long-term monitoring of Bimini's populations of large sharks, we have come to expect higher catches of blacktips towards the end of the summer months, but seven on one check in extreme weather conditions was certainly an entry for the diary!

Due to the longevity of our research programme, the long-line survey has enabled us to investigate population trends for large coastal sharks over the long term. The main species in question – lemon, nurse, blacktip and tiger sharks – are abundant in the commercial shark long-line fisheries of the north-west Atlantic and our longitudinal study can contribute important regional data that are species-specific and will improve management of these species and ultimately their conservation. Furthermore, biological samples taken during surveys have contributed to our study of the genetic family tree, mating system and life history of the lemon shark, and have identified how blacktips captured in The Bahamas and the United States belong to different populations.

Our 30-year data-set is currently being scrutinised by University of Massachusetts Master's student Alex Hansell in collaboration with former Shark Lab PhD candidate Dr Steve Kessel of Windsor University, Canada. They are assessing how the shark assemblage in Bimini's environs has changed over time and how other factors, such as water temperature, lunar cycle, bait type or soak time, might influence our catches. Importantly, with this historical data-set we are able to examine long-term trends in shark abundance, which improves our understanding not only of natural population fluctuations, but also how they are disrupted by anthropogenic influences. This is particularly important for top predators that can exert controlling influences on the ecosystems they inhabit and may be susceptible to human-driven population declines. Finally, given the recent designation of The Bahamas as a shark sanctuary, it is hoped that in the future this study can be used as a benchmark against which a continued long-line survey will be measured to assess the effectiveness of the sanctuary in protecting regional shark populations.

Indonesian Manta Project | Words by Sarah Lewis

Conserving mantas with compassion and inspiration

Photo by Shawn Heinrichs

In January 2014, Indonesia's Minister of Fisheries and Maritime Affairs announced new regulations that afford full protection to reef and oceanic manta rays; no longer operating the biggest manta ray fishery in the world, Indonesia is now the planet's largest manta ray sanctuary. This law represents a significant milestone for manta ray conservation. It marks, however, just the beginning of an extensive process to ensure that Indonesia's mantas are truly protected.

Ultimately, species conservation is about changing human behaviour, as it is human behaviour that has become the primary driver of the global decline of species. The societal aspects of conservation are often overlooked, however, with the result that well-intentioned initiatives often falter when they fail to engage communities in the conservation process. My recent experience with Indonesia's manta regulations cemented my conviction that these 'human' factors are the defining variables in effective conservation.

When this landmark legislation came into force, the Indonesian conservation community rallied behind it, creating a wave of inspirational media activity leading up to, and following, the announcement of the new law. Powerful imagery and stories about Indonesia's manta rays featured in the press around the world, building national pride and inspiring the global community to believe that significant conservation successes can be achieved in even the most challenging places. Once the media attention had subsided, though, everyone was anxious to see whether Indonesia would live up to its new title as 'the world's largest manta sanctuary'.

Indonesia is a vast country spread across more than 17,000 islands and enforcing the law was not going to be easy. However, just months after it had been passed, the Wildlife Conservation Society (WCS), working closely with the Indonesian government, made headlines announcing the arrest of several traders in manta gill plates in Bali and Surabaya. These arrests, swiftly followed by prosecution resulting in heavy fines and unprecedented prison sentences of up to two years, sent a decisive message that Indonesia was serious about protecting its mantas! They marked the beginning of a series of covert sting operations and prosecutions that are now dismantling the manta trade network in Indonesia.

Law enforcement is only one facet in a comprehensive manta ray conservation strategy, however; research also plays an important role. In partnership with the Indonesian government, Conservation International and other organisations, The Manta Trust is conducting research to gain a deeper understanding of the country's manta ray populations. Its Indonesian Manta Project employs various research techniques – photographic identification, acoustic and satellite tagging, genetic analysis, community interviews, fishery surveys – that together enable us to collect key data that create a nationwide knowledge base of manta ray distribution, population ecology and threats. Thanks largely to the support of the Save Our Seas Foundation, we have made significant progress in unlocking some of Indonesia's manta mysteries and helping the Indonesian government to make more informed management plans for the species.

After witnessing at first hand the depressing scenes of fished manta rays despite the creation of the manta sanctuary, I realised that enforcement and ecological knowledge alone are not enough; it is also vital to understand how social factors affect human interactions with the environment, especially where communities depend on natural resources for their primary livelihoods. Our mission is to employ a more holistic approach to species management – one that takes into account the circumstances of fishing communities and engages them in the formulation of solutions that address their needs.

Lamakera, a remote community that is believed to be the world's largest manta ray fishery, has become the focal point of this approach. Working alongside fellow marine conservation organisations Reef Check Foundation Indonesia and Misool Baseftin, the Indonesian Manta Project has engaged the community in a long-term initiative to transform its focus from hunting to research, tourism and sustainable fisheries. We began by listening to and working with the local people to identify how best to do this. Having now spent a fair amount of time in this community, I admit this undertaking seems daunting, especially in view of the sensitive cultural and economic issues. There is hope, however, as the community is now committed to working with us to develop alternative livelihoods. The hunters have also shown a surprising empathy towards the mantas they catch. One encapsulated the dilemma they face: 'We don't want to be cruel. It's sad to catch them. But it's also sad to be hungry. We feel sorry for them, but we also feel our bellies.'

The waters surrounding Lamakera are some of the most productive in the region, attracting an abundance of megafauna, including oceanic manta rays, whale sharks and several whale and dolphin species. As a result, we identified ecotourism based on ocean safaris as an excellent alternative livelihood opportunity, with the community's unique culture and traditions as an additional drawcard. We are working with the local people to develop these options by means of community training, biodiversity surveys and mock tourist assessments.

A properly orchestrated transition programme is essential if the Lamakera community is ever to fully realise the potential of marine ecotourism and sustainable fisheries. The cornerstone of this transition is our community-based research initiative. Lamakera fishermen have inexplicable skills in locating manta rays and a wealth of knowledge about the local ecology, which we are now leveraging for research purposes instead of hunting. Community members are being trained and employed as manta researchers, providing an alternative livelihood that incorporates traditional knowledge while simultaneously unearthing important information about this manta population. It is inspirational to witness the excitement and joy of a hardened hunter when he first interacts with a live manta – an experience that can transform his life. We have now engaged all the primary hunters and they are eager to learn and become full members of the research programme.

Our philosophy remains the same: focusing on building relationships of trust with these communities. With their involvement at the heart of the Indonesian Manta Project, we ensure initiatives end up with strong local ownership. Indonesians have immeasurable natural treasures to take pride in and, as outsiders looking in, we have an opportunity to empower these communities to celebrate and protect their natural environment, while simultaneously deriving sustainable livelihoods.

Photo by Michael Scholl

CetaceaLab | Words by Janie Wray

The Wall Islets

I roll out of bed, grab my boots and reach for my camera. Two steps to the sliding door and then I am on the deck and suddenly very awake. A north-west wind chills me to the bone, but there is no time to go back for a sweater. Five humpback whales are surfacing together, only metres from shore. There is just enough light to take photos as they dive, massive tails lifted to the sky. They are gone as quickly as they appeared.

This is the start to another day at the Wall Islets, a cluster of tiny islands in the middle of Caamano Sound off the north coast of British Columbia: our own Galapagos of the Great Whale Sea. Today I am the only human on this island; even the larger islands in the distance are uninhabited and rarely visited by people.

In place of phones or the Internet, there is the sound of the ocean reaching for the shore. Through millennia the waves have smoothed the edges of this one big granite boulder that makes up the body of the islet. Just beyond the shoreline kelp beds trail dark golden fronds against the ebbing tide. Above me an eagle's nest sits empty near the top of an ancient cedar tree. Leaves drip with dew that shines with life as the first rays of morning light start the day. I turn back into the cabin to get the coffee going.

This small shelter perched on a cliff overlooking the sea is one of the research outposts built by the North Coast Cetacean Society (NCCS), a non-profit organisation dedicated to whale research and conservation. NCCS operates a main facility at CetaceaLab on Gil Island, at the mouth of Douglas Channel. We built this outpost to study the movement of orca and humpback whales that spend time here from May until late October. Years ago we had installed a hydrophone – an underwater microphone – in this isolated location to determine if we could record any presence of whales. We were in for the shock of our lives!

We secured the hydrophone just offshore at a depth of 18 metres (60 feet) and threaded the cable up through the intertidal zone to a land-based transmitter. Back at CetaceaLab, we turned on the system and started listening. Soon we were recording a steady stream of humpback feeding and social calls. Unexpectedly, we also realised this area was an orca highway! Every day we heard the chatter of talkative orca pods.

Clearly, there was a lot going on at the Wall. We decided to station an observer here to gain more insight. Having chosen a bluff that offered a 180-degree view over the open sea, we scoured nearby beaches for straight driftwood posts, strapped sheets of plywood to our boat and started building. The result is a simple one-room cabin with no plumbing and just enough power to charge a laptop. Equipped with a camp stove, a coffeepot and a massive pair of binoculars called 'Big Eyes' set up on a tripod, it was all we needed.

Then the fin whales arrived. Fin whales are the second largest creatures on the planet, but they can be hard to detect, communicating at a frequency lower than the human hearing range so their calls often go unnoticed on hydrophone recordings. Once we had

and whales

an observer at the Wall, we found that this is one of the few places where fin whales pass very close to shore. With humpbacks and fin whales returning in ever-greater numbers to the northern coast of British Columbia, it turned out that we had a front-row seat.

For all these whale populations – northern resident and Bigg's orcas, humpbacks and fins – this area of the British Columbia coast is vitally important habitat. The underwater soundscape is one of the quietest along the coast of North America, and these are some of the world's most productive cold-water seas. It is an exceptional feeding, rearing and social space. It is also an unparalleled research setting.

CetaceaLab's 15-year history of year-round visual and acoustic data is the foundation of a growing number of research projects aimed at improving our understanding of cetacean ecology, behaviour, habitat use and social structures. The use of outposts like the Wall broadens our range and enriches our research by enabling us to track the movements of individuals and groups through the area.

The Wall's peaceful setting is a contrast to our growing anxiety about the future of this place and the well-being of the whales that depend on it. Development pressure is increasing on this wild coast, and the possibility of seeing hundreds of oil and gas tankers travelling these waters is very real. At CetaceaLab, we are racing against time to make the case that the Great Whale Sea needs protection.

For now, however, the sense of urgency falls away as I settle into the day's work. By 7 am I am looking for whales: methodical scans every 30 minutes, from one end of the horizon to the other. I keep a hand-held radio tuned to the hydrophone and my camera at hand. Before the day is over I have seen the short puffs of orca blows, heart-shaped plumes from humpbacks and the tall, pillar-shaped blows of fin whales.

As the sun sinks into the ocean towards the west, a telltale ring of bubbles appears on the water nearby and the surface erupts with the enormous gaping mouths of feeding humpbacks. Further out, I can see the black dorsal fins of a small pod of orcas. Soon I will pull the Big Eyes into the cabin for the night. I am already looking forward to my bunk and to one of the greatest privileges I know: falling asleep in a tiny cabin on a windswept rock, suspended between a sky bright with stars and a sea alive with the calls of whales.

The Wall Islets, a cluster of tiny islands off the north coast of British Columbia, Canada, are home to an isolated research station of the CetaceaLab's.

Securing the future of sharks and rays through science

3rd Southern African Shark and Ray Symposium

Shark Spotters | Words by Alison Kock and Sarah Waries

South Africa has one of the richest chondrichthyan (shark, skate, ray and chimaera) assemblages in the world, with 204 species described so far. But shark and ray populations in southern Africa are facing considerable threats from overfishing, habitat destruction, persecution and climate change. To secure a future for sharks and rays we need current scientific information about their biology, ecology, population trends and behaviour to guide effective management and conservation strategies.

In September this year, Shark Spotters and the Save Our Seas Foundation hosted the third instalment of the Southern African Shark and Ray Symposium at False Bay, Cape Town. The overarching goal of the symposium is to advance the scientific knowledge of sharks and rays in southern Africa – and ultimately to secure their future.

The symposium was well attended, with 110 delegates representing major academic institutions, government agencies, NGOs and industry. Networking opportunities between scientists, managers and policy-makers were consequently abundant, encouraging collaboration between the various stakeholders. It is through working together in this way that we stand the best chance of conserving sharks and rays.

A generous grant from the Save Our Seas Foundation allowed for travel grants and student support. This resulted in an overwhelming student response; more than half the participants were students and early-career scientists. Science can be a tough space to navigate and resources such as funding and advisory support are limited. Being able to connect with experienced researchers can help students to advance their scientific goals and avoid pitfalls.

Most previous research has focused on fisheries or a handful of charismatic species. This year there were 34 presentations on a minimum of 25 different species, covering diverse topics from shark deterrent and mitigation, trends in fisheries' catches, vulnerable species, movements, diet and trophic interactions, and new methodologies to address more complex questions. Many of the talks focused on endemic and less charismatic species, some presented comprehensive overviews of shark diversity and management plans and others highlighted the importance of collaboration between scientists from different areas, as well as between disciplines. A couple of presentations from government representatives provided valuable information to guide scientists on how they can work with government to support the challenging and ambitious goals of policy and management.

It was clear that one of the major obstacles to furthering shark and ray research in South Africa is lack of resources. There are many students wanting to tackle this research, but limited funds and opportunities are inhibiting their growth and advancement. Participants discussed ways of getting creative to attract funds, such as using charismatic sharks or rays as umbrella species or collaborating on large-scale national projects that address a wide range of ecological questions in order to leverage funding. Although there were two studies on species from Mozambique, a target for the symposium's future growth is to garner greater participation from other southern African countries.

A full day of workshops followed the two days of scientific presentations. The Two Oceans Aquarium hosted a valuable and in-depth workshop on the safe handling and care of sharks and rays when working with them in the field. A hands-on component enabled delegates to acquaint themselves with common equipment used to secure and ventilate sharks and to get guidance from a veterinarian on best practice for any invasive techniques they may use. The Save Our Seas Foundation, together with its Shark Education Centre, provided thoughtful and useful information about communicating science, from using social media and film to providing advice on how to engage effectively with journalists. Finally, new software that automatically matches images of sharks' dorsal fins, with the aim of building a global database for white sharks, was presented.

In addition to this year's scientific agenda, we included two events to get the public involved and held our very own False Bay *Shark Week*. The goal was to celebrate our beautiful ocean and its diverse inhabitants, both two-legged and those with gills, fins and flippers. A #LoveFalseBay speaker evening and outdoor photo exhibition were designed to connect people with False Bay's secret underwater world, to create awareness for both positive and negative interactions with our ocean, and to remind people of the special place we live in and how we as a community can ensure it stays that way. Lastly, the Shark Education Centre, Shark Spotters and Waves for Change held a special education day for members of the Cape Flats community.

The symposium and public events were truly inspiring. The major goals, namely advancing science, fostering collaborationf, public involvement and providing leadership to younger scientists and students, were achieved and this gives us hope for the future of shark and ray science in southern Africa.

HIGHLIGHTS OF THE 3RD SYMPOSIUM

The previous symposia were hosted by the KwaZulu-Natal Sharks Board in 2011 and Oceans Research in 2013. This year Shark Spotters and the Save Our Seas Foundation hosted the third instalment in September.

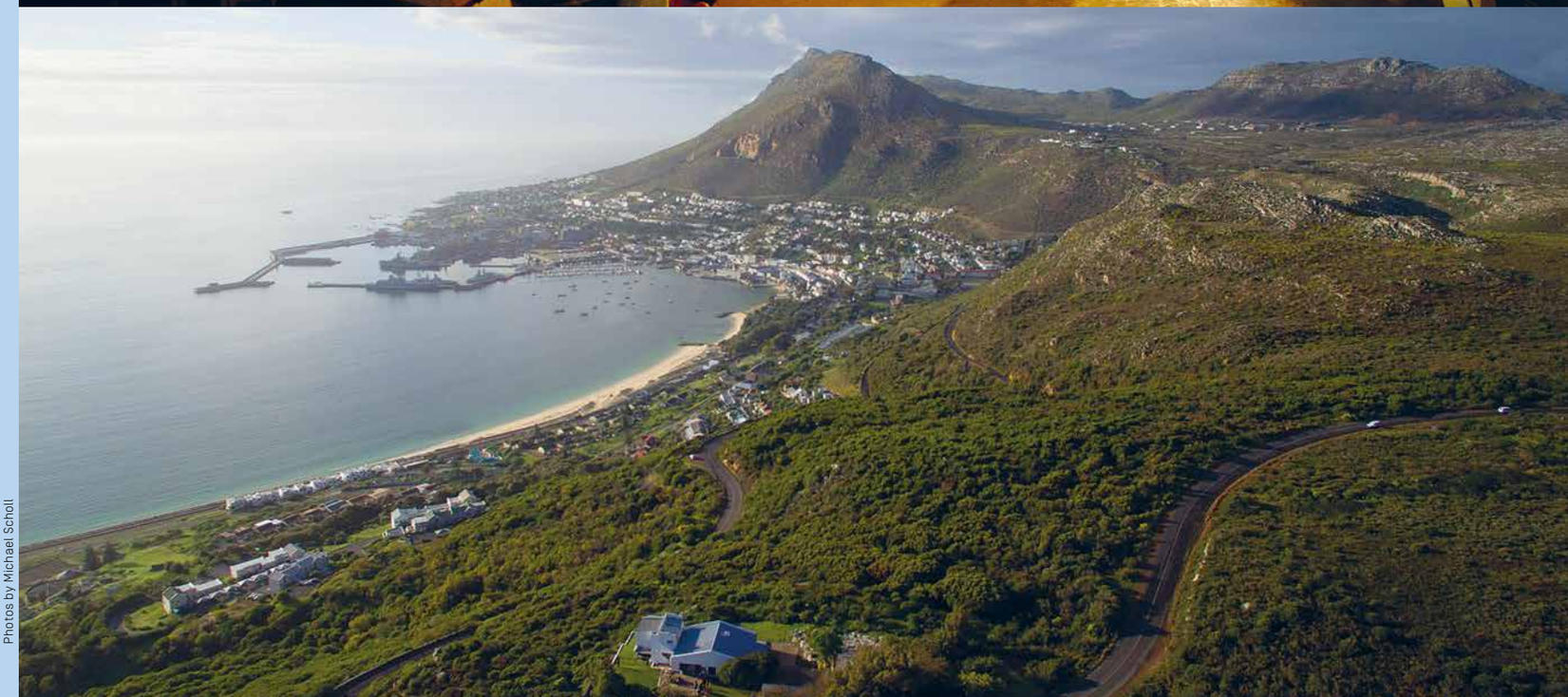
Best professional presentation: Gregg Oelofse, City of Cape Town, who presented on the challenges and lessons learnt from dealing with shark bites in Cape Town.

Best student presentation: Gibbs Kuguru, Stellenbosch University, who presented his research on the genetic structure of smooth hammerheads in Mossel Bay.

Dr Malcolm Smale from Bayworld was recognised for his outstanding contribution to shark science.

>500: The number of people attracted to the #LoveFalseBay speaker evening.

The spectacular Blue Horizon Estate, with its beautiful vista over False Bay, was the venue for the event.



Photos by Michael Scholl

MARINE CONSERVATION PHOTOGRAPHY GRANT

CALL FOR ENTRIES

The Save Our Seas Foundation believes that photography is a powerful tool for marine conservation. We seek emerging conservation and wildlife photographers with a passion for marine subjects to apply for our 2016 grant. This is a unique opportunity for photographers to go on assignment, earn an income and gain experience under the guidance of *National Geographic* photographer Thomas Peschak.

Visit *www.saveourseas.photo* to find out more, and explore our 2014 grant.

Photo by Tom Peschak

Applications close

January 15 2016

Photo by Martin Etrmiska | SeaPics.com

Next issue

The oceans, although they cover more than half of the planet, are minimally protected. On land, around 15% of the earth's area is protected; in the sea, this number is close to 4%. Next issue, we will cover the controversial topic of marine protected areas, their benefits, drawbacks and the hope we place in them. These scalloped hammerhead sharks *Sphyrna lewini* are gathered at Cocos Island, a national park of Costa Rica.

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 less than 10 years the Save Our Seas Foundation has grown to become a major player in the fight to save the world's oceans and the wealth of marine life they contain. While the SOSF itself is not a research institute, its generous contributions of financial, practical and scientific support have, to date, facilitated more than 160 marine research and conservation projects around the world.

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

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