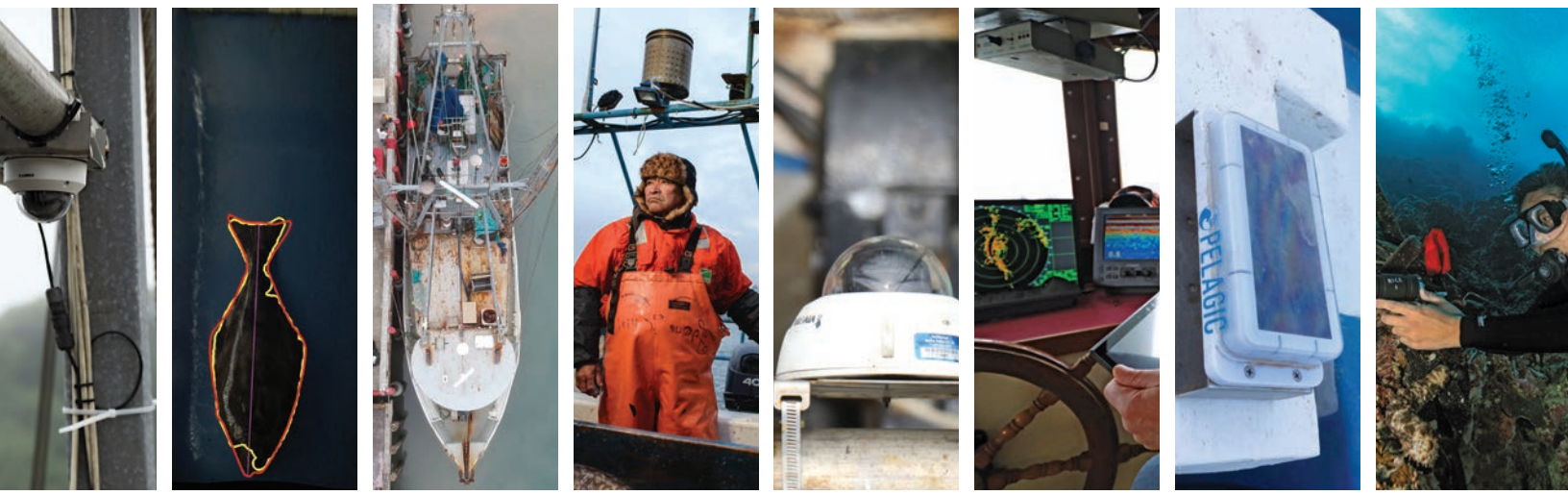
Smart Boats and Networked Fisheries

New pathways to sustainable fishing in the digital age



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Credit: Hector Licon

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Our ocean at a crossroads

For thousands of years, the world's vast ocean has sustained us. Today across the globe some 260 million people depend on marine fisheries for their livelihoods, and 3 billion people worldwide rely on seafood as a major source of protein. Well-managed fisheries around the world prove that this life-giving resource can be sustained for generations to come. Alarmingly, however, these success stories remain rare bright spots amidst a rising tide of unsustainable fishing. In the absence of an ambitious vision and plan of action, it is clear that global fish stocks will continue to decline and we will face a growing ecological and humanitarian crisis.

Technology has helped create this crisis by giving fishermen the ability to increase their range and efficiency. What is now becoming clear is that technology can also deliver an antidote—by putting new tools in the hands of fishermen and empowering fishing communities to reclaim their future. The challenge before us is daunting; but if we act with urgency to apply the transformative power of the digital revolution to fisheries management, we can reverse the trend lines of today and secure the benefits of healthy and abundant fisheries for future generations.

Today across the globe some 260 million people depend on marine fisheries for their livelihoods, and 3 billion worldwide rely on seafood as a major source of protein.

The two pillars of sustainable fishing

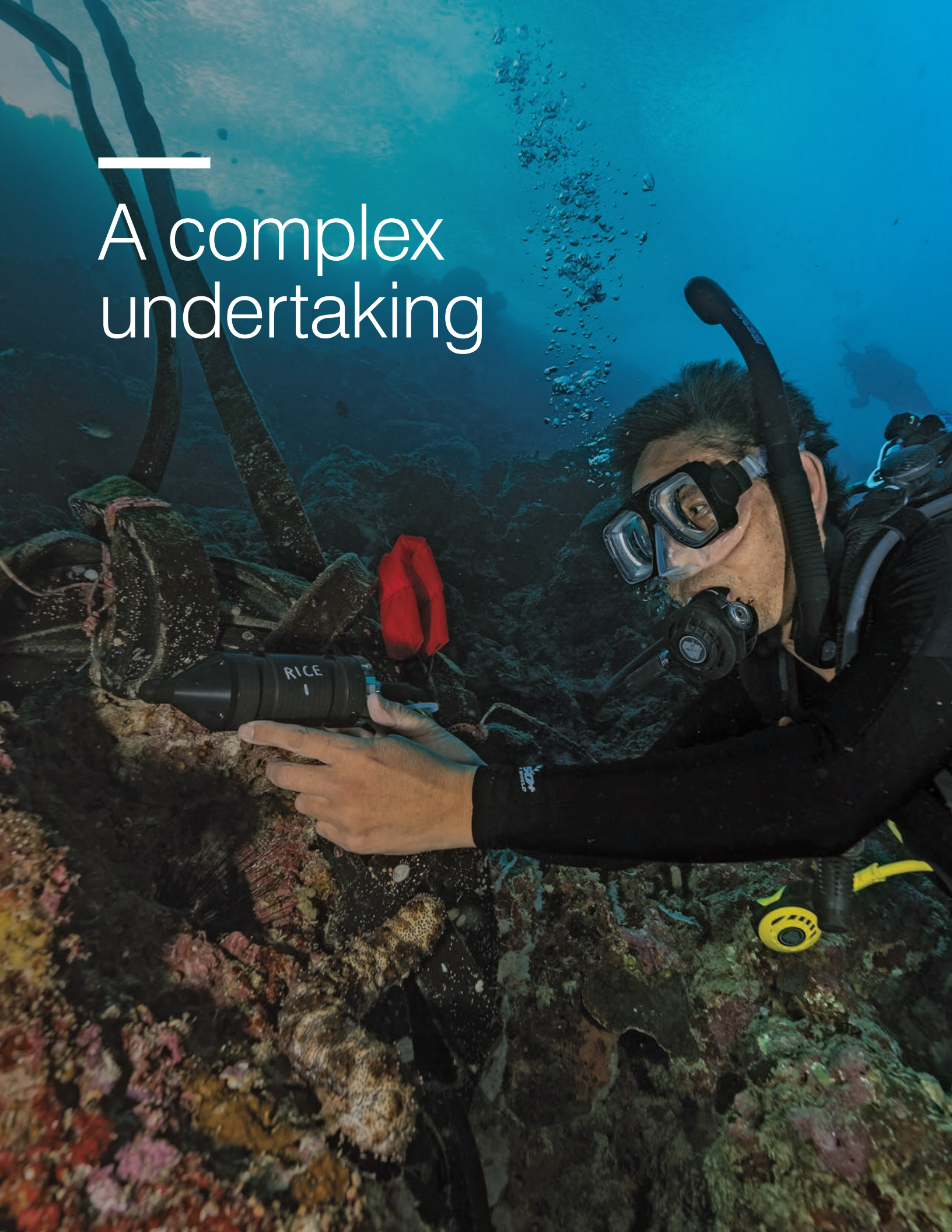
We have learned that two essential elements—incentives and information—are what make it possible for fisheries management to succeed.

Getting the incentives right is the first critical task. Where the tragedy of the commons prevails, a downward spiral ensues: as fish stocks decline, the imperative for fishermen to land the biggest possible share of a dwindling supply of fish only becomes more intense. By contrast, where a mechanism is found to give fishermen a secure stake in their fishery, the potential to unlock a virtuous spiral exists: fishermen become self-interested stewards of the resource, working hard to put in place solutions that give them dedicated access to more abundant fish stocks over the long term.

Harnessing actionable information is the second crucial need. In all too many fisheries, a lack of timely data frustrates even the best of intentions. In its absence, managers struggle to formulate appropriate limits on fishing activity, and fishermen lack the tools by which to shift to more sustainable practices. In successful fisheries, by contrast, good information underpins everything. This is true of many indigenous fishing communities, where traditional knowledge allows for adjustments in fishing practices based on what is observed. It is also true of some information-rich industrialized fisheries, where scientists set catch limits based on exhaustive data sets and catch is quantified with precision as soon as nets hit the deck.

Building smart incentives and good information into fishery management is, therefore, the simple-sounding formula that can solve one of the most urgent challenges of our time.

A complex undertaking



Yet grim reminders that the task is far from simple abound. In the absence of smart incentives and good information, fisheries across the globe are plagued by illegal and unsustainable fishing practices, human rights abuses, fraud and predatory business relationships. Seafood supply chains remain unmatched in their complexity and lack of transparency. There is dangerous inertia in the face of ocean climate change, which is already creating vexing new variables for the trajectory of fish populations and other marine life. The overall trend line of global overfishing continues to rise.

Moreover, efforts to reform management—to incentivize conservation and improve information systems—have often proved fiendishly complex.

First, although rights-based systems have now been proven to incentivize conservation, they remain incredibly challenging to design and implement effectively at scale across vastly different fisheries contexts. The essential elements of these systems—including a mechanism for making equitable allocations of fishing rights between users, the capacity for fishermen to easily track and transfer quota and a shared confidence that all participants in the fishery are abiding by the agreed rules of the road that will lead to long-term collective benefits—can be laborious to construct. These complexities have stymied numerous efforts to adopt rights-based programs, as well as producing some programs that lack core design elements and thus make only limited conservation gains.

Second, systems the world over for collecting and utilizing vital information on fish populations, fishing activity, catch levels and changing ocean conditions are antiquated or nonexistent. Even in the most information-rich fisheries, methods by which data are captured, stored, shared and utilized have been largely unmoved by the dramatic changes in data collection and processing we have seen reshape almost every other sector.

There are many dimensions to these ubiquitous fishery information failures. One critical component is that fishing fleets remain isolated and disconnected on the world's seas. That means accurate information about what is caught and discarded rarely reaches scientists and managers; and even on vessels with human observers or new electronic monitoring (EM) systems, data collected onboard are only shared after a trip is completed and often takes weeks or months to be collated and used. Meanwhile, fishermen at sea lack access to oceanographic, market and other real-time data that could inform their choices about where and how to fish.

Even more fundamentally, in the absence of a common body of timely and accurate data that both fishermen and managers trust, the system breaks down. Depending on the governance structure, poor information can lead to regulatory restrictions that fishermen reject and seek to evade or a hands-off free-for-all that puts fisheries at severe risk of collapse.

The cascade of failure resulting from poor governance and poor information is the true cause of the crisis in global fisheries. Until now, although these failures have been overcome through significant investments of time and money in some fisheries, the prospects of scaling solutions globally have appeared bleak.

The transformative potential of the digital revolution

Rapid and sometimes radical advances in digital technology applications have left almost no sector of the economy or corner of the globe untouched. The potential for these same forces to disrupt global fisheries in ways that can overcome the incentive and information challenges we face—and in so doing help restore the health and abundance of the world's ocean—is increasingly clear. New technologies cannot themselves fix the fisheries crisis that we face. But they do open an unprecedented window of opportunity to dramatically broaden access to the fishery management approaches that have been proven to work. New tools that transform the collection and flow of data can burst open the door for effective incentive-based governance at scale. They can empower fishermen as active, conservation-oriented stewards with a direct stake in sustainability. And they can arm fishermen with the tools by which to lay claim to the sustainable fishing future that they overwhelmingly want.

New technologies cannot themselves fix the fisheries crisis that we face. But they do open an unprecedented window of opportunity to dramatically broaden access to the fishery management approaches that have been proven to work.

The transformative power of digital technology is growing exponentially. The number of internet users globally has now reached 4.2 billion, while the number of people with smartphones is set to top 2.5 billion this year. Constantly improving hardware, software and connectivity have enabled billions of inexpensive and accessible devices to make and receive calls, take high-resolution photographs, run ever-more-capable applications and transmit and receive location information. Dizzying improvements in sensor and camera technology allow us to collect data in places and of a quality and volume previously unimaginable. Broadband and other networks allow data to be shared across vast distances in real time at a price-point that is falling fast, while innovations such as cloud computing transform data storage possibilities. Machine learning, meanwhile, has growing potential to synthesize and help us make use of vast arrays of data that would otherwise be impossibly unwieldy.

All around us, we see evidence of the digital revolution's potential to conserve our environment, improve business outcomes and save lives.

Equally remarkable are the waves of innovation that are being unleashed by this new digital architecture. An entire ecosystem of connected devices, the "internet of things," has emerged. As network ubiquity, smaller sensors and more affordable chips with enhanced processing power continue to extend the reach and power of internet of things innovation, it is transforming almost every sector of the economy, from manufacturing and scientific research, to transportation and urban planning, to the spaces where we work and live.

All around us, we see evidence of the digital revolution's potential to conserve our environment, improve business outcomes and save lives. Crop farmers are flying drones equipped with near-infrared sensors over their fields to detect where fertilizer and other inputs need to be applied in order to maximize yields. Manufacturers are deploying autonomous self-healing systems that allow physical assets to perform maintenance on themselves as required, without the need for human involvement. IBM's supercomputer Watson can detect cancer cells from a biopsy faster and more reliably than trained oncologists, relying on a vast library of tagged images that it uses to continually "learn" and improve. These and myriad other present-day examples represent merely the early stages of a growing wave of digital transformation.

Fisheries and emerging technologies

Credit: Noel Lopez Fernandez

One arena still largely untouched by these models of positive digital transformation is the world's fisheries. Indeed, to the extent that technology has changed fishing practices and management, it has generally served to accelerate ecosystem decline and cement the place of fishermen as "villains" in the storyline of fisheries collapse.

Fishermen have always relied on technological improvements to increase their ability to locate and catch fish. Acoustic fish finders, GPS navigation, bigger and more efficient engines and hydraulic systems that enable the use of bigger and better fishing gear are among the areas where technological change has had the greatest impact. In the absence of effective governance, however, these innovations have only worsened the long-term challenges that fishermen face, sharpening the tools of overfishing and hastening ecosystem decline.

Broad access to this kind of real-time data could give fishermen more power in the seafood marketplace, provide scientists with information that could enable safe increases in catch limits, catalyze fleet-wide innovations that could lead to cleaner fishing and vastly expand management options.

Similarly, the incorporation of new technologies into fisheries management has rarely focused on catalyzing the kinds of change that could engage fishermen in service of sustainability. On the contrary, technologies have been deployed overwhelmingly as an enforcement tool, providing regulators with new mechanisms to monitor fishing activities but doing precious little to help fishermen succeed. Thus, governments have invested in Vessel Monitoring System (VMS) programs that allow them to track the movements of fishing boats on the open ocean. And in some instances, they have encouraged or mandated the adoption of EM technology so they can observe what is happening on the deck. Yet the opportunity to harness the power of digital technology to drive systems change in fisheries management remains completely unrealized.

The extent of this missed opportunity can be seen starkly in many fisheries where EM is being trialed. At considerable expense—often shouldered by fishermen—cameras are affixed to fishing vessels in order to capture video footage of what is caught and discarded at sea. In most programs, that data are recorded to a hard drive, which then travels back to the dock with the boat. After fishermen mail these hard drives to regulators or third-party providers, the tape is painstakingly reviewed, often weeks after the fact. In the absence of infractions, it is then shelved, never having the opportunity to serve a non-enforcement function.

This enforcement-focused process can itself serve an incredibly valuable purpose. However, what is noteworthy in the context of digital technology's potential is the failure to harness the data either in real time or for the direct benefit of fishermen. Broad access to this kind of real-time data could give fishermen more power in the seafood marketplace, provide scientists with information that could enable safe increases in catch limits, catalyze fleet-wide innovations that could lead to cleaner fishing and vastly expand management options. And that's to say nothing of augmentations of monitoring systems that could incorporate new functionalities such as sensor technology—for example, to cross-reference catch data with oceanographic conditions.

If we are clear-eyed about the scale and seriousness of global fishery management failure, we should feel enormous urgency to encourage a generational leap in existing fisheries-related technologies, and to reimagine the purposes they serve.

Bob Dooley: Veteran fisherman thinks tech is key to accountability and better business

Veteran commercial fisherman Bob Dooley of Half Moon Bay, California thinks smart deployment of emerging technology could be a game-changer for fish stocks, fishery managers and fishermen alike.

Dooley has been at the forefront of many of the country's most dramatic fishery recovery stories. And after more than 40 years on the water, Dooley has developed a pretty simple philosophy on successful fisheries management.

"Everything you need to run a successful fishery starts with accountability," Dooley said. "It leads to better decisions and better results. I think we should be looking at every option to increase accountability and decrease its cost."

Better technology, Dooley says, can do both.

In some fisheries, accountability is achieved through human observers, which are expensive and are usually paid by fishermen (and their customers). Instead, Dooley suggests, EM equipment can provide accurate compliance and catch data. Installed fleetwide, an EM system could provide near real-time catch data for an entire fishery.

Better data lead to a better understanding of what's happening on the water and, eventually, better approaches to manage individual stocks.

"As more boats become connected, we'll have the capability to not only provide better data for the fishery, but also run more of our businesses from our boat, whether it's ordering supplies or communicating with customers."

Imagine an integrated system on a fishing vessel that not only tracks which fish have been caught and discarded, but also incorporates the vessel's location and ocean conditions and enables real-time communication of this information to shore. Meanwhile, the crew can view integrated information about their catch in relation to management requirements and market conditions.

Dooley thinks this sophisticated future is within reach. "Pieces of it are available today and would make an immediate impact on how well we manage fisheries," he says.

Captain Bob Dooley of Half Moon Bay, California, has been on the forefront of many of the country's most dramatic fishery recovery stories.

Towards a smart boat future

Although many existing technology applications in fisheries can seem rudimentary and ill-conceived, rapid changes in other sectors provide a powerful signal that a better course exists and can quickly be adopted. Indeed, although the dominant theme of existing fisheries technology applications is discouraging, there are discrete technology innovations that are already blazing a new trail.

These innovations are exciting because they address in some form the twin challenges of smart incentives and good information. For example, in the Gulf of Mexico, recreational headboats now report their catch to authorities electronically and in real time using tablet technology. This provides scientists and managers with valuable information that can improve outcomes. But it also creates a precise and widely-accepted catch history that can form the basis for equitable initial allocation decisions if a proposed transition to rights-based management gains traction in the future. In Sweden, fishermen are now able to buy and sell quota through a user-friendly online platform called FishRight. This gives fishermen access to accurate real-time information, and in doing so, it also ensures that rights-based management strengthens fishing businesses by giving fishermen greater certainty and flexibility. On the U.S. West Coast, meanwhile, groundfish fishermen are exploring next-generation EM technology that can provide more cost-effective coverage. This will satisfy the rights-based management program's 100% monitoring requirement, while also continuing to give participants certainty that others are playing by agreed ground rules that over the long term will benefit them all.

These kinds of innovations are early rays that could be harbingers of a new day in fisheries technology applications. The ultimate smart boat vision looks beyond these individual use cases to a future in which data are collected, shared and utilized for a variety of purposes in close to real time. The creation of these rich data streams will in time unleash waves of innovation that strengthen all aspects of fisheries business and management. Governance will improve, sustainability goals will be achieved, profitability will increase and fishermen will take center stage as empowered custodians for the fisheries upon which their livelihoods depend.

This vision may sound audacious, but it is now for the first time within reach thanks to the staggering pace of change in digital technology—most especially networks, sensors and artificial intelligence (AI). Expanding networks are rapidly shrinking our world. Parts of the ocean once considered remote can now be connected by wireless, broadband or satellite. In regions where sharing even small data packages from sea back to land were once cost-prohibitive, it is now straightforward to watch fishing activity via livestream. Similarly, sensors are becoming smaller, cheaper and more powerful, with deployment growing by a factor of ten every five years. It is now realistic to incorporate sensor technology into even modest fishing operations, capturing valuable data that can aid science, advance conservation and add value throughout the supply chain. AI, including machine learning, offers a third powerful tool. Software can

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Carlos Aguilera

Josue Ramírez: Using technology to build accountability in Mexico's curvina fishery

Josue Ramírez Ramírez is a third-generation fisherman from El Golfo de Santa Clara, Mexico, working in one of the most complicated fisheries in the Western Hemisphere.

Fishing is vitally important in the Upper Gulf of California: Nine in ten people here make their living from fishing, and curvina is one of the most important species. But the illegal fishing of another species in the Upper Gulf—totoaba—is pushing the endangered vaquita porpoise to the brink of extinction, which has created the need for curvina fishermen to show that they are fishing legally and abiding by rules put in place to protect the vaquita. Regulators have considered closing the curvina fishery, but a new management system that requires strict accountability has turned curvina into one of the most regulated fisheries in Mexico.

Technology is helping legitimate fishermen like Ramírez prove he's following the rules.

"It is very important for us to stay out of prohibited zones," Ramírez said, "and our onboard systems show fishery managers where we are and, more importantly, where we're not."

There are more than 700 registered curvina boats in the region, and nearly all of them are equipped with systems that track location and activity. They also use a mobile phone-powered catch accounting system to ease inspections when Ramírez returns to shore.

"Monitors now use their cell phones to scan our boats' QR codes," Ramírez said. "That speeds up the entire process and connects us directly to our catch data."

The trackers and catch accounting system are increasing accountability in the fishery and could help fishermen eventually achieve an eco-certification and access new markets. For the time being, Ramírez is happy that the technology has helped keep his fishery open.

"We're all affected by illegal fishing," Ramírez said. "We can't afford to have our fishery closed, and we're willing to do our part to show that we can be part of the solution."

Josue Ramírez Ramírez, a curvina fisherman from Golfo de Santa Clara, has been fishing since he was 13.

navigate large data packages to quickly isolate relevant information—for example, fishing events in lengthy video footage—saving time and money, and allowing fishermen, scientists and managers alike to make use of valuable data immediately.

The path to pursuing this smart boat vision will look very different in fisheries of varying sizes and management contexts.

In large and highly regulated fisheries, the most important advance may be breaking down silos between different aspects of fisheries business, science and management. For example, in many such fisheries, VMS units and human observer coverage have been mandated for enforcement purposes; there is a separate scientific sampling program that relies on tows by expensive government vessels; fishermen create their own business systems and generate their own inputs relating to catch; various fishery participants may create separate channels by which to exchange catch and market information with one another; and managers collate catch data from various sources in order to tally it against established limits. In contrast with this chaotic picture, if rich and real-time data is collected and made available from each fishing vessel, it creates immediate potential to precipitate the cross-leveraging of these different functions in ways that dramatically improve efficiency and performance.

In small and unregulated fisheries, such systems have the potential to create a management architecture—perhaps entirely separate from government—that has previously been wholly lacking. Low-cost systems that are able to capture and share essential data such as the total number of fishery participants and total time spent at sea could open the door to a governance framework that can prevent collapse and put such fisheries on the path to recovery.

Applications and Benefits

Regardless of the fisheries context, this vision of integrated real-time data streams in service of business, scientific, management and enforcement needs has enormous potential to move all fisheries in the direction of smart incentives and good information. Here are some of the discrete applications and benefits we believe are both critical and achievable.

- **Accessible compliance monitoring.** Smart boat technology will sharply reduce compliance monitoring costs for fisheries with high levels of accountability, while enabling it in fisheries where compliance monitoring is currently limited or non-existent. Existing EM cost drivers include video data storage, human review of video footage and postage and handling of hard drives. All these costs can be forced down sharply by smart boat systems that utilize machine learning to isolate relevant data and automate data transmission through network connectivity. An expansion of compliance monitoring would be transformative. Among other things, it would sharply curtail illegal, unregulated and unreported (IUU) fishing, and it would vastly expand the range of effective applications for the rights-based programs that establish smart incentives for fishermen.

- **Improved fisheries science.** Smart boat technology will transform fishing vessels into platforms of scientific discovery—gathering critical fishery-dependent and oceanographic data and feeding into science-based management processes in real time. Scientific assessments of stock health are the foundation of sustainable fisheries, and more timely and comprehensive data will allow managers to react to in-season signals, for example, to limit—or to expand—fishing opportunities.

- **Expanded "precision fishing."** Smart boat systems will provide fishermen with real-time data that equips them to fish smarter—in particular by avoiding imperiled fish and marine wildlife. In many fisheries, the likelihood of encountering species fishermen wish to catch or avoid can be predicted by overlaying oceanographic and catch data—but to date, such processes have often been cumbersome and cost-prohibitive. Expanding this method of "precision fishing" could save countless sharks, sea turtles and other marine wildlife, while obviating the need for some time and area closures that can be economically crippling for fishermen.

- **Reduced business costs.** Smart boat applications will offer enormous upside for fishermen, one key component of which is facilitating greater efficiency. Data analytics on weather and ocean conditions, and the probable location of target species, can limit time on the water, securing significant cost savings in areas including fuel, labor and maintenance.

- **Increased market power.** Smart boat connectivity will provide fishermen with on-the-water access to up-to-date market information, empowering them to make informed choices about when to fish their quota in response to real-time market fluctuations. Connectivity will also pave the way for disruption of established fish purchasing power dynamics, for example, by allowing fishermen at sea to offer their product to a wider range of buyers on new and more competitive platforms.

- **Supply chain proof of provenance.** Smart boat technology will offer a solution to the most vexing piece of the seafood traceability puzzle, by capturing immutable and verifiable catch data at the vessel level. Integrated electronic tags will provide certainty to buyers throughout the supply chain—certainty existing traceability systems that attach to products only after unloading cannot claim. Moreover, sensors linked wirelessly to a digital traceable catch record can guarantee not only where the product was caught, but also quality indicators such as temperature in the hold. These value-adds could significantly increase ex-vessel prices for some species.

Yasuhiro Otomo: Keeping a remote eye on underwater nets

Fishing is time-consuming work. That's especially true in set-net fisheries: boats burn hours and fuel patrolling their nets and don't have any idea what they've caught until they pull the net above water.

Enter Yasuhiro Otomo. The 2011 Great East Japan earthquake and tsunami damaged his home port and forced him to spend even more time getting to his nets. Otomo needed a faster and more efficient way to monitor his nets, so he developed smart buoys that keep tabs for him—remotely. Think of the buoys as the Ring Doorbell or Nest Camera of the ocean.

"I didn't want to fish faster, I wanted to fish smarter," Otomo said. "Being able to monitor my nets from my smartphone would save time and money, and allow me to match my catch to markets."

With support from KDDI telecom, he developed a pilot project to combine Internet-connected buoys that track data like air temperature, atmospheric pressure, water temperature, water pressure, tidal current and salt concentration with underwater cameras that give him an instant view of what is—or isn't—in his nets.

"It's disappointing to pull up an empty net," said Otomo. "But it's also expensive. If I know a net is empty, I can just move to the ones with fish. The whole trip is more efficient. Or, if a net has enough catch, I can go retrieve it to avoid overharvesting."

Otomo's goal was to cut costs and increase profit, as well as benefit the ecosystem. For example, in fisheries with strict catch limits, knowing how many fish are in a net would allow fishermen to know when they've caught their limit. They could retrieve their nets sooner and reduce overharvest. Pairing catch data with water temperature and current data could help scientists analyze how climate change is affecting fish migration or location patterns.

"There are many benefits to this technology beyond saving me time and money," Otomo said. "I think it shows that solving problems that affect fishermen can also help us preserve the ocean."

Yasuhiro Otomo, who fishes in the Pacific Ocean, developed a pilot to monitor his set nets remotely via the Internet.

- **Improved quality of life at sea.** Smart boat systems that displace human observers for compliance monitoring purposes will be especially welcome for crew members on small vessels where space is limited. Quality of life at sea will also improve as network connectivity enables more sustained contact with family and friends via access to email and social media.

- **Strengthening climate resilience.** The potential for smart boats to collect and make available rich and real-time data from the sea will be critical as we work to build climate resilience into fisheries and other aspects of ocean management. By capturing more granular and widespread data than ever before on fishing activity, fish populations and habitat conditions, we will be able to conduct better resource assessments, undertake more accurate goal-setting and performance-tracking and enable truly adaptive management in the face of warming and acidifying oceans and shifting fish stocks.

Building momentum for change

This prospect of widespread benefits—not only for the marine environment tomorrow but also for fishing businesses today—holds incredible power as a driver of adoption. From experience, we know that narrowly enforcement-focused technologies in fisheries move forward either through government mandates or not at all. Limited voluntary pilots of EM systems have shown promise, but they have stubbornly resisted scaling as most fishermen conclude that there's not enough upside for them.

Working with fishermen, technologists, governments and other stakeholders, we believe now is the time to demonstrate the transformative power of digital technology to improve fishery management outcomes, and to lay claim to a future in which healthy and abundant fisheries continue to sustain us for generations to come.

Yet there's also a palpable hunger among fishermen for access to more powerful tools by which to take control of their futures. Without information, and without positive incentives to engage in sustainable practices, fishermen are relegated to being "regulated" users of a public resource, a state of affairs that's proved to be a lose-lose proposition wherever it's been tried. We believe there is a widespread appetite for new approaches—new ways to construct alternative management programs in a wider variety of contexts and access to more accurate and dynamic information about their fisheries.

Our immediate challenge is to seize upon this receptivity by incubating, testing and proving the full potential of smart boat technologies to deliver both business and conservation outcomes. Working with fishermen, technologists, governments and other stakeholders, we believe now is the time to demonstrate the transformative power of digital technology to improve fishery management outcomes, and to lay claim to a future in which healthy and abundant fisheries continue to sustain us for generations to come.

Chris Brown: “We should harvest data at the same rate we harvest fish.”

When Chris Brown pictures the massive number of individual vessels fishing American waters, he sees an opportunity to launch the largest scientific study on the planet.

“Fisheries have gotten used to making decisions and policy based on very small amounts of data,” Brown said. “Technology offers us a chance to kick that habit. Every boat is a chance to improve fishery science and to turn fishermen into partners in our effort to conserve fish stocks for future generations.”

Brown is speaking from experience. Working in partnership with The Nature Conservancy and the Gulf of Maine Research Institute, he’s been an early adopter of onboard EM technology, which deploys on his fishing boat to identify species and record length data for each catch.

“The camera systems are amazing,” Brown said. “They’re producing the best data we’ve ever collected.”

The potential of new technology goes far beyond cameras and compliance. The more accurate the data managers rely on, for example, the faster they’ll be able to respond to changes in abundance, and the faster fishermen will be able to reap the benefits of recovering species.

“Every permitted vessel should have equipment that reports where you haul and set, the surface and bottom temperature and salinity levels,” Brown said. “Just imagine how much better we’d understand fish stocks if every vessel on the ocean were a remote data collector.”

The challenge, according to Brown, is developing incentives that encourage fishermen and fishery managers to embrace the change.

“It’s true that fishermen are stubborn. We don’t like change. But the same is true of regulators and fishery scientists. We need to find a way to push both sides into the data age.”

For Brown, that means tireless evangelism to fishermen, scientists and regulators about the possibilities of new tech-driven data collection. “This is an exciting and strategic new direction for fishery management, and everyone I talk to eventually agrees that it’s the right way to go. But it takes time.”

Based in Point Judith, Rhode Island, Chris Brown has been a commercial fisherman for more than 40 years. “We should harvest data at the same rate we harvest fish,” said Brown.

Smart boat technologies in action

Credit: Alaska Fisheries Science Center

CHINA:

Improved tracking of fishing behavior and catch can benefit scientists, managers and fishermen in the world's largest fleet

Improved science for managing fish stocks and more adaptive decision-making

China's Zhejiang Province is the beating heart of the world's largest fishing nation. Centrally located along the Chinese coast, the province lands more fish than any other. On its own, Zhejiang would be among the ten largest fishing nations in the world. Zhejiang has a track record of management innovation, with successful practices by the province often adopted as new national policies. As part of sweeping management reforms in China, the central government recently turned to the province to implement pilot projects for management using catch limits instead of traditional restrictions on fishing effort.

The blue swimming crab fishery, which is the most valuable in Zhejiang Province, was selected for a project that allocates both fishing territories and quota to participating vessels in the Zhoushan Archipelago. The pilot reinforced the importance of tracking fishing behavior and catch data for scientists, fishery managers and industry leaders to implement more effective management. The province is now expanding its pilots to test new electronic logbooks, more fully using existing VMS units and reconfiguring cameras installed on many vessels for safety monitoring to also record catch.

While many data streams already exist for fisheries management, including a new human observer program, logbooks and records of catch that are corroborated by both buyers and fishermen, there is still more work to be done. For example, a common issue is that these data sources are often not integrated to form a more holistic picture of the state of the fishery. Advanced data management and analysis platforms could be used to identify gaps in data, visualize trends and incentivize adoption of more integrated electronic tools.

The combination of a forward-thinking mindset, energetic tech industry and experimental approach to policy development puts China in a position to drive change by adopting new and emerging technologies faster than most other countries. For example, in the near future Zhejiang could leverage machine learning tools to automatically identify and count catch for crab, transmit these results via cellular network to the cloud and enable a more efficient and integrated system of management that cuts paper records out of the equation.

SWEDEN:

An online platform helps fishermen stay profitable and meet strict conservation requirements

Streamlined and enhanced business operations

For years, fishermen in Sweden have collaborated with government officials and EDF to design a sustainable fishing system for the country that could be replicated across Europe. In 2017, they launched a new management system for Sweden's demersal fleet. The system is based on individual, transferable quotas with increased flexibility to trade and transfer quota throughout the year. One goal was to address the wasteful practice of discarding fish that are caught inadvertently—often in excess of a fisherman's quota—and then thrown overboard, frequently dead or dying.

This January, a European Union ban on discarding fish came into effect, and Sweden was ready. The country had already adopted an online platform, FishRight, which allows fishermen to trade quotas in real time. The individual quota system was an important management reform to better control harvest levels, but without the technology to support swift, transparent quota transfers, fishermen would have struggled to stay within the new rules eliminating discards. Thanks to FishRight, fishermen can use any device (phones, tablets, laptops, etc.) to check their available quota and apply for transfers to better match the fishing conditions and their catch.

Swedish fishermen are now free to fish, knowing they can stay within sustainable fishing limits, rather than exceed their quota and be forced to stop. It's an elegant solution that comes at a critical time. Many countries were unprepared for the discard ban and may be facing disarray as they struggle to comply. As an open source platform that other countries can adopt, Sweden's FishRight program can help scale success throughout Europe.

HUMBOLDT CURRENT:

Using technology to foster cooperation and engage fishermen in support of climate-resilient fisheries

Improved science for managing fish stocks and more adaptive decision-making

The Humboldt current off the west coast of South America is a rich upwelling current that supports some of the world's most productive fisheries, including the world's largest single-species fishery, for anchovy. The current is subject to large swings in ocean environmental conditions because of phenomena like the El Niño Southern Oscillation, leading to "boom and bust" cycles for many species of fish. Climate change is expected to increase and intensify this environmental variability, in unpredictable ways.

The fishing economies of Chile and Peru—two of the world's largest fishing nations—will depend on their ability to monitor and adapt to these changes, and their effects on ocean wildlife. In the Peruvian industrial anchovy fishery, research and commercial fishing vessels already monitor environmental conditions and other factors that may signal a fluctuation in fish populations. Until recently, however, these data were not being consolidated and fully used. Now, the Peruvian government's Marine Research Institute (IMARPE) and the National Fisheries Society of Peru (SNP) have teamed up to consolidate ocean observing data from both research and large-industrial commercial fishing vessels, creating an accessible and comprehensive database. This is fostering better cooperation between the fishing sector, management entities and scientific institutions, as well as prompting a move towards more complete ocean observing coverage for Peru.

The small-scale fisheries in the region—with large fleets of small boats—could also be a critical means of collecting data. These vessels fish predominately nearshore but also operate offshore and even in international waters (more than 200 miles). They fish for diverse species, including mahi-mahi and giant squid, and are major contributors to local and international markets. Equipping these vessels with ocean observing technologies, such as temperature and biophysical sensors, connected to a wireless upload system that can feed into the cloud, would provide an invaluable database and help create early warning systems for major climatic changes that could affect global markets and local fishing communities.

HUMBOLDT CURRENT:

Using traceability technology to verify the legitimacy of catch in artisanal fisheries

Improved traceability and curbing illegal and unregulated fishing

Chile's small-scale artisanal fisheries provide livelihoods to almost 90,000 fishermen and millions of Chileans who live in the communities along the country's 2,600 mile coastline. Ensuring that the catch from these artisanal fisheries are of legal origin, meet proper food handling and quality standards and are within the size limits is a constant challenge in a country with so many rural areas and such a long and remote coast.

Recently, Chile's National Fisheries Service (Sernapesca) partnered with technology provider Shellcatch, with support from EDF and the Association of Open Air Markets (ASOF), to pilot an onboard technology for small-scale fishing vessels to trace their catch all the way to the marketplace. The system links to iPhone QR sensors and is automatically integrated with the National Fisheries Service's online system. It will dramatically improve the ability of enforcement authorities to cut down on illegal fishing while providing consumers with more confidence to purchase legal, traceable seafood. Improving on this pilot technology and scaling it to all of Chile's artisanal fisheries will be a huge leap forward for sustainable fisheries and sustainable seafood consumption in the Humboldt current region.

MEXICAN CURVINA IN THE GULF OF CALIFORNIA:

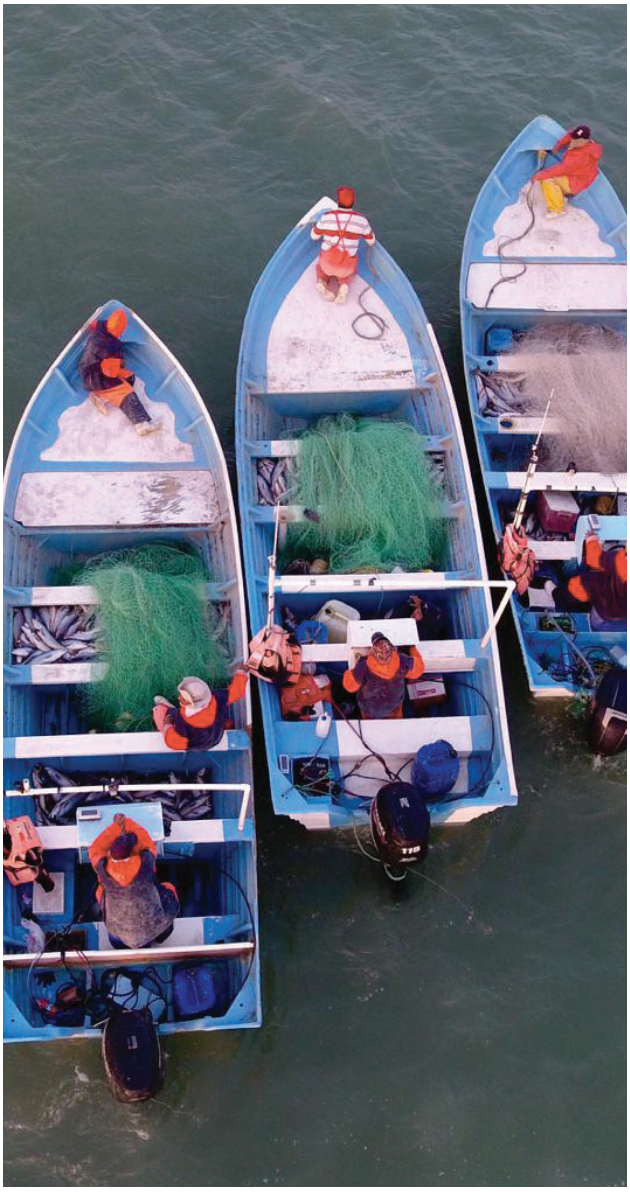
Fishermen in a small-scale fishery use trackers and app to help protect a critically endangered porpoise

Better, more cost-effective monitoring and protection of imperiled wildlife

The curvina fishery in the Upper Gulf of California provides livelihoods for over 2,000 families in four fishing communities, including the indigenous Cucapah community. It is one of the most regulated fisheries in Mexico and the first Mexican finfish fishery with a catch share program. The Upper Gulf is also the home of the endangered vaquita porpoise, which is killed by poachers fishing illegally for totoaba, a fish that is highly valued in Asia for its giant swim bladder.

In order to both protect the vaquita and sustain the communities that depend on the curvina fishery, EDF formed a partnership with fishermen and Mexican authorities to improve information, compliance and stewardship. During the 2018 season, the technology company Pelagic Data Systems installed tamper-proof electronic trackers on small-scale fishing boats. These trackers provide near real-time data about vessel location, ensuring that fishermen are staying out of a protected zone for vaquita and alerting enforcement officials of any violations. Women and young people who participate in the Catch Accounting Program use a digital platform with automatic reports, called "WebControl Pesca." This platform works through a smartphone app, which identifies an optical recognition (QR) code linked to the official permit.

Through the app, enforcement officials receive photographic evidence of the boat's registration, details on when it enters and leaves the water and confirmation that only authorized fishing gear is being used. By effectively deploying these technologies as part of a well-designed management system, fishermen can demonstrate to a global community focused on the urgent task of vaquita conservation that the curvina fishery is a responsible partner.



Carlos Tirado

MEXICAN HAKE IN THE PACIFIC:

Using technology to help fishermen achieve a high quality, sustainable product

A better quality product, full traceability and access to premium markets

Hake fishermen in the Gulf of California have worked hard towards a sustainable fishery. Now they are looking to technology to provide traceability, improve their product quality and access premium markets. Ten years ago, a new fishery emerged in the northern Gulf of California, where approximately 80 boats catch hake at depths of 200 meters or more. The fishery was entirely unregulated, and concerns began to grow about a damaging race to fish, so the fishermen reached out to EDF and the Mexican government to improve the situation. Today the fishery has hake-specific permits, and EDF is working with the government and fishermen to develop a new fisheries management plan and a companion set of regulations for the first time ever. Still, there are challenges to ensure that this hake reaches a market that provides proper value for its story. Currently, most of the hake catch is sent to markets in Mexico as a frozen product where it fetches modest prices as a generic whitefish.

Two key technological improvements could greatly improve the economic outlook for hake fishermen to continue their sustainability journey. First, improved quality—through low-cost refrigeration techniques and sensors to ensure the fish is kept at appropriate temperatures through processing—will go a long way towards commanding a higher price for a premium product in both domestic and export markets. Second, fishermen are looking for new approaches to comply with new regulations and fully document their catch—including satellite tracking coupled with online catch accounting, EM and reporting. This would facilitate the possibility of eco-certification, where Mexican hake could demonstrate full traceability from vessel to end-market.

U.S. PACIFIC GROUNDFISH:

High-tech monitoring to support fishery sustainability and fishermen profitability

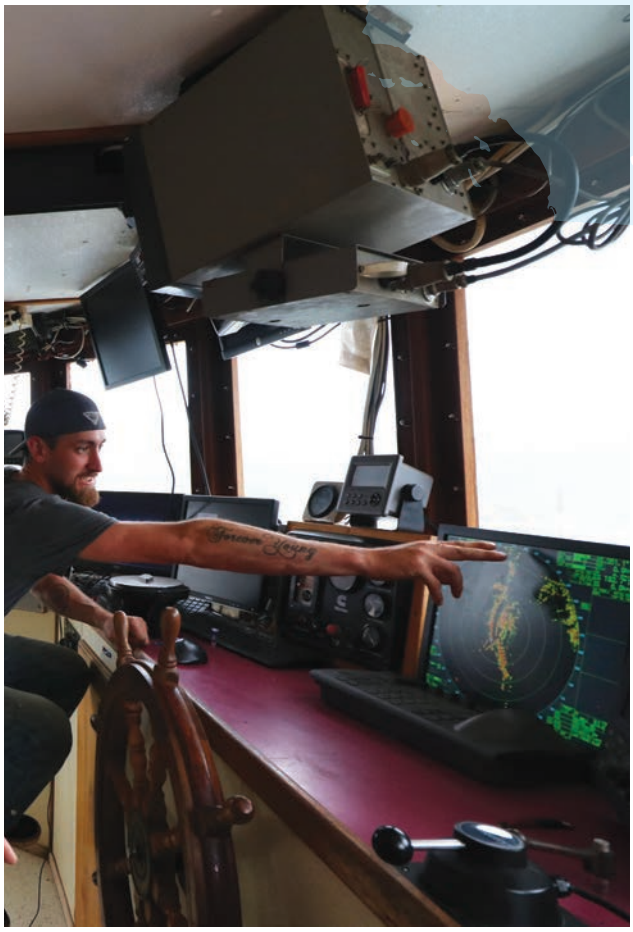
More cost-effective monitoring, improved science for managing fish stocks and more adaptive decision making

The U.S. Pacific groundfish trawl fishery has rebounded from the brink of collapse to become a global model for sustainable fishing. Fishermen got here by working with EDF and many partners to establish secure fishing rights, science-based catch limits and full accountability for every fish caught. Thanks to the combination of stewardship incentives and increasingly reliable information about harvest, fishermen have benefited from increasing harvests and faster than expected recovery rates of key target fish stocks. Many species in the fishery have recovered years ahead of schedule and more than a dozen are certified sustainable by the Marine Stewardship Council (MSC) and the Seafood Watch Program of the Monterey Bay Aquarium.

But fishermen struggle with the steep costs and inflexibility associated with having human observers aboard every vessel to monitor catch. With help from EDF and others, they have tested "traditional" EM systems that store raw video data from an entire trip, which is then manually removed via hard drives and mailed to analysts for review. Mailing hard drives is time-consuming—one more task before heading home to see family after a long fishing trip—and creates delay (in some cases up to a month from when data are collected to when they can be used for business or management purposes).

EDF is partnering with fishermen and others to pilot next-generation monitoring technologies. The promise is real-time monitoring data that is pre-processed on the vessel, transmitted wirelessly from the sea and stored in the cloud to be accessed as needed by fishermen and regulators. This new technology has the potential to dramatically reduce costs and burden on fishermen while empowering fishermen to use catch data to inform their decisions about fishing activity and for broader business purposes.

Over time, wireless transmission of data can be paired with machine learning algorithms that isolate relevant fishing activities—reducing transmission volumes and review times, further driving down costs. The benefits of these innovations could help incentivize the spread of EM in fisheries on a global scale.

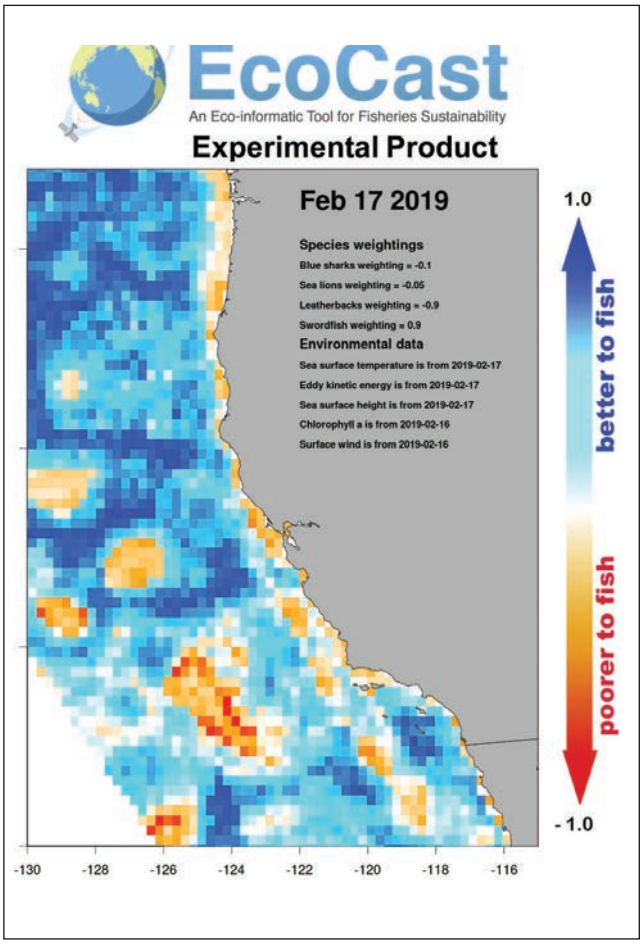


PACIFIC SWORDFISH AND ECOCAST:

Using real-time and predictive "hot spot" mapping for fishermen to fish smarter and avoid imperiled wildlife

Better targeting fish and avoiding wildlife

Cutting-edge technologies are helping fishermen on the U.S. West Coast sustainably harvest abundant swordfish while avoiding protected species such as sea lions, turtles and sharks. EcoCast is a real-time data tool developed by a team of academic and agency scientists. It collects sea surface temperature, chlorophyll levels and other environmental and biological data, then overlays information from fishing vessels on catches and interactions with sensitive species. A model then predicts good areas to fish for target species and "hot spots," creating a map to help fishermen avoid areas with a potentially high risk for bycatch of ocean wildlife. Now being piloted in the U.S. West Coast swordfish drift gillnet fishery, this model empowers fishermen to fish cleanly and minimize their bycatch.[1] If successful, EcoCast could eventually open more fishing opportunities, by providing a more targeted alternative to season closures currently used to protect endangered leatherback sea turtles.[2] Over time, this model of "dynamic ocean management" could benefit fishermen and marine wildlife in fisheries around the world.



[1] NOAA. (n.d.). EcoCast: An Eco-Informatic Tool for Sustainable Fisheries. Retrieved from https://coastwatch.pfeg.noaa.gov/eco-cast/

[2] Hazen, E. L., Scales, K. L., Maxwell, S. M., Briscoe, D. K., Welch, H., Bograd, S. J., ... & Kohin, S. (2018). A dynamic ocean management tool to reduce bycatch and support sustainable fisheries. Science advances, 4(5), eaar3001.

ALASKA:

Machine vision could bring a cutting edge approach to managing halibut bycatch in the North Pacific

More cost-effective monitoring, improved science for managing halibut stocks and more adaptive decision-making

Pacific halibut, caught commercially by longline fishermen, is one of the most valuable fish species in the North Pacific. At the same time, trawl fishermen sometimes catch halibut unintentionally as bycatch, particularly when targeting Pacific cod and flatfish species. They must stay within strict halibut bycatch limits or risk ending their fishing season early. Now, the Alaska Fisheries Science Center of the National Marine Fisheries Service is at the cutting edge of efforts to develop new tools to help account for and manage halibut across fisheries. Working with researchers from the University of Washington and fishing partners, they are testing computer vision technology and machine learning to quantify Pacific halibut discards from trawler catches as well as detecting and measuring halibut catches on longline vessels.

Alaska Fisheries Science Center

The partners have developed EM hardware and software that automatically detects when a Pacific halibut is released overboard and measures each discarded halibut, generating data to be ultimately integrated into overall catch accounting. On longline vessels, the machine vision system will automatically count and measure halibut and other species as they are brought on board or discarded. On trawlers, a metal chute, or "photo booth," is integrated into the catch handling protocol. As fish are passed down the chute by fishermen, sensors detect the fish and take its picture, and an algorithm automatically measures it. Researchers also collected a tagged image library consisting of thousands of images to develop and train another machine vision algorithm to identify fish species, flagging images that cannot be sorted for manual review. The algorithm is 94 percent accurate in recognizing the most commonly imaged species.[3]

Using the chute system, estimates can be made quickly, which means fish spend less time out of the water, increasing their survival rate when discarded. This would have positive implications for fishermen concerned with low halibut bycatch caps that could end up costing them fishing opportunities. A stated goal of the project is to share code and other developments widely with other fisheries.

[3] NOAA Fisheries. (2018, July 17). Expanding Electronic Monitoring Technologies in the North Pacific Fisheries. Retrieved from https://www.fisheries.noaa.gov/feature-story/expanding-electronic-monitoring-technologies-north-pacific-fisheries

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