APEX PREDATOR

CAN A CREW OF SCIENTISTS AND VOLUNTEERS ARMED WITH HOMEMADE TRACKERS SAVE SHARKS FROM EXTINCTION?

BY BRIAN LAM

DATA DRIVEN Dr. Neil Hammerschlag (wearing a gray T-shirt) tracks sharks using a new kind of marine-animal tag that he helped design. His data could describe behavior and migration patterns in moment-by-moment detail.

I'M ON A SMALL BOAT.

A woman in a bikini stands next to me dumping gallons of blood into the sea. Beside her, a man in board shorts strings barracuda heads onto large fishhooks as crooked as a witch's finger, and in front of him, toward the bow, an engineer fiddles with an instrument that looks like a cross between a model rocket and a giant hypodermic needle. I'm covered in fish guts.

TAGGING GROUNDS The Bahamas' South Berry Islands Marine Reserve contains 70 square miles of cays and sand flats.

We are in the Bahamas, in a marine preserve, fishing for sharks. We have a research permit to do what's otherwise illegal in this country, but the boat and its crew have a rough, paranoid quality to them, everyone as superstitious as pirates. Since I came on board, we haven't had a single strike. The ocean seems empty, the crew is agitated, and I get the sense that I'm being blamed for the dry spell. The lead fisherman tells me flatly, "I think you're bad luck."

Just as the captain raises the anchor to motor to another spot, a spool of 900-pound monofilament begins unwinding furiously off the stern. A buoy attached to the line pinballs across the choppy ocean. A cameraman in a wetsuit readies his $50,000 waterproof HD-camera rig. A scientist grabs a steel lasso and a cordless drill, and an engineer snatches up the rocket-looking thing, which includes a plastic tube filled with sensors and a satellite transmitter.

The rocket-looking thing is one of the reasons we're all here. It is a prototype of a new kind of shark tag, one designed to last decades, not days or months as current models do. It will record a shark's behavior every few seconds, beaming back data when it can. If the tags work, scientists will get an unprecedented look into the secret lives of sharks. But in order for them to work, we have to tag a shark. And to tag a shark, we have to catch one.

Then the line goes limp, and the hook comes up empty.

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THE SHARK'S ROLE in our oceans is almost entirely a mystery. Because scientists typically track sharks for only a few months and because sharks live for decades, the gaps in our knowledge are immense. We don't know—with much detail—their migration patterns or where they mate and give birth. More important, we don't understand their contribution to the health of the oceans, though it's almost certainly significant. Most sharks are apex predators, akin to lions on the African savannah or polar bears in the Canadian Arctic, and those predators typically serve critical roles in maintaining the ecosystem.

One thing scientists do know is that sharks are in trouble. Every day, more than a quarter-million sharks die as bycatch or as a result of the finning trade. Some ecologists say populations are down by 90 percent from just a few decades ago. No one knows what might happen if they fall beneath a certain threshold or disappear entirely.

"The ocean is like a fancy Swiss watch," says Neil Hammerschlag, director of the marine conservation program at the University of Miami. "I don't know how all the gears work together. But I do know that if you take a major spring out, it's not going to work as well as it is supposed to."

"THE OCEAN IS LIKE A FANCY SWISS WATCH. IF YOU TAKE OUT A MAJOR SPRING, IT'S NOT GOING TO WORK AS WELL AS IT IS SUPPOSED TO."

CATCH AND RELEASE A captured hammerhead will often struggle until it dies from exhaustion, so tagging operations need to be as fast and gentle as possible.

Hammerschlag, 34, spends nearly every weekend out on the water in South Florida, armed with hooks, lines, and tags. As a result, he is intimately acquainted with the limits of current technology; most tags, he says, are too expensive and don't last long enough. Two years ago, he partnered with Marco Flagg, an engineer, to develop a new device. The production version of the HammerTag, he says, will last years and maybe even decades attached to a shark; it will be hundreds of dollars cheaper; and it will provide a thousand times the data.

Data, Hammerschlag says, will lead scientists to identify nurseries and hunting grounds for the first time. It will reveal life cycles to determine when the animals are most vulnerable. And with enough of it, conservationists could influence legislators. Without effective legislation, Hammerschlag says, shark populations will surely continue to decline—and the ocean with them.

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THE DAY I'M SUPPOSED TO FLY from San Francisco to the Bahamas to go shark tagging, I fall ill. The fever's slight, but the

cough is the kind that makes your brain rattle in your skull. I manage to let Hammerschlag know I'll miss the plane and try for one the following day. Then I pass out. Twenty-four hours later I wake up and still feel terrible, but I pack my fins, underwater camera, mask and snorkel anyway. I send the crew members of the research vessel an e-mail saying I'll be arriving by seaplane—the ship is already 25 miles north of Nassau. They write back that they'll send a speedboat to pick me up. At the end, they sign off, "Request you bring five cases of beer."

A red-eye brings me to Nassau, where I deplane, pick up the beer—five cases of High Rock—and meet my seaplane pilot, Paul, who is wearing jean cutoffs and no shoes. Paul has lived in the Bahamas his entire life and has been flying nearly half of it. He rests his toes on the aluminum pedals and says, "Once you fly barefoot, you can never live anywhere else."

After jamming all the beer inside Paul's tiny plane, I climb in. Paul tells me the research vessel is about 30 minutes away, somewhere between the Berry Islands and Chub Cay. When I first heard that we'd be working from a research vessel, I imagined some grotty live-aboard, given the current state of scientific funding. Not so. The vessel I am flying to meet has a robotic sub, a six-person helicopter, full dive gear, surfboards, Jet Skis, and small, medium, and large tender craft. It also has shag carpet, a hot tub, a bar, an interior design reminiscent of a James Bond set, and a fully uniformed crew, including a chef from Australia. Hammerschlag, it turns out, has some wealthy backers who are willing to let him use their boat. The only stipulation is that passengers sign a nondisclosure agreement. Apparently, the ship's owners would rather not be named.

As we approach the Berry Islands, Paul angles the plane toward the ocean. The stall sensor goes off a split second before its pontoons slap the water. We're at low tide, so the water is only about knee deep. I kick open the door and hop down into the lagoon. After a little while, a zodiac from the research vessel shows up. I begin loading the beer and my luggage into the craft, and I ask the driver, "What did I miss?"

"We just caught a 10-foot hammerhead and two juvenile tiger sharks," he says.

"Where's Neil?" I ask.

"He got cut up pretty bad wrangling the second tiger."

THE VESSEL HAS A ROBOTIC SUB, A SIX-PERSON HELICOPTER, FULL DIVE GEAR, SURFBOARDS, JET SKIS, AND SMALL, MEDIUM, AND LARGE TENDER CRAFT.

Pretty bad, it turns out, means 15 stitches in his finger and blood everywhere. When I see Hammerschlag on the research vessel, he is wearing a large bandage and looks concerned. "Please don't make a big deal out of my cut," he says. "I grazed my finger on a tooth. It wasn't an attack." He then launches into a volley of shark trivia meant to be comforting. For instance, while shark attacks number 80 a year globally, he says cases of humans biting other humans average an impressive 1,600—and that's just in the state of New York. Also, sharks tend to mistake humans for food in brackish water, not in clear salty water like the Caribbean. And he explains that during the last moments of their attack, sharks don't rely on sight or smell. Instead, they rely on gel-filled electromagnetic sensing pores called the ampullae of Lorenzini for direction. It is because of this sixth sense, Hammerschlag theorizes, that he is standing before me with a bandaged hand. As the crew maneuvered the shark onto the stern, it sensed the whirling metal propeller nearby and twisted violently. Without malice or intent, its tooth—corkscrewed on one side to cut through turtle shells—simply happened upon the soft flesh of his finger. It was not an attack.

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I HAVE TIME ONLY TO DROP my baggage by a bunk when I get a tap on my shoulder. It's time to go tagging. I jump on the little boat that will serve as our platform. Scattered over the decks I see spools of lines and giant hooks. It is then that I realize that shark tagging is actually a lot like sport fishing—but with a rodeo at the end. My colleagues on the boat, a combination of shark conservationists and eco-conscious volunteers, would disagree with me. Science and sport are separate, they would say. But it sure does not look like it.

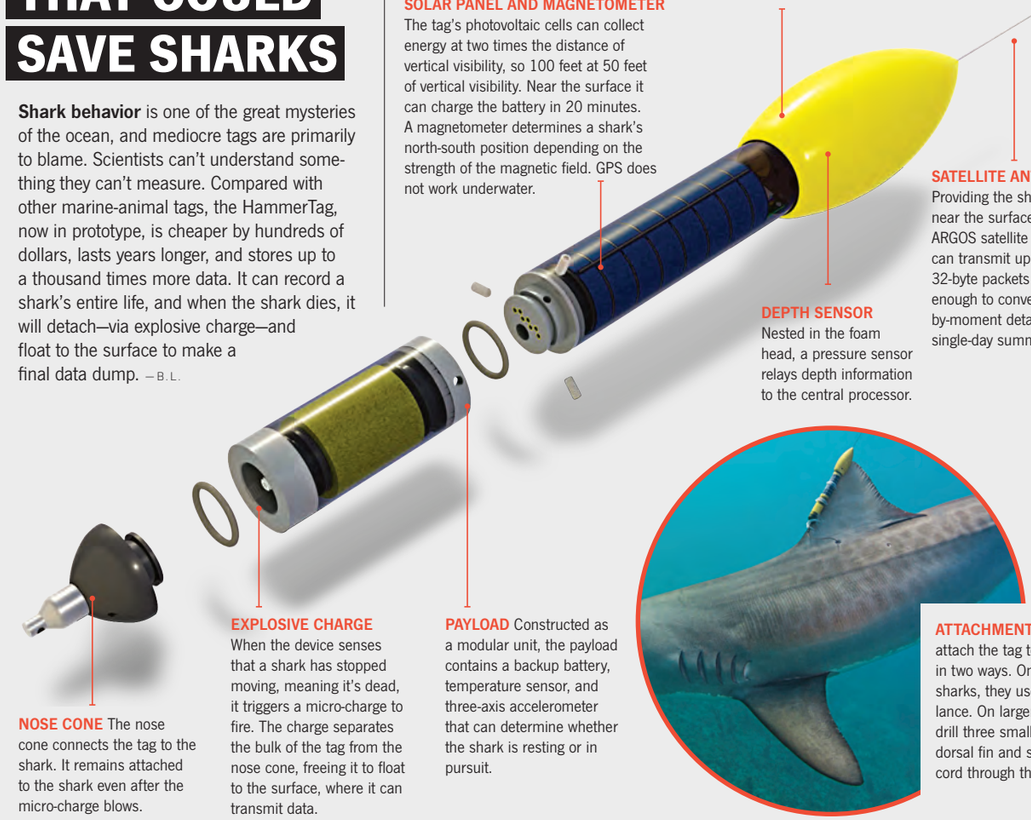
Amid the fishing-like gear, sit several buckets and pipes drilled with holes and stuffed with guts. These are called SADs, or shark attractant devices, and they are thrown overboard to bleed all night in the warm sea. There's also a four-foot-long cooler filled with chum: fish heads; rotting barracuda, jack, grouper; and a few gallons of fish blood. I ask Hammerschlag what he calls it, but he doesn't have a name other than "the cooler," which sounds boring. I christen it "the Chum Coffin."

As soon as the hooks are out, we chum. The waters run red with blood and white with chunks of hand-mashed fish from the Chum Coffin, leaving an oily sheen on the surface. A field tech, nicknamed Dirty Curt, warns divers to stay clear of the slick.

TEAM SHARK Hammerschlag, fellow scientists, and students prep a shark together. During tagging, they pipe oxygenated water over a shark's gills to ensure that it continues to breathe.

THE TAG THAT COULD SAVE SHARKS

Shark behavior is one of the great mysteries of the ocean, and mediocre tags are primarily to blame. Scientists can't understand something they can't measure. Compared with other marine-animal tags, the HammerTag, now in prototype, is cheaper by hundreds of dollars, lasts years longer, and stores up to a thousand times more data. It can record a shark's entire life, and when the shark dies, it will detach—via explosive charge—and float to the surface to make a final data dump. —B.L.



"Did anyone explain to Brian how Curt got his nickname?" Virginia Ansaldi, Hammerschlag's lab manager, asks.

"No, and don't tell him," Hammerschlag says. Curt, who looks a bit like Popeye, says, "Please don't call me Dirty Curt."

The process of taking rotten fish steaks and picking off thumb-size bits of meat is called "chunking." It tends to leave the chunker smelling badly. But this afternoon it is our only diversion. We get no bites. As the day grows long, a tropical storm creeps overhead, which punctures the sea with pinpricks of rain. I have no rain jacket, and I am cold. My cough rattles back to life. Dirty Curt calls it a day. We might not have gotten a shark today, but with all the chum we're dumping, we're bound to get some tomorrow, the crew tells me. At the worst, we'll get some the following day—the last day of the expedition. That night, the air conditioning breaks. I sleep on deck, under a towel and a bright moon.

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A MARINE-ANIMAL TAG is a simple device. It consists of a sturdy outer shell, sensing and communications equipment, and a means to connect the tag to the shark. Some tags transmit their data by satellite link; others quietly log information until they're recovered by fishermen. Some tags measure general location with light readings; others use magnetometers to get a more accurate north-south position and compass headings.

No matter the tag, though, none are particularly high-tech. Satellite communications that move at one bit per second. The kind of processor used in cheap digital wristwatches and discount microwave ovens. You'll find more groundbreaking componentry in your grandfather's cellphone.

If tags are such crude devices, why haven't scientists made better, cheaper, longer-lasting ones? On a breezeless afternoon, while standing on the bow of our tagging boat, I pose this question to Marco Flagg, the designer of the HammerTag. One reason, he says, is that higher-end electronics use more power, and power management is critical at sea. Another, Flagg tells me, is that there isn't a lot of money to be made selling marine-animal tags to scientists, with their high standards and tiny budgets. The economics look even worse when devices last years.

But economics aren't Flagg's concern. He's a self-taught engineer who makes his money doing contract work for the Special Forces and deep-sea outfits. At the time of the expedition, he is developing underwater positioning systems for submarine war games and an alert system for scientists so fascinated by their surroundings that they don't notice they're about to run out of air. Tags are just a sideline, and he probably never would have

started working on them if a 17-foot great white hadn't mauled him 18 years ago.

The attack happened off the central California coast, while Flagg was testing a prototype diver-locator beacon. He was in a kelp forest off Point Lobos about 50 feet down when a set of jaws clamped around his torso. The shark probably would have killed him had it not chipped a tooth on his dive tank and the beacon's metal housing, prompting it to retreat. Flagg managed to get to the boat, where he kept his wetsuit on fearing his guts might fall out, but remarkably, he needed only 15 stitches. When a local shark scientist later interviewed him about the attack, he offhandedly mentioned he needed new tags. Flagg, who had every reason to avoid sharks for the rest of his life, said he'd give it a try.

Since then, Flagg has made various improvements to marine-tag design, but it wasn't until he met Hammerschlag that he felt compelled to rethink tags entirely. Hammerschlag challenged him to create a tag that could outlive a shark. For an engineer, it was a problem in need of solving.

Flagg began by rethinking the power source. Marine-tag makers have typically eschewed the use of photovoltaics, opting instead for batteries. The assumption was that sharks don't surface long enough to make use of solar panels. Flagg tested this notion by attaching a solar-powered tag to his back and diving to 100 feet. To his pleasant surprise, he found that his panels still charged effectively in as little as 2 percent of the surface light.

With a new power source in hand, Flagg turned to energy management. He reduced power consumption by 90 percent by better controlling sensor activity and satellite transmissions. Paired with a backup battery that can last two years without recharging, the improved tag, he calculated, could last 50 years, perhaps longer.

Because his new tag was so much more energy-efficient, Flagg could add new sensors, allowing scientists to gather multiple data streams at once, including precise depth, acceleration along three axes, highly accurate location information, and water temperature. He also tweaked the transmission system. The HammerTag can send daily reports whenever it makes a satellite connection, but it also has a failsafe. When it senses that a shark is no longer moving and has reached an unsurvivable depth, it assumes the shark is dead, and a small explosive charge separates the tag from the body. The tag then floats to the surface and transmits a final batch of data.

Even with the improvements, Flagg reduced the price of his tag dramatically. While commercial devices with less capability and a shorter lifetime can cost up to $5,000, the final HammerTag will cost about $2,500. The lower the cost, Flagg argues, the higher the rate of adoption and the more shark data scientists will have.

SOMETHING BITES OUR LINE, AND THE BUOY TAKES OFF. THE BOAT GOES FROM LETHARGIC TO FRANTIC. I GET READY TO JUMP IN THE WATER.

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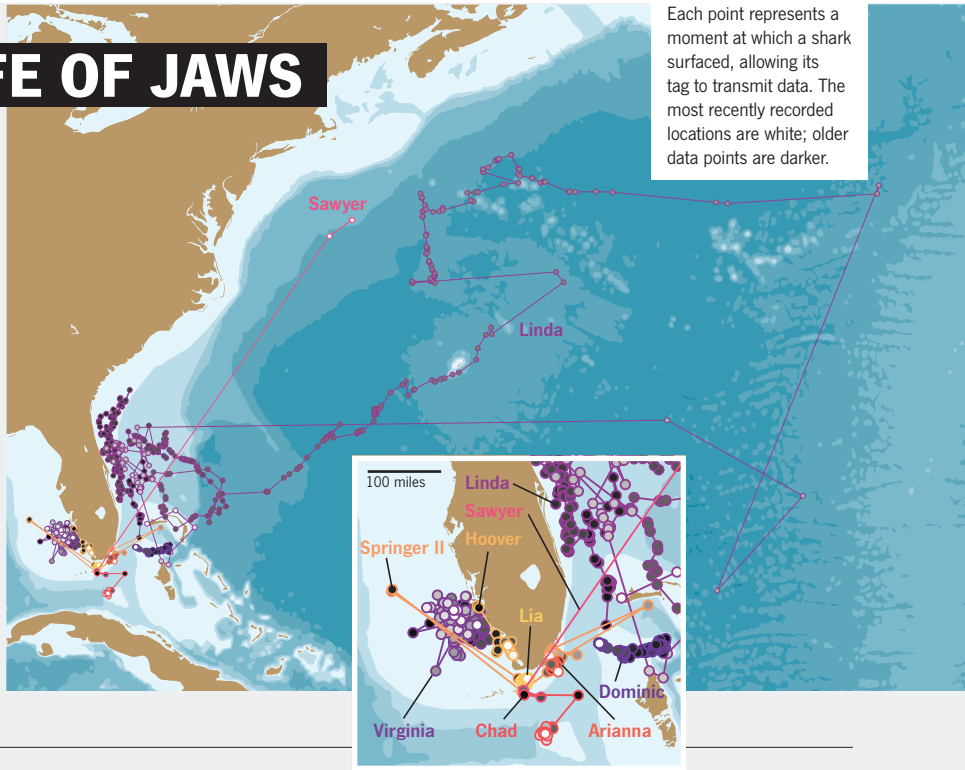
OVER THE COURSE OF THE SECOND DAY, we troll different spots, most of which are shallow enough that I can see straight to the sea-grass-covered bottom. When the shallows turn up nothing, we try our luck at the edge of a 6,000-foot trench. We tell stories to pass the hours. Ansaldi recalls the time in Hawaii

THE SECRET LIFE OF JAWS

After tagging more than 75 sharks, researchers at the University of Miami have built a database that tracks the movements of several species. The nine individuals here have vastly different migration patterns. The bull shark Lia covered only 20 miles over 74 days, while Linda, a tiger shark, traveled more than 2,000 miles up the Eastern seaboard. "She encircles an area the size of a billion football fields," says Hammerschlag. "I had no idea we would see that scale."—KATIE PEEK

BULL SHARKS	GREAT HAMMERHEADS	TIGER SHARKS
Hoover 83 days 90 miles	**Arianna** 84 days 16 miles	**Dominic** 139 days 90 miles
Lia 74 days 20 miles	**Chad** 20 days 60 miles	**Linda** 310 days 2,100 miles
Springer II 104 days 340 miles	**Sawyer** 61 days 1,100 miles	**Virginia** 128 days 120 miles



Each point represents a moment at which a shark surfaced, allowing its tag to transmit data. The most recently recorded locations are white; older data points are darker.

SHARK TRACKING DATA COURTESY NEIL HAMMERSCHLAG

when she had to stomp barefoot on the carcass of a rancid tuna to create a paste for chumming. Dirty Curt is busy plotting. He says the current will take the bait into the deeper water. "In 30 minutes, we should have a shark," he says. But as anglers know, predictions are a dangerous business. No sharks appear.

The crew chums more aggressively. I help Ansaldi haul the Chum Coffin onto the rail of the boat, where she dumps a few gallons of blood directly into the sea. Austin Gallagher, one of Hammerschlag's PhD candidates, is bailing fish over the stern so furiously that he slips and falls headlong into a crimson pool of gore. No matter how much bait we spread, though, our hooks go unnoticed.

That night, I hear crew members whispering to each other about their bad fortune. Dirty Curt comes up to me and says, "We haven't caught a thing in the last two days, and the only thing that's changed is you."

"Well, for surfers, not finding sharks is the best luck you can have," I say, laughing weakly. Dirty Curt just stares.

BIG HAUL Sharks are much less powerful out of the water. Hammerschlag guides a bull shark away from the boat after tagging.

HAMMERSCHLAG JUMPS UP AND YELLS THE SINGLE WORD WE'VE ALL BEEN WAITING TO HEAR, "SHARK!"

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THE THIRD DAY IS OUR LAST before heading home, and I wake up determined to change our luck. I ditch my plain shirt and put on the official, if slightly dorky, expedition T-shirt that everyone else is wearing. Perhaps solidarity will break the curse.

When I board the tagging boat, I find that Dirty Curt has been considering my luck too and has fashioned me a charm: a necklace of monofilament looped through the eyes of a rotting rock hind grouper. He hands it to me roughly. "Don't come within 50 feet of the boat without this necklace," he says. I figure I'll do just about anything to see a shark at this point, so I throw it on. Grease and blood begin to soak into my expedition T-shirt.

We chum valiantly all day, but with four hours of sunlight left, we're still coming up empty. The sharks are elsewhere. We motor the boat into a channel between Chub and Bird Cays known for its fast current. Dirty Curt says we may catch sharks as they funnel through the hourglass waterway.

Almost immediately, something bites our line, and the buoy takes off at a furious pace. The boat goes from lethargic to frantic in a matter of seconds, with everyone madly assembling gear. My job is to photograph the tagging from the ocean, providing a shark's-eye view of the event. I take off the fish head, change into my neoprene rash guard, and get ready to jump in the water. We motor into position, and Dirty Curt begins to reel in the hook, but there's no resistance. It comes up empty.

Dirty Curt looks slowly around the boat. He sees the fish head hanging from a post.

Hammerschlag, speechless, points a finger at me, and Dirty Curt yells, "*No one told you to take the fish head off!*"

I can feel every sullen crew member looking at my neck. I don't say anything—I just slip the necklace back on. I smell like a Chinatown fish market, and I wish this day would end.

The awkward moment is broken by the radio. "Berry Island Club here," it squelches. A radio operator from a dock a few hundred feet away has been watching us fish. "If you're looking for sharks, down current there's a local hammerhead that shows up when we clean our fish," he says.

Following the tip, we drift a mile down and drop anchor on a sandy shallow bottom. It is our last fishing spot on the trip. We have only a bit of sunlight left before the expedition's end, but it seems that everyone's just about given up. I know I have.

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IN AN AGE OF SENSORS AND NETWORKS, animal tagging is ripe for disruption. The HammerTag does not simply imply a new twist on tagging, it represents a paradigm shift. Flagg tells me that he can imagine a day when tag relay stations sit around the world. Instead of satellites, tags would connect to the stations over Wi-Fi, dumping massive loads of data directly into the cloud for all scientists to see. Researchers could monitor sharks and anything else large enough to accommodate a tag. Instead of mapping a single species, the data would convey the movements and actions of an entire ecosystem.

Hammerschlag says he would like to have other kinds of data as well. He is considering a tag that would turn on a video camera when it senses sudden acceleration. Scientists could sit in their offices while watching sharks devour a school of smaller fish. It would be an entirely new way to see the ocean.

Even current tags, which might report as few as five or six location blips a month, have revealed their share of surprises. Scientists have found that hammerheads roam hundreds of miles northeast of their predicted range. Great whites, it

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EMMA SMITH/333 PRODUCTIONS

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seems, can dive nearly half a mile down and also occasionally gather in a place between Hawaii and California known as the shark café. For scientists working to protect sharks and the oceans along with them, this kind of data is invaluable. After all, how can they protect what they don't understand?

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WITH AN HOUR OF LIGHT LEFT on the last day of tagging, the team is already packing its gear, resigned to yet another sharkless afternoon. Hammerschlag tries to put a brave face on things. Even when we don't find sharks, he says, that's data. "Apex predators are rare," Gallagher echoes. "And becoming more so. They're usually found away from mankind, and so it takes more and more gear to find them."

As we exchange conciliatory banter, waiting out the day, I look up to see Hammerschlag staring at the horizon. I can't see exactly what he's looking at, just that his eyes are tracking something. Then he jumps up and yells the single word we've all been waiting to hear, "*Shark!*"

The buoy is running, but faster than before. Water is spraying off the float as it rips through the chop. Ansaldi and Gallagher pull in the other lines so they won't tangle. Flagg gets tagging gear ready, including a mini harpoon the size of a leather awl. Dirty Curt readies a lasso made of braided metal for the front of the shark and a rope lasso for the tail.

From a distance of about 10 yards, Hammerschlag identifies our catch as a black-tipped reef shark. It moves erratically, one minute drifting, exhausted, the next thrashing against its invisible foe. Everyone is rushing around.

I ask whether it's time to take off the fish head, but no one listens to me. I look at the lashings, which seem solid, toss off my charm, and jump into the water. I don't know what compels me to do so. Perhaps it's a sense of duty. Perhaps it's just an excuse to get rid of my foul-smelling necklace.

I spend a few seconds treading water and calming my breath and make three or four spins to scan the blue beneath me for more sharks, which I assume must be everywhere. I can't see any, other than the one we have on the line.

The shark is perfect, in the scientific sense. It's old enough and big enough for tagging but young enough that it has no scars from battles with fishermen or prey. I am just feet from it, floating face-to-face with one of nature's most fearsome creatures. Its jaw hangs open, and I can see row upon row of teeth. As the crew reels the animal toward the boat, I move in to touch it but stop. I feel ashamed, as if I'm grabbing for a trophy that does not belong to me. I'm not a scientist. I'm not helping the species survive. What right do I have to lay a hand on this perfect form?

Standing on the stern, Curt expertly lassoes the shark, settling the noose just behind the dorsal and pectoral fins. Slowly, he and another researcher draw the shark toward the stern of the boat, tying the lasso to the boat once the shark is close enough. Someone puts a piece of PVC pipe attached to a water pump into the shark's mouth, and oxygenated water begins to gush over its gills.

There is an urgency to the work. When tagging, scientists not only need to land a shark, they have to do so in such a quick and artful manner that the animal feels little stress. Too much strain can exhaust a shark. It might swim off only to die a few days later.

With practiced precision, silent and focused and smiling faintly, Ansaldi and Gallagher use a syringe to draw a vial of blood from a hidden vein, filling it up with blood as red as yours or mine. They also clip a piece of fin as a sample for genetic testing and drill a small hole in the dorsal fin, so they can attach the tag with a zip tie.

And then they're done. Hammerschlag signals me to get out of the water, and the team works together to loosen the lines and push the shark back into the water. It swims off under the satellite eye of science.

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IN THE WEEKS and months following the Bahamas expedition and other weekend trips like it, Hammerschlag and Flagg begin to see results. The tags have flaws; earlier prototypes aren't transmitting enough data. Flagg has to refit the surface detection sensors so the tags know when to transmit. But even with these shortcomings, the prototypes provide extraordinary amounts of information. By luck, a colleague of Hammerschlag's recovers a HammerTag from a shark captured in the wild. It contains 200,000 data points—one for every four minutes the shark swam. And it reveals surprising behavior.

"[This] 14-foot tiger made frequent dives during the night to over 1,000 feet, including one massive dive to 1,300 feet lasting two hours, during which the shark was twisting, only returning to the surface to plunge to the depths again and perform the same behavior," Hammerschlag tells me by phone. "Who knows what it was doing? Perhaps it was battling in the night with other sharks. I can't say." PS

Brian Lam is based in Honolulu. He is still scared but no longer terrified of sharks.