

The Algorithmic Ocean: How AI Is Revolutionizing Marine Conservation

Driven by a childhood marked by war and environmental devastation, Dyhia Belhabib developed an innovative technology to combat illegal fishing.



The Cutter Douglas Munro and crew searching for illegal, unreported, and unregulated fishing activity including high seas driftnet fishing. Source photo: U.S. Coast Guard

By: Karen Bakker

Dyhia Belhabib’s journey to becoming a marine scientist began with war funerals on TV. Her hometown, on the pine-forested slopes of the Atlas Mountains in northern Algeria, lies only 60 miles from the Mediterranean Sea. But a trip to the beach was dangerous. A bitter civil war raged across the mountains as she was growing up in the 1990s; the conflict was particularly brutal for Belhabib’s people, the Berbers, one of the Indigenous peoples of North Africa. As she puts it: “We didn’t go to the ocean much, because you could get killed on the way there.”

The ocean surfaced in her life in another way, on state-run television. When an important person was assassinated or a massacre occurred, broadcasters would interrupt regular

programming to show a sober documentary. They frequently chose a Jacques Cousteau film, judged sufficiently dignified and neutral to commemorate the deaths. Whenever she saw the ocean on television, Belhabib would wonder who had died. “My generation thinks of tragedies when we see the ocean,” she says. “I didn’t grow to love it in my youth.”

By the time she was ready for university, the civil war had ended. The Islamists had lost the war, but their cultural influence had grown. Engaged at 13 to a fiancé who wanted her to become a banker, Belhabib chafed at the restrictions. Her given name, Dyhia, refers to a Berber warrior queen who successfully fought off invading Arab armies over a thousand years ago; Queen Kahina, as she is also known, remains a symbol of female empowerment, an inspiration for Berbers and for the thousands of Algerian women who took up arms in the war of independence. In a society where one in four women cannot read, Belhabib realized she didn’t want to go to university only to spend her life “counting other people’s money.”

One day, her brother’s friend visited their house. He was a student in marine sciences in the capital city, Algiers. When he described traveling out to sea, Belhabib felt a calling for an entirely unexpected path. “It was,” she recalls, “a career I had never heard of, and one that challenged every stereotype of women in Algerian society.” Soon after the visit, she moved to Algiers to study at the National Institute of Marine Sciences and Coastal Management, where she was one of the only women in her program. She also broke off the engagement with her fiancé, so that she could focus full-time on studies. She still vividly remembers her feelings of

freedom, fear, and unreality on her first trip out to sea. While other students dove for samples, she floated on top of the water, trying to survive. “I never learned how to swim, and I still don’t know how,” she admits.

Belhabib graduated at the top of her class, but was repeatedly rejected when she applied to universities overseas. Her luck turned when she met Daniel Pauly, one of the world’s most famous fish scientists, at a conference. Unintimidated by the fact that Pauly had just won the Volvo Prize — the environmental equivalent of a Nobel — she introduced herself and told him she wanted to study with his team. Although she did not yet speak fluent English, Pauly accepted her as a student. When she began her doctoral research, over 90 percent of the world’s wild fisheries had been eradicated, and Pauly was sounding the alarm about a new, global surge in illegal fishing that was decimating marine food webs and depriving coastal communities of livelihoods. He wanted her to work on Africa, where illegal fishing had reached epidemic proportions.

Belhabib spent the next few years in West Africa. When her research uncovered the extent of illegal fishing to feed Chinese and European markets, she made the front page of the *New York Times*. “Being African myself, I was able to bring people together to openly share data in a way they never had before,” she explains. It’s not hard to imagine her corralling government officials: Disarmingly frank and engagingly energetic, the whip-smart, hijab-wearing Belhabib stands a little over five feet tall and talks a mile a minute, with a self-deprecating laugh and a talent for gently posed, biting direct questions.

Her startling findings touched a nerve. Tens of thousands of boats commit fishing crimes every year, but no global repository of fishing crimes exists. A fishing vessel will often commit a crime in one jurisdiction, pay a meager fine, and sail off to another jurisdiction, thus operating with impunity. If a global database of fishing vessel criminal records could be created, Belhabib realized, there would be nowhere left to hide. She suggested the idea to a variety of international organizations, but the issue was a political hot potato; national sovereignty, they argued, prevented them from tracking international criminals. Undeterred, Belhabib decided to build the database herself. Late at night, while her infant son was sleeping, she began combing through government reports and news articles in dozens of languages (she speaks several fluently). Her database grew, word spread, and her network of informants — often government officials frustrated with international inaction on illegal fishing — began expanding. She moved to a small nonprofit and began advising Interpol and national governments. The database, christened Spyglass, grew into the world's largest registry of the criminal history of industrial fishing vessels and their corporate backers. But the registry, Belhabib knew, was useful only if the information made its way into the right hands. So in 2021 she cofounded [Nautical Crime Investigation Services](#), a startup that uses AI and customized monitoring technology to enable more effective policing of marine crimes and criminal vessels at sea. Together with her cofounder Sogol Ghattan, who has a background in ethical AI, she named their core algorithm ADA, in homage to Ada Lovelace — the woman who wrote the world's first computer program.

Belhabib is attempting to tackle one of the most intractable problems in contemporary environmental conservation: illegal fishing. Across the oceans, the difficulty of tracking ships creates ideal cover for some of the world's largest environmental crimes. After the end of World War II, the world's fishing fleets rapidly industrialized. Wartime technologies that had been developed for detecting underwater submarines were repurposed for spotting fish. The size of nets grew exponentially, and offshore factory ships were outfitted so they could spend months at sea, extending the reach of industrial fishing into the furthest reaches of the ocean. As the world's population grew, fish protein became an increasingly important source of food. But warning signs soon appeared: crashes in key fish populations, an alarming trend of "fishing down marine food webs," and a series of cascading impacts that rapidly depleted marine ecosystems.

In the wake of depleting stocks, fishers should have responded by reducing their take. Instead, they redoubled their efforts. After the world's leading fishing nations — China and Europe are the largest markets — overfished their own waters, they began exporting industrial overfishing to the global oceans. China's offshore fishing fleet of several hundred thousand vessels, which received nearly \$8 billion in government subsidies in 2018, is [now the largest in the world](#).

Governments of wealthier nations subsidized massive fleets of corporate-backed vessels to fish the high seas, using bottom trawling and drift nets stretching for dozens of miles, killing everything in their path. Artisanal fishers were squeezed out, and as fish stocks collapsed, rising food

insecurity generated protests and political unrest. In West Africa, for example, fishing boats from the world's wealthiest nations have depleted local fisheries to such an extent that waves of migrants — faced with food insecurity and uncertain futures — have begun fleeing their homes in a desperate, risky attempt to reach European outposts such as the Spanish Canary Islands; thousands of migrants have died at sea. The smaller fishing fleet, meanwhile, has struggled to remain solvent; impoverished fishers are increasingly vulnerable targets for criminal organizations seeking mules for hire to transport drugs, or boats to serve as cover operations for human trafficking.

Over 90 percent of the world's fish stocks are now [fished to capacity or overfished](#). Despite this, scientists' calls for reduced fishing have largely fallen on deaf ears.

Conventional attempts to manage fisheries are stymied by the limits of logbooks and onboard human observers, and local electronic monitoring systems. Fishing boats that exceed quotas or fish in off-limits areas are rarely caught, operating with impunity in front of local fishermen's eyes; and even if caught, they are even more rarely punished.

Marine Panopticon

The world's oceans are experiencing an onslaught: As fish have become scarcer, illegal fishing has surged. Rather than merely document the decline of fish stock, Belhabib decided to do something about it. Her solution: to combine ADA, her AI-powered database of marine crimes, with data that tracks vessel movements in real time. She began by tracking signals from the marine traffic transponders carried by oceangoing ships — also known as automatic information

systems (AIS). AIS signals are detected by land transceivers or satellites and used to track and monitor individual vessel movements around the world. AIS signals are also detected by other ships in the vicinity, reducing the potential for ship collisions. Belhabib and her team then built an AI-powered risk assessment tool called GRACE (in honor of the pioneering coder Grace Hopper), which predicts risks of environmental crimes at sea. When combined with vessel detection devices such as AIS, GRACE provides real-time information on the likelihood of a particular ship committing environmental crimes, which can be used by enforcement agencies to catch the criminals in the act. Belhabib's database means that criminal vessels — which often engage in multiple forms of crime, including human trafficking and drug smuggling, as well as illegal fishing — now find it much harder to hide.

The high seas are one of the world's last global commons, largely unregulated. The UN Convention on the Law of the Sea provides little protection for the high seas, two-thirds of the ocean's surface. The adoption of a new United Nations treaty on the high seas in 2023 will create more protection, but this will require years to be implemented. Even within 200 nautical miles of the coast, where national authorities have legal jurisdiction, most struggle to monitor the oceans beyond the areas a few miles from the coast. And beyond the 200-mile limit, no one effectively governs the open ocean.

So Belhabib hands her data on human rights and labor abuses over to Global Fishing Watch, a not-for-profit organization that collaborates with the national Coast Guards and Interpol to target vessels suspected of illegal

fishing for boarding, apprehend rogue fishing vessels, and police the boundaries of marine parks. The observatory visualizes, tracks, and shares data about global fishing activity in near real time and for free; launched at the 2016 U.S. State Department's "Our Ocean" conference in Washington, it is backed by some of the world's largest foundations. Its partners include Google (which provides tools for processing big data), the marine conservation organization Oceana, and SkyTruth — a not-for-profit that uses satellite imagery to advance environmental protection.

Global Fishing Watch uses satellite data on boat location, combined with Belhabib's data on criminal activity, to train artificial intelligence algorithms to identify vessel types, fishing activity patterns, and even specific gear types (tasks that would require human fisheries experts hundreds of years to complete). The tracking system pinpoints each individual fishing vessel with laser-like accuracy, predicts whether it is actually fishing, and even identifies what type of fishing is underway. Their reports have revealed that half of the global ocean is actively fished, much of it covertly.

Fred Abrahams, a researcher with Human Rights Watch, [explains](#) that this approach is just one example of a new generation of conservation technology that could act as a check on anyone engaged in resource exploitation. His team at Human Rights Watch uses satellite imagery to track everything from illegal mining to undercover logging operations. As Abrahams says: "This is why we are so committed to these technologies . . . they make it much harder to hide large-scale abuses." Abrahams, like other advocates, is confident that the glitches — for example, AIS

tags are not yet carried by all fishing vessels globally, poor reception makes coverage in some regions challenging, and some boats turn off the AIS when they want to go into stealth mode — will eventually be solved. Researchers have recently figured out, for example, how to use satellites to triangulate the position of fishing boats in stealth mode — enabling tracking of so-called dark fleets. These results can inform a new era of independent oversight of illegal fishing and transboundary fisheries. Meanwhile, researchers are developing other applications for AIS data, including assessments of the contribution of ship exhaust emissions to global air pollution, the exposure of marine species to shipping noise, and the extent of forced labor — often hidden, and linked to human trafficking — on the world’s fishing fleets.

It’s a herculean task for one organization to police the world’s oceans. And Global Fishing Watch’s data is mostly retroactive; by the time the data is analyzed and the authorities have arrived, fishing vessels have often left the scene. What is still lacking is a method for marine criminals to be more effectively tracked in real time, and apprehended locally. This is where Belhabib’s next venture comes in. She is now working with local governments in Africa — where much illegal fishing is concentrated — to provide them with trackers and AI-powered technologies to catch illegal fishing and other maritime crimes in the act. As she notes: “When you ask the Guinean Navy how much of their territorial waters they can actually monitor, it’s only a fraction of a vast area. They simply don’t have the resources.” Belhabib’s system pinpoints vessels that may be committing infractions, and assesses the risk live on screen. This allows

the Coast Guard and other agencies such as Interpol to more easily find illegal fishers, while reducing the costs of deployment, monitoring, and interdiction.

She cautions, however, about the use of similar digital technologies to track illegal migrants. The European Union, for example, has strengthened its “digital frontier” through satellite monitoring, unmanned drones, and remotely piloted aircraft, in some cases relying on private security and defense companies to undertake data analytics and tracking. But [these technologies are often focused on surveillance](#) rather than search and rescue of migrants stranded at sea. As Belhabib relates: “Recently I spoke with the Spanish Navy and they told me they watched over 100 people die when a boat full of migrants capsized and they could only save a few people. They told me, ‘We take their fish away, they risk their lives to have a better and decent life.’ It’s heartbreaking and avoidable.” In Belhabib’s view, Digital Earth technologies should prioritize ecological and humanitarian goals, rather than surveillance and profit. Digital Earth technologies enable more rapid detection and, in some cases, prediction of marine crimes. Digital monitoring, combined with artificial intelligence, allows precise analysis of fishing vessel locations and movements at a global scale. Although this does not guarantee enforcement, it could enable more efficient policing of the world’s oceans. The use of digital technologies enables conservationists to tackle two common flaws that lead to failures in environmental enforcement. First: data is scarce; if available, there is often a time lag, geographical gaps, or data biases. This makes evidence-gathering difficult or impossible. Second, enforcement often comes too late.

Environmental criminals can be prosecuted, but legal victories are uncertain, and happen after the damage has been done. These shortcomings of contemporary environmental governance — sparse data, unenforceable regulations, and patchy, sporadic enforcement that punishes but fails to prevent environmental harm — can be overcome by digital monitoring, which mobilizes abundant data in real time to gather systematic evidence and enable timely enforcement.

These techniques appear to be achieving some success. In Ghana, for example, there has been a long-standing conflict between industrial fishing boats and small-scale, artisanal fishers using canoes and small boats to fish near the shore. Satellite data has [helped the government's Fisheries Enforcement Unit](#) track and reduce the incursions of larger fishing boats into near-shore waters. In Indonesia, the world's largest archipelago country with the second-longest coastline in the world, the government has entered into an agreement with Global Fishing Watch data to monitor fisheries and share the data about vessels' movements publicly online, a major step forward in transparency in fisheries enforcement. The Indonesian partnership is an example of the longer-term aim of Global Fishing Watch: to share its geospatial datasets and online mapping platform with governments around the world.

Despite these recent gains to combat illegal fishing, digital tech is also exacerbating the underlying problem, as fishers themselves have started taking advantage of digital strategies. One example is the growing use of fish aggregating devices, which use acoustic technology, combined with satellite-linked global positioning systems, to

better spot schools of fish. Fishers can effectively assess location, biomass, and even species, allowing them to aggregate and fish more efficiently. [Digitization is ratcheting up the already intensely competitive fishing industry](#) and accelerating the overfishing of endangered species.

Even if conservationists can win this digital arms race, there is a more fundamental problem: The underlying structural drivers of overfishing — consumer demand, particularly in Asia and Europe, and a lack of adequate governance for the high seas — are not solvable by digital technologies alone. Governance reform and digital innovation must work in tandem. For example, in the absence of government regulation, digital monitoring of fishing on the open ocean would be unlikely to scale up. But the adoption of the new UN treaty on the high seas in 2023 included a significant commitment to creating new Marine Protected Areas, aligned with Global Biodiversity Convention's commitment to protect 30 percent of the Earth's land and oceans by 2030.

These new developments create an impetus for digital monitoring; and, in turn, digital monitoring will increase the likelihood that Marine Protected Areas will be effective at protecting fish populations. This illustrates two key points about environmental governance in the 21st century: the interplay between digital and governance innovation, and the fact that planetary governance of the environment is possible only with planetary-scale computation.

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