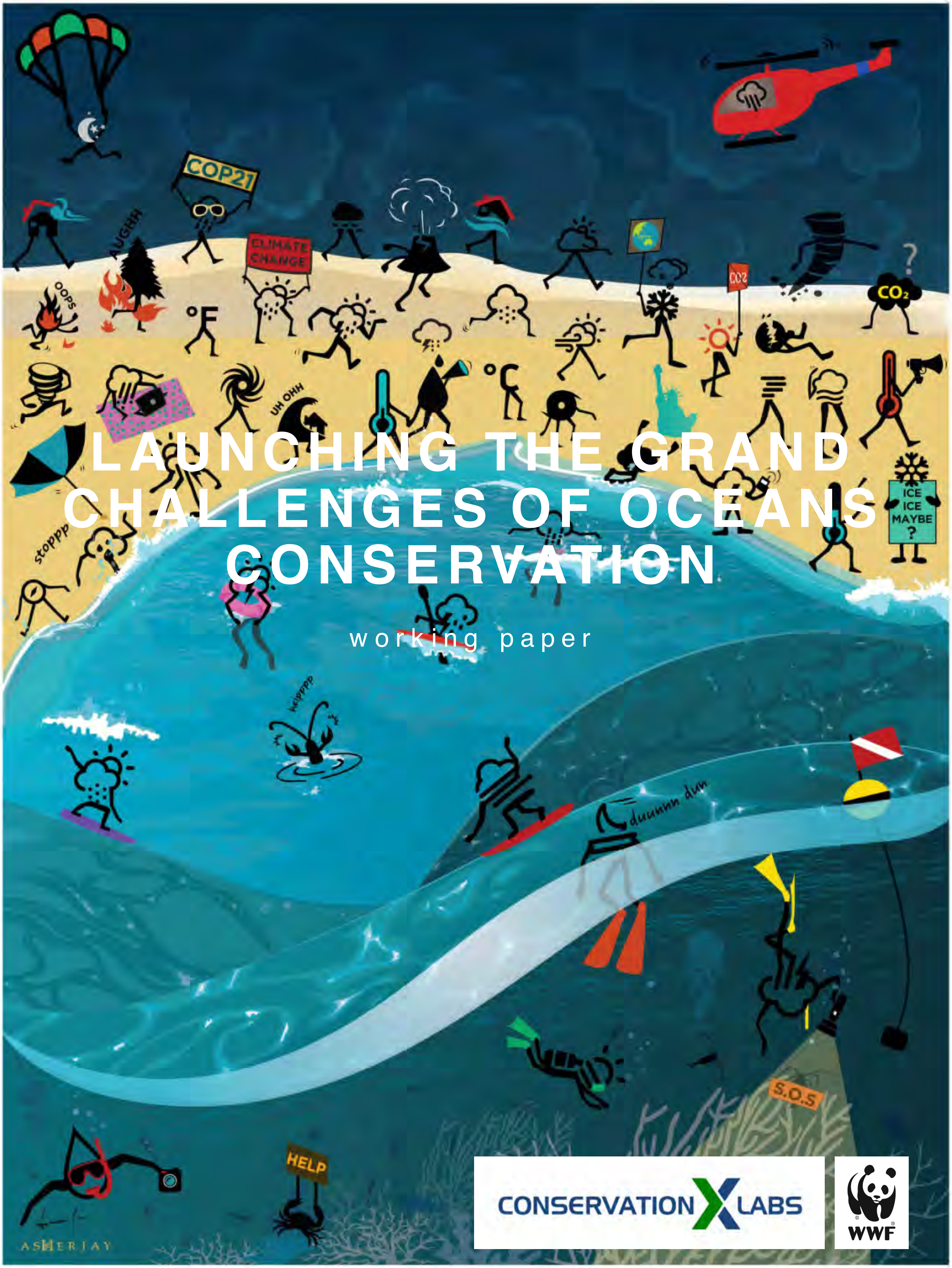
LAUNCHING THE GRAND CHALLENGES OF OCEANS CONSERVATION

working paper



CONSERVATION X LABS

WWF

About the Cover

"It's A Sign" © Asher Jay 2015

"It's a Sign" invites viewers into a comically imaginative world where climate reality is vividly brought to life by dramatically engaged, humanoid, weather icons. The pictographs that bring alive this narrative are extremely familiar to people from all walks of life because these symbols are not only encountered on all digital interfaces, but even on weather reports at the end of televised news segments. This seeds effortless mnemonic associations within all viewers between their daily routines and the global impact expressed by climate change in the Anthropocene. By depicting natural hazards, such as earthquakes, tsunamis, floods and tornadoes, and extreme weather conditions, as emotionally active anthropoid characters, Jay re-frames phenomena inherently larger than life, accessible and corporeal. This work encourages people to get to know local weather and global climate at least as well as they know their immediate neighbors and , the piece aims to tangibly tether our planet's climate-scape to our every day vocabulary.

About Asher Jay

Asher Jay is saving the world’s threatened wildlife—with creativity. Jay uses groundbreaking design, multimedia arts, literature, and lectures to inspire global action to combat illegal wildlife trafficking, advance environmental issues, and promote humanitarian causes. Her upcoming projects will tackle biodiversity loss during the Anthropocene and expose threats to the world's most traded and endangered mega fauna.

Jay’s projects have each become global sensations. Yet her ultimate goal is to motivate the one person she believes holds the real power to determine nature’s fate. You.

www.asherjay.com

VISION

Our vision *is to* harness disruptive financial, technological, *and* behavior change innovations *to* dramatically increase the efficacy, speed, *and* sustainability *of* conservation efforts, *and to* ensure that we will bring *the* most transformative ideas *to* scale.

OCEAN CONSERVATION LANDSCAPING FRAMEWORK:

The Challenge *of* 9.6 Billion

We are in the middle of a period of extraordinary change on the planet, a sixth great mass extinction. Unlike the previous mass extinction events, this is the first extinction in Earth's history that is driven by the actions of a single species. During this period, the earth has been fundamentally changing physically, chemically, biologically, and ecologically.

The twin forces of environmental degradation and global climatic disruption have led to a crisis in nature. The chemistry of our oceans and atmosphere is changing. The planet's natural cycles are showing unprecedented variability. Entire ecological communities are reorganizing or disappearing. Invasive species at multiple scales—from microbial pathogens, to insects, birds, and mammals—are crossing into new geographical areas.

These trends are unlikely to reverse anytime soon. The planet's population is expected to rise to 9.6 billion by 2050, and with it, a need for a 70% increase in food production, coupled with a 1.9-fold increase in irrigation, a 2.4-fold increase in nitrogen deposition, a 2.7-fold increase in phosphorous deposition, and a 2.7-fold increase in pesticide use, if there is not a significant improvement in plant productivity. The biggest challenges will not only be population growth, but also meeting the desires of an emerging middle class for protein, consumer goods, and energy, while simultaneously decreasing our environmental footprint.

Billions of dollars are spent on conservation efforts but although we may be winning individual battles, we are losing the war. A result of this exceptional human transformation of the planet is the dramatic increase in our planet's extinction rates. Extinction rates are currently 1,000 times that of background extinction rates, and these even exceed other mass extinction events by at least an order of magnitude. One in every four mammals and one in every eight birds now face a high risk of extinction in the near future. But with only an estimated 9% of marine species known to science, the mass extinction in the ocean is likely to be even more immense. Moreover, 95% of the 1.8 million named species have yet to be evaluated for their conservation status, and almost none of those are in the ocean. What we do know is that, based on trends of 5,829 populations of 1,234 mammal, bird, reptile and fish species, marine populations have shown a decline of 49% between 1970 and 2012.

Conservation is not succeeding quickly enough or effectively enough to meet these challenges. In a world with an ever-increasing population and billions of consumers emerging out of poverty, our natural resources are under increasing pressure. The problems of extinction and habitat destruction are increasing exponentially while our solutions increase incrementally.

Conservation has been at times historically technophobic, risk-averse, and backward looking, but this is starting to change. Just as we are driving extinction, we have the power to reverse it. We can apply our unparalleled innovation capacity and harness exponential technological advances to engineer resilience to global environmental changes, change demand and incentive structures to alter our behavior, and improve our ability to monitor and protect species around the world. Much as humanity has caused these problems, we have the ability to solve them.

The time of conservation as a predominantly philanthropic and academic activity has passed; we have entered into an urgent new reality where the conservation of our natural ecosystems and resources is fundamental to human, economic, and national security. We have unique opportunities to build new companies, new markets and new innovations, and to bring in new solvers and new disciplines into conservation.

This vision for conservation will generate new opportunities and create radically different ways of conserving our environment. And as life began in the sea, so will we. We will begin this new vision with our oceans.

Smart Gear 2.0

WWF, in partnership with industry leaders, governments, scientists, and fishers, launched the International Smart Gear Competition in 2004 to reduce bycatch by improving fisheries gear. The focus in the competition was on gear modifications for "fishing smarter": modifications that increase the chances of escape for non-target species, or reduce the overall numbers of non-target species caught. The competition invited submissions of practical, cost-effective solutions, and offered cash prizes totaling $65,000.

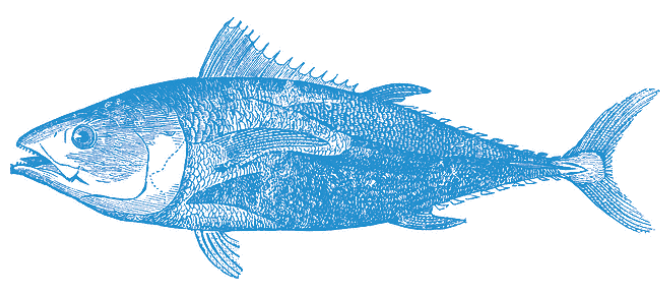
Despite its modest funding, the competition has been a success. Smart Gear was designed to inspire creative thinkers through open innovation for ideas that have practical applications for fishing smarter. In particular, it was highly effective at sourcing great ideas from those closest to the problem—people engaged in the fishing industry. It was less effective at attracting innovators outside of the industry. Designed to find new solutions, it also did not have a formalized pathway to scale or commercialization for the innovations/innovators that won the prize. Nor were there avenues to bring even more promising ideas that required additional technical or engineering expertise to fruition.

Now, after more than a decade, there is an opportunity to build on the Smart Gear model. This analysis looks at expansion through three lenses:

1. **Expand the scope of the problem**. How can we expand the focus of the innovation program from reducing bycatch to addressing other grand challenges in marine conservation?
2. **Expand the scope of the program.** WWF has recognized that there were many workable ideas that were not yet ready for the Smart Gear prize, but that could have had an even greater impact if given the chance to develop. How can we source new ideas, refine and iterate product design and engineering, and move them along a product development pathway? What partnerships could we create with universities, industry, and engineering and design firms? How could we harness open innovation to improve design and performance through maker faires, hackathons, and challenges? What are the costs and benefits of doing so?
3. **Incubate, accelerate, and scale**. As it is insufficient for ideas to languish as prototypes or pilots, we explore acceleration pathways for new companies and innovations coming out of a new set of challenges and other design processes. This may include developing potential partnerships with existing incubation and acceleration programs, creating a dedicated conservation accelerator, licensing intellectual property and then taking the technology to market directly, supporting innovators around engineering, product development, design, and business; and creating a new global fund to take the most promising ideas to scale.

In this analysis, we will review how we may build on the inspiration gained from Smart Gear, to transform the ocean conservation space by creating a pipeline of new innovations, bringing in new solvers and new solutions, and by taking those solutions to scale. The first step is the Big Think.

Smart Gear was designed to inspire creative thinkers through open innovation for ideas that have practical applications for fishing smarter



The Big Think

The Big Think is a problem-solving catalyst, connecting existing dots in new ways to unlock innovative answers. Complex problems, by definition, have many forces at play and affect many parties. We use collaborative engagement to tackle these complex and systemic problems. This process is designed to widen the problem-solving lens and harness the collective intelligence that resides both within and outside of the conservation community, facilitating the network to uncover synergies and co-design innovative solutions that no one entity could do on its own.

Specifically, we will use the Big Think to achieve the following:

First, we will use the Big Think to help prioritize the most critical problems for ocean conservation and build the investment and commitment behind a new set of global competitions. We will also use this event to design the innovation and acceleration platform itself.

The Big Think will look at additional sourcing pathways (expanded prizes or challenges, hackathons, design sessions, directed innovation, university competitions), incubation, and acceleration, and explore which approaches would work best in addressing the most pressing challenges. The scaffolding for the Grand Challenges and Oceans X Labs will be built from this unique co-design event.

Second, the Big Think will build a tribe around a set of Grand Challenges for Oceans Conservation. As conservation needs to expand its ranks to include new disciplines, new solvers, and new solutions, the Big Think can help build a community of practice for the next generation of conservationists to accelerate and substantially increase conservation's impact through its transformation.

We will build a novel community from the existing conservation movement, but will also engage technologists, biological engineers, designers, makers, innovators, hackers, marketers, financiers, and anthropologists. Our role is to be a catalyst, connector, amplifier, and mobilizer within the conservation community, relying upon an ecosystem of institutions and individuals that enable us to effectively understand, source, test, and accelerate conservation solutions. It is only through productive, collaborative approaches like this that we can start solving these critical conservation problems.

Third, the Big Think will create a set of commitments to help us reimagine oceans conservation. We will ask participants to provide their technical expertise and introductions, to work with us and our innovators on refining ideas, and to partner with us to launch the Grand Challenges for Oceans.

The Big Think is intended to galvanize support for a global fund for a set of Grand Challenges and to create an innovation pipeline. This could include the creation of a global partnership to fund the creation of new innovations, development of incubation and acceleration platforms, new vehicles to unlock university intellectual property and apply it to oceans conservation, and co-financing and investment to help bring both existing enterprises and new technologies to scale.

The aim of the Big Think is to benefit from the collective genius of the extraordinary individuals we have brought together. Through a synthesis of their expertise, we can refine our existing ideas, realize our vision, and create new opportunities for ocean conservation.

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The Ocean Grand Challenges: Expanding *the* Scope

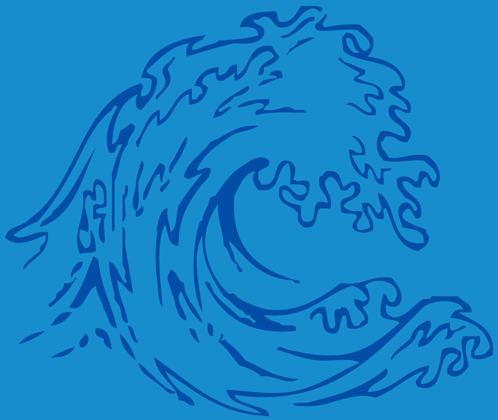
The oceans, despite covering most of the planet, are among the least-understood ecosystems on Earth. What data we do have indicate that they have been heavily exploited, and that a significant portion of the planet is dependent on this ecosystem for its wellbeing. The oceans' fisheries are overtaxed, marine habitats from mangroves to reefs are increasingly degraded, and the basic chemistry and geophysical processes of the oceans are changing, including their pH, temperature, volume, and circulation patterns. This set of challenges is daunting. However, we have an opportunity now to harness our ingenuity to better understand the rates of change underway within ocean systems, to restore degraded ocean environments, and to develop substitutes for products that are threatening the oceans.

LANDSCAPING MAP

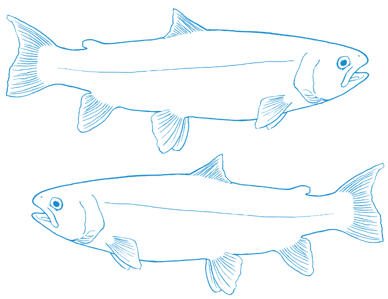
Simultaneous to understanding leverage points for disruptive change in the oceans, we have developed a method of mapping and a systemic model for understanding the field of ocean conservation via technology. It involves collaborative sense-making through desk research and interviews.

This work is best presented in slide format: **please click here for a tour of the model**. The tour will guide you through the systemic components that need to be considered when approaching conservation technology from a holistic perspective. Due to the large size of the map, it can only be viewed in full online or projected on a wall. **Click here to explore the full map online**.

Ten Grand Challenges *for* Ocean Conservation



1. **A Blue Revolution for Oceans: Reengineering Aquaculture for Sustainability**
2. **Ending and Recovering from Marine Debris**
3. **Transparency and Traceability from Sea to Shore: Ending Over-Fishing**
4. **Protecting Critical Ocean Habitats: New Tools for Marine Protection**
5. **Engineering Ecological Resilience in Nearshore and Coastal Areas**
6. **Reducing the Ecological Footprint of Fishing through Smarter Gear**
7. **Arresting the Alien Invasion: Combating Invasive Species**
8. **Combating the Effects of Ocean Acidification**
9. **Ending Marine Wildlife Trafficking**
10. **Reviving Dead Zones: Combating Ocean Deoxygenation, Dead Zones, and Nutrient Runoff**



Challenge 1
A Blue Revolution for Oceans: Reengineering Aquaculture for Sustainability

THE PROBLEM

Global demand for protein is anticipated to skyrocket in the coming decades. Aquaculture has the potential to produce a significant proportion of the world's nutrition. And while the current aquaculture industry is a vital producer for the global fish market, supplying 58 percent of the fish we eat, much aquaculture (particularly predatory fish and prawn) remains unsustainable, degrading both land and marine habitat, risking the introduction or spread of invasive and genetically modified species and pathogens, and polluting surrounding ecosystems. Many aquaculture farms are also economically unsustainable. Ninety-five percent of aquaculture occurs in the developing world where access to current technologies and capital, coupled with weak regulation, are barriers to change. Moreover, while aquaculture is a direct response to depleted fisheries, as an industry it relies heavily on wild-caught fish to feed captive fish. The following constraints need to be overcome to solve this grand challenge.

THE CHALLENGE

Develop aquaculture technologies, products, and systems that are more sustainable, reduce harmful by-products or environmental degradation, and replace less sustainable products & systems.

Aquaculture has the potential to transform global food systems for the better. To do so requires innovations in three areas: (a) system design; (b) inputs; (c) product innovation.

Sustainable Design: *Aquaculture farms, particularly those farming carnivorous fish, are inefficient, result in significant pollution, and can threaten human health.* The challenge is to produce whole-system aquaculture farms that produce multiple species and products in a closed-loop system that generates both safe, nutritious food and does not harm the environment. Current threats to the ocean environment from aquaculture include escapement and species invasion (non-native/GMO), disease transfer from cultured fish to wild fish, and conversion of critical habitat, such as coastal wetlands and mangroves, to ponds. New designs and technologies need to address water pollution from antibiotics, herbicides, pesticides, piscicides, disinfectants, suspended solids, and other effluents. Further elements to the challenge could include rethinking where aquaculture should take place — alternative ideas may include aquaculture within cities, on barges, in reclaimed land, or farther offshore in the open ocean.

Rethinking Feed: *The challenge is to create highly nutritional feed for aquaculture products that is sourced without environmental degradation.* We would be seeking solutions for aquaculture that reduce the burden on the natural environment to produce food for people. At present, marine ingredients in feed for fish come in large part from wild fish stocks. This can deplete natural fishery populations. By incentivizing the creation of replacements for wild fish in feed, aquaculture could become significantly more sustainable, nutritious, and profitable.

New Ocean Products: *The vast majority of aquaculture farms produce just a few products such as shrimp and certain finfish. The challenge is to vastly expand the range and quality of aquaculture products to meet rising human demand for protein while decreasing aquaculture's environmental footprint.* Fish and other species from aquaculture farms can be less nutritious than wild fish and even potentially unhealthy for humans as a result of bioaccumulation of antimicrobial carcinogens, antibiotics, and toxic algae. In addition, there is little effort to domesticate new wild fish species or to develop non-fish or shellfish products. The opportunity for more production from algae, invertebrates, and low trophic-level fish species could result in significant increases in the production of nutritious food.

Aquaculture as a solution is expected to at least double in outputs by 2050.

BACKGROUND

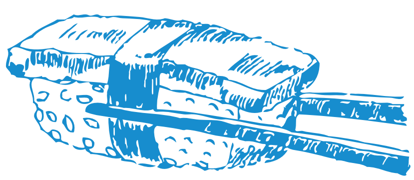
State of global aquaculture: While fisheries globally are nearing the point of collapse, the worldwide demand for protein is expected to continue to grow rapidly. Aquaculture as a solution is expected to at least double in outputs by 2050. To date, aquaculture food supply per capita and total production value have grown at an annual rate of almost 9% for decades, and farmed seafood has overtaken production from capture fisheries. Fish farming has enabled seafood consumption (and access to protein) to continue to increase even as marine fisheries production has flat-lined.

Production is heavily concentrated in Asia, particularly China [**FAO**]. Given that agriculture already uses 11% of the world's land surface [**FAO**], and that climate change particularly threatens global rice production [**IRRI**], aquaculture presents a huge opportunity to meet rising demand for food.

Environmental health: Most aquaculture occurs in natural systems (lakes, coastal ecosystems) using underwater cages or man-made rafts, longlines or racks, which have a variety of effects on the local biogeography and overall environmental health. There is a higher risk of disease or parasite outbreaks within farms and between farmed and wild fish where highly intensive farming practices are used in small containment areas. Escaped fish may weaken the genetic strength of wild populations, bring novel diseases, and introduce exotic invasive species into ecosystems. Local waterways and ecosystems risk pollution and depletion of ecosystem health as a result of excessive fish and aquaculture waste. Just as with production of terrestrial crops, excessive use of chemicals including fertilizers and pesticides can harm marine organisms and human health. Conversion of critical coastal habitat such as mangroves, estuary mouths, sea grass beds and other sensitive systems to aquaculture is leading to the destruction of vast stretches of valuable ocean habitat and species globally.

Inputs: While helping to relieve pressure on at-risk and collapsed fisheries, aquaculture has its own unique sustainability challenges. The most prominent sustainability challenge is the feed used in aquaculture, which accounts for 40-70% of production costs and puts heavy demands on wild fisheries, which are the primary source of current feeds. With the dramatic growth in the aquaculture industry, prices for fish meal and fish oil—prime constituents of many aquaculture feeds—are skyrocketing [**Lux Research**]. Fish meal and fish oil largely come from harvested pelagic fish like anchovies and for one kilo of farmed fish it can require anywhere from 0 to 20 kg of wild fish. Further, many of the species harvested for fish meal and oil are targeted indiscriminately and even referred to as "trash fish" when in actuality the catch from these trawl catches can include numerous fish of high value and ecological significance, but which are not of any market value because of their size.

Market structure: Aquaculture as an industry is poorly managed and relatively unregulated globally. According to the FAO, around 90% of the world's 18.9 million fish farmers are small-scale producers from developing countries. Aquaculture is currently facing major economic pressures in the form of rising feed prices, which may present opportunities to introduce better and more sustainable feed technologies. Sustainable businesses can also demand higher prices for their products, create new distribution networks that help producers access larger or higher value markets, and be better insulated from price volatility.



EMERGING SOLUTIONS

Aquaculture may be the protein source of the future, yet as the industry currently stands, it is in need of innovations to improve efficiency, sustainability, and long-term viability.

Here are a few emerging examples of behavioral, technological and financial innovations with the potential to drive systems-wide change.

Sustainable Design: Improvements in design can rethink both where we grow fish, as well as how we grow them.

While redesigning aquaculture systems to reduce their environmental impact on coasts, we may alternatively rethink the need to grow fish in coastal waters. New **techniques for open-ocean aquaculture** could relieve pressure on near coast ecosystems and open up significant new space for producing seafood.

Kampachi Farms is a Hawaii-based mariculture company that has focused on off-shore fish production for Yellowtail sushi-grade fish, and reduction of fish meal as feed. Similarly, there may be opportunities to integrate aquaculture with terrestrial agriculture. Combined agriculture and aquaculture farms can also create new sources of vegetarian feed that provide substitutes for fish-based feeds, diversify incomes, and create secondary products through high quality organic fertilizers. **Aonori Aquafarms** has turned the coastal Baja desert into shrimp farms, harnessing mats of native Pacific seaweed not only as a natural food source for shrimp, but also as a protective cover that moderates the environment variation and reduces energy consumption. Aquaculture in urban environments also serves to bring food closer to consumers. **Oko Farms** in New York has created a demonstration aquaculture project in Brooklyn, New York. Other models of urban aquaculture propose using barges to cycle riverine water through racks of mollusks to grow seafood while reducing the nutrient pollution in urban environments. Aquaculture can also be integrated with urban farming such that high value plants directly utilize nutrient wastes.

Aquaculture can rebuild natural capital, rather than destroy it.

Veta La Palma is an estate covering 28,000 ha in Spain with integrated dry crops, rice fields, and marshlands that supports sustainable aquaculture while simultaneously providing habitat to 250 bird species. When the company began, only about 50 bird species were recorded in the area. Veta La Palma designed its fish ponds to allow for up to 20% loss of productivity—not to disease, or escaped fish, but to resident waterfowl. Veta La Palma illustrates how holistic business practices can lead to productivity gains while taking into account ecosystem services beyond 'provisioning', such as enhanced landscape and biodiversity value.

Rethinking Inputs: There is significant research attention focused on alternative feed sources for aquaculture, including generating feed from soy, seaweed, ethanol/biofuels waste products, algae, yeast, bacteria, and insects. **Enterra Feed Corp.**, based in Vancouver, is operating what appears to be the world's first commercial-scale facility to turn black soldier fly larvae into feed for farmed fish, livestock, and pets. The company's $7.5 million insect-rearing production facility in Langley, British Columbia, has the capacity to transform 36,000 tons of food waste each year into 2,500 tons of protein and oil and 3,000 tons of organic fertilizer. The company has secured approval to sell its products in Washington, Oregon, California, Indiana, Illinois, and Idaho [**ImpactAlpha**]. **Calysta Nutrition** is developing and producing FeedKind™, a new and natural fish meal replacement produced through an efficient, methane-eating natural microbe that produces protein. FeedKind™ has a smaller carbon footprint than soy and is proven to be a healthy, readily available, and highly digestible alternative for fish meal.

New Ocean Products: While aquaculture focuses primarily on fish, harvesting seaweed or other ocean plant/algae may have significant potential for providing sustainable food supplies, particularly in integrated productive systems. Seaweed production may be net-carbon-negative; red seaweed thrives in nitrogen-polluted waters and removes excess nitrogen from the water. Cultivation of sea lettuce may help reduce ocean acidification. Examples include the development of red seaweed varieties with bacon taste [**Business Insider**], and harnessing kelp in novel ways and for novel uses [**Ocean Approved**]. **AquaSpark** is the first venture fund committed to accelerating the deployment of innovations for aquaculture. Having just closed their first round of funding, several very promising technologies and farm systems have now received early stage investment. Venture capital can bring small aquaculture facilities to scale. In addition, the BioMarine industry association is in the process of creating angel-stage funding for small innovation opportunities.

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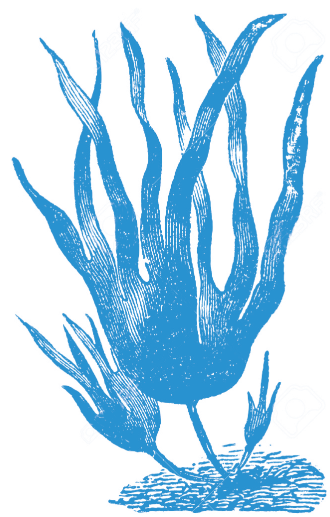

Challenge 2
Ending and Recovering from Marine Debris

THE PROBLEM

The ocean is downstream from everywhere else on Earth. Many major river systems and waterways in population centers have a direct path to the oceans, resulting in more than 5.25 trillion pieces of plastic debris weighing over 250,000 tons, among other trash, being deposited in the ocean. Marine debris continues to rise as a result of increased human activity in river basins and ineffective waste management systems across the globe. This has lead to debris (including clothing fibers, plastics, and other pollutants) conglomerating in massive ocean garbage patches. These patches are a challenge to address as a result of the composition and depth to which the trash penetrates. Plastic marine debris breaks down into smaller pieces until they are microscopic and distribute throughout the water column. These areas are in the global commons and, with no clear owners, responsibility is diffuse.

THE CHALLENGE

Reduce plastic marine debris in the oceans by 90% in 10 years, and undo the harm that has already been done.

The **Marine Debris Grand Challenge** would focus on the three elements of the input system: (a) reinventing material goods at the chemical level so that rogue trash entering the ocean can quickly and easily biodegrade, (b) stopping plastic pollution and other debris from entering the ocean, and (c) creating innovations to manage and clean up the trash already in the ocean and reversing its negative side effects.

PROBLEM STATEMENT

Around 80% of marine debris floating in the world's oceans is plastic. Although most marine debris is from the land, an additional source is from galley waste and other trash from ships, recreational boaters and fishermen (nets and floats), and offshore oil and gas exploration and production facilities.

At present, 15—40% of littered or dumped plastic enters the oceans every year. More than 5.25 trillion pieces of plastic debris are currently in the ocean, increasing by 4—12 million metric tons per year, with an average of 13,000 pieces of floating plastic per square kilometer of ocean. However, the exact quantity of particulate plastic (or microplastics) in the ocean is still unknown and difficult to measure. Ocean plastics break down into smaller pieces until they are microscopic. Scientists still do not know where more than 99% of ocean plastic debris ends up, how long it takes to degrade, and what impact it is having on marine life. What is known is troubling.

Ocean plastics absorb chemical pollutants, becoming highly toxic. Studies have shown that the concentration of toxic chemicals, such as PCBs and DDT, can be up to a million times greater in plastic debris than the concentrations found in seawater. Such large and small debris are eaten by sea life, including fish, sea birds, turtles, and marine mammals, introducing toxins into the food chain, and causing problems through blockage or perforation of the digestive tracts of sea life. According to recent papers, many more organisms ingest small plastic particles than previously thought. Floating debris can also negatively affect physical habitats such as clogging up coral reefs or mangroves, reducing their productivity.

Despite efforts toward standardized waste management in North America and Europe, the net amount of nonbiodegradable matter entering the ocean continues to grow. This is especially true for Asian and Latin American countries where growing participation in consumer economies outstrips the capacity (or frequently the existence) of waste management facilities. No nation takes full responsibility for cleaning up marine pollution in international waters. Even if a country were to do so, the clean up would only temporarily solve a fraction of the problem, as existing waste disposal patterns would soon replace what was removed.

EMERGING SOLUTIONS

Any solution needs to change the impact of products entering in the oceans, reduce the input of such products, and extract the debris that is already there.

Rethinking Plastics: Stopping plastic pollution is a two pronged initiative that simultaneously (a) accelerates green chemistry substitutions for materials innovation toward ocean-friendly polymers that will replace traditional plastics in everyday goods, and (b) develops a closed loop, ecologically benign waste management system for both the developing and developed worlds. As the developing world industrializes, it presents opportunities to rethink assumptions and leapfrog traditional technology.

Several efforts to create ocean-biodegradable plastics are underway from large chemical companies, food and beverage distributors, and small startup companies. **Mango Materials** transforms waste methane into biodegradable plastics that are economically and functionally competitive with oil-based plastics. The methane is captured and fed to naturally occurring bacteria that produce the biodegradable plastic. Once that product is no longer needed, the polyhydroxyalkanoates (PHA) will break down in a microbe-rich environment producing methane that can be turned back into PHA with Mango Materials' cradle-to-cradle process. Biodegradable plastic could be used in consumer goods, as well as for fishing gear, like nets. **Think Beyond Plastic** is an incubator and small-scale venture fund to build products and markets for biodegradable and recycled plastic products. Similar developments are occurring with replacements for Styrofoam. **Evocative Design** has developed packing materials that use agricultural fibers and mycelium (mushroom) as a replacement.

Waste Stream: Because most plastic and other debris that reaches the ocean passes either through rivers and streams or wastewater/stormwater outfalls, there is significant opportunity to disrupt the waste stream. Currently, there is little innovation occurring in waste stream technology. But the ability to filter, sort, and separate materials cheaply could both incentivize the creation of new products from recycled materials, as well as prevent these materials from reaching the ocean. This is particularly important for microplastics and other nanopollutants. Finally, there are also schemes to remove plastics before they hit the waste stream by creating building materials out of recycled plastics, such as plastic bricks.

Ocean Friendly Products: Ocean friendly products constitute objects and systems designed to be ocean friendly, not ocean trash. Solutions include ocean friendly product design for consumer and industrial products and a shift toward closed loop material goods; systems design for waste management that is accessible for all socioeconomic groups; improved infrastructure and ship design for ocean transportation of goods; and closed loop innovations in textile recycling such as that innovated by **Worn Again**, so that used clothes and textiles can be collected and processed back into new yarn, textiles, and clothes.

Extraction and Reuse: There have been a number of attempts to passively or actively clean up ocean plastic. The area involved and the relatively low density of plastic in the ocean have made most ideas untenable. The city of Baltimore has attempted to address this problem at its source through the solar and current powered **Inner Harbor Water Wheel**, which collects trash off the Jones River before it reaches Baltimore Harbor.

One effort that has received a significant amount of attention for both its audaciousness and its innovative approach is Boyan Slat's **Ocean Cleanup Initiative**, one of the first attempts to intercept and remove plastics from the ocean through large arrays. The technical and financial feasibility of the design has attracted significant criticism—large V-shaped barrier arrays anchored on the sea floor concentrate plastics carried on ocean currents toward a central platform, which extracts the plastic and stores it for transport. However, Ocean Cleanup has achieved significant support and funding. According to claims, the array is estimated to be nearly 8,000 times faster and 33 times cheaper than conventional cleanup methods, but the criticism is that it vastly over-estimates its ability to solve the problem, and is not financially sustainable. Time will tell.

Bureo Inc. is a company that has established a fishing net collection and recycling program along the coast of Chile, transforming the waste into skateboard decks. Their program, called "Net Positiva," buys ripped nets from fishers who would otherwise need to dump them in the ocean to avoid prohibitively expensive dumping fees. **Envision Plastics** has partnered with Method to create bottles with 5% post-ocean high-density polyethylene, collected from beaches. The challenge is to create high-end consumer products with a higher degree of post-ocean plastics, but at equivalent costs to existing plastic products.

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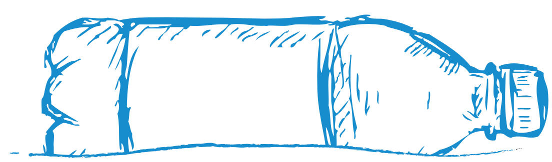

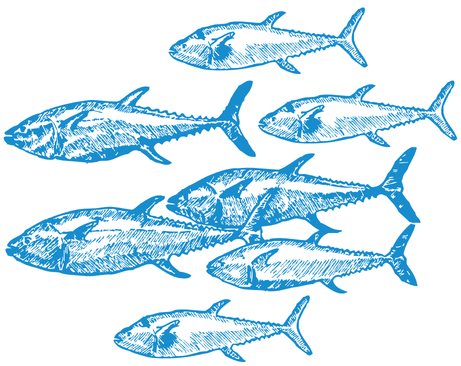

Challenge 3
Transparency and Traceability from Sea to Shore: Ending Overfishing

THE PROBLEM

Overfishing remains the largest direct threat to marine ecosystems. With 80% of all global fisheries at or beyond full exploitation, managing the massive quantity of fishing—including illegal as well as legal overfishing—remains an immediate challenge. Current fishing fleets are estimated to be 250% larger than what is sustainable, and this system is plagued with insufficient resources to effectively stem the tide. Moreover, the supply chain for seafood products involves a complex web of middlemen that mask the origins of fish, making enforcement of sustainability standards difficult. Challenges for overfishing include monitoring fishing activity at the source, creating more efficient tracking and enforcement mechanisms, increasing barriers to entry for unsustainable fish products into global markets, and influencing demand structures associated with seafood products.

THE CHALLENGE

Transform the monitoring and enforcement of fisheries management through innovations and systems that prevent overfishing, ensure true end-to-end traceability, and produce actionable data on the health and quality of fisheries for communities to act more sustainably.

The challenge would seek innovations in four areas:

1. Suitable technologies and innovations that would allow for better measurement & management of small-scale, artisanal fishing, and inshore fleets for sustainability of both communities and ecosystems, including ways to empower these groups as enforcers of fishing regulations and accelerate better data collection.
2. Technologies that improve the monitoring and management of industrial fishing.
3. Innovations for 100% end-to-end traceability, reducing mislabeling, and enhancing monitoring of seafood products from sea to store.
4. Traceability tied to novel financial mechanisms that incentivize fishers to behave sustainably by connecting well-regulated markets to the fishers themselves.

PROBLEM STATEMENT

An estimated 80% of global fish stocks are fully exploited or overexploited.

Fisheries have provided increasingly lower yields over the past few decades. Some industrial fishing fleets have begun to deplete stocks of fish species not previously consumed in an effort to keep up with the demand for seafood, or use trawling practices that are devastating to marine ecosystems. Though overfishing is generally driven by unsustainable practices even when not explicitly banned, illegal or unregulated fishing can drive overfishing even when local communities are attempting to manage their fish stocks. Coupled with the

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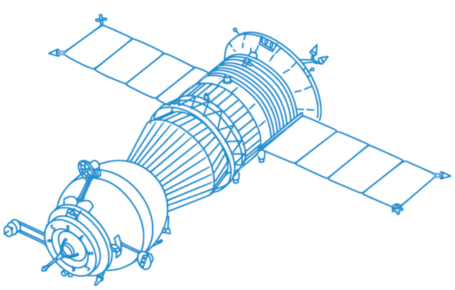
fact that territories and barriers in the oceans are often muddled in political controversy or are difficult to delineate physically, there can be no enforcement of protected areas without serious investments of financial and human resources.

Once the seafood products enter the global market at packaging and processing plants, tracking the source becomes more complicated for management officials, wholesalers, retailers, and consumers. The seafood supply chain is comprised of a worldwide network of hundreds of thousands of producers (fishers and fish farmers), thousands of processors, and tens of thousands of wholesalers and brokers that buy and sell over 800 commercially important species of fish, crustaceans, and mollusks. A single fish may circle the globe and be touched by 20 different entities before making its way to the consumer. However, key identifying information—the species name, where and when it was caught and with what type of gear, and where it was processed—rarely accompanies a fish on its journey from the ocean to the plate.

Although illegal behavior may grab headlines, in many of the most critical habitats there are few laws to enforce. Unreported and unregulated behavior has at least as large an impact on fish stocks as does overtly illegal activity. Developing countries account for 50% of the seafood entering international trade, yet represent only 7% of the Marine Stewardship Council certified fisheries. Progress toward ensuring sustainable management and end-to-end traceability requires finding new solutions for fisheries in developing countries that are designed for local constraints of cost, environment, suitability, and education levels. In addition to these tools, it is critical to help build local governance and management capabilities.

Further, local demand is often overlooked as a driver of overfishing trends. Fisheries in the developing world are critical to local nutritional needs. Seafood contributes at least 15% of the average animal protein consumption for 2.9 billion people and as much as 50% for some small island and West African states. For many of those who live in poverty (under $1.25 per day), seafood is a major source of omega-3 fatty acids that are essential for brain development and provides important micronutrients. The services of well-managed fisheries sustain coastal communities that rely on subsistence fishing for food. Unfortunately, these developing world fisheries are often some of the most threatened. They are also places where innovations specifically designed for the constraints faced by these communities could help mitigate overfishing.

Overfishing as a phenomenon of human behavior has broad implications. The ocean as a whole is difficult to manage and protect as territorial lines are often disputed and surveillance of key fishing areas is minimal at best, facilitating the myriad unsustainable behaviors that result in overfishing. Fishing is an economic driver as much as a source of food with over 2.1 million estimated motorized fishing vessels, 90% of which are small vessels less than 12 meters long. Because fish stocks are often hard to quantify and visualize and fisherman struggle to maintain economic security, the tragedy of the commons is a frequent occurrence where fish stocks are depleted rapidly in the pursuit of individual yields.



EMERGING SOLUTIONS

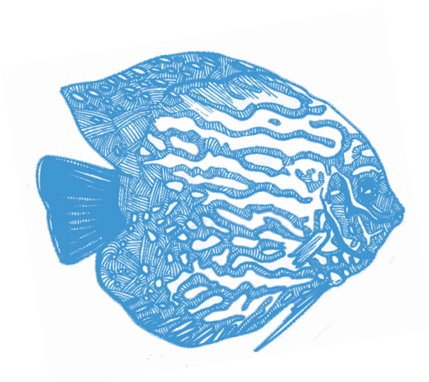
Traceability has been a focus area for the application of innovation and technology. However, it has largely focused on the highest value fish in the highest margin markets in Europe and North America. Efforts to scale the solutions to more markets and fisheries are needed to ensure that traceability becomes more than a high-end consumer concern.

Management of Artisanal Fisheries: **Pelagic Data Systems** has developed low-cost, rugged sensors that can monitor fleet locations, activity, storage temperature, and catch methods that can help artisanal fisheries sell to premium markets and meet certification standards. The system is $200 for two years of service, and has been deployed in Indonesia and Honduras. The system harnesses cell phone networks once the users return to land, and it is solar powered.

Management and Enforcement of Industrial Fishing & GeoFencing: **SoarOcean** and **Conservation Drones** are harnessing low-cost drone technology to improve conservation monitoring and enforcement for marine systems. WWF and navama developed a new vessel-tracking tool called Map My Track, and a data-sharing platform, TransparentSea.org, which offers fisheries worldwide the possibility to register and make their fishing activities transparent. With their registration, fisheries agree to share satellite AIS 24/7 data, vessel monitoring systems (VMS) data or other location-based data for their vessels with independent experts from WWF, navama, other NGOs, governments, and science.

Traceability from Sea to Store: Numerous data and inventory management tools have been developed. These include **Fish Trax**, an electronic fishery information platform that revolutionizes the way fisheries information is collected, analyzed, and shared; **ThisFish**, a web-based traceability tool that collects catch, processing, and handling information from harvesters and processors; and **SeaTrace**, which gives consumers and retail buyers on-demand access to detailed information about the seafood they are purchasing through a QR code that, when scanned with a mobile app, shows information about the fisher (including images), when and where the fish was caught, as well as nutritional information. Finally, **TraceAll Global** has developed web-based supplier management tools for supermarkets and restaurant chains that enable creation of an audit trail of the ingredients, sources, and production conditions of the inventory they are purchasing as well as smartphone-based systems to enable fishers in remote areas to document their catch, trade with processors, and fish legally and sustainably.

The European Union invested €3.9M into the **FishPopTrace** research program to develop traceability approaches using single-nucleotide polymorphisms (SNPs) to determine species identity and population of origin for major commercial fish species. The **Fish Barcode of Life Initiative** (FISH-BOL) is a global effort to coordinate the assembly of a standardized reference sequence library for all fish species. Advanced sequencing techniques, including nanopore technology, will soon permit portable, field-based, whole genome sequencing. This will allow for on-the-dock identification of the population and origin of a fish, including whether or not that population is sustainably managed.



Challenge 4
Protecting Critical Ocean Habitats: New Tools for Marine Protection

THE PROBLEM

Marine Protected Areas (MPAs) have been growing in number in recent years, driven in part by the Convention on Biological Diversity. As the necessary parks of the sea, MPAs face significant challenges with monitoring and enforcement, mostly limited to single interventions or scattered mixtures of innovative uses of technology and traditional vessel-based monitoring. The enforcement and monitoring of MPAs is made largely ineffectual by distance and the inability to monitor and enforce remotely. Moreover, the establishment of MPAs as static plots of the ocean has been called into question, as the dynamics of oceans and marine species make ecological protection difficult in a single location. Locating and solidifying MPAs is an imprecise science that lacks the information and technological integration to be more efficient in achieving conservation outcomes.

THE CHALLENGE

Real-time monitoring of everything on or below the water with surveillance technology and data analytics designed for affordability and autonomy within the developing and developed world.

This challenge would seek innovations that:

1. Create open source tools and data analytics to map baselines to better assess ecosystem productivity;
2. Allow for mobile, low-cost, real-time monitoring and surveillance of MPAs against threats (e.g., identifying illegal fishing practices such as dynamite fishing, or violations of no-take zones), including transparent, low cost, cooperative tools for fishing communities to monitor and self-police MPAs; and
3. Harness novel approaches to real-time adaptive management of relevant marine areas.

PROBLEM STATEMENT

Around 3.4% of the world's oceans are protected in what are designated marine protected areas (MPAs), yet most of that fraction of the ocean is neither well managed nor well protected, if protected at all. Expansion of MPAs is largely an effort of policy and the political apparatus. Fully protected areas, such as strict nature reserves or wilderness areas where all resource removals are prohibited, are rare. Most MPAs represent mixed-use areas that have bans on catching specific fish or restrictions on the timing or type of fishing, but that still allow some, often significant, human activity. Protected areas in the ocean, unlike a forest patch, are far more difficult to manage and face increasing challenges, especially as they expand to enforce boundaries and policies with no observable boundaries or protective barriers to the sea. Moreover, marine species and ecosystems do not respect human-set political boundaries; they are dynamic systems characterized by constant change.

Economically and environmentally, ecologically coherent and well-managed networks of MPAs make sense. It is estimated that nearly 41% of the ocean is strongly affected by human activity, with no region entirely untouched by humans. WWF estimates that the benefits of expanding MPAs to cover 30% of the ocean (especially critical habitats) will outweigh the costs at least 3 to 1, with the net improvement in economic benefits of $920 billion over the next 35 years. MPAs not only further environmental protection, but by allowing source populations to replenish fishing grounds, also maintain the sustainability and economic strength of local fishing industries.

Political processes create these

networks, yet enforcement and accountability remain major challenges as marine parks globally are commonly understaffed, cannot adequately oversee all protected coastline and marine space, may come into confrontation with local traditions, and may suffer from corruption. Even when properly managed, eco-tourism can drastically impact the health of local ecosystems unless properly controlled. At the heart, this requires affordable, autonomous systems that can monitor, survey, and measure the activities and ecological processes in MPAs and novel financial systems to ensure that MPA management allows for broad sharing of benefits.

EMERGING SOLUTIONS

Potential solutions overlap not only with the solutions for wildlife trade and illegal fishing, but also with new solutions for addressing land-based poaching of endangered species. The number of technologies that will enable monitoring and surveillance of wild populations is rapidly increasing. This includes new underwater, aerial, and satellite-based sensors, as well as an abundance of new autonomous vehicles. Developments in autonomous underwater vehicles (AUVs) and surface gliders are advancing rapidly. As an example, **Liquid Robotics** recently won the Economist Ocean Innovation Challenge, for its second-generation Wave Glider, a hybrid wave- and solar-powered glider that could help protect against illegal fishing as well as monitor MPAs. Advances from other companies in gliders and AUVs are expected to quickly exceed the capabilities of the Wave Glider. **OpenROV** has pioneered open-source, frugal design for underwater exploration. The XPRIZE Foundation has indicated plans to launch a prize competition for breakthrough underwater vehicles that could advance autonomous marine vehicle technologies even further.

Next generation innovations include creating a connected ecosystem, allowing scientists and conservationists to see changes to an ecosystem the instant they occur. Future innovations may harness FM bands and hydrophones, borrowing from work done by **Rainforest Connection** to fight rainforest poachers and illegal loggers with autonomous, solar powered listening devices derived from recycled android cell phones. The **University of Washington's Applied Physics Lab** has proposed using acoustic detection to alert park rangers in Costa Rica's Cocos Island to the illegal fishing of sharks. The solution would utilize existing technology for recording acoustic data and combine it with real-time sensors to alert park rangers and direct their swift action toward the area of warning. Other emerging technologies will allow us to capitalize on new swarming autonomous vehicles (AUVs) or the ability for multiple AUVs to "mule" energy and integrate data from centralized moorings.

Finally, there is significant opportunity to capitalize on ship monitoring systems, such as AIS or VMS. By capitalizing on increased satellite surveillance — perhaps even highly distributed cube satellites — it may be possible to expand the capabilities of a system such as SkyTruth to many more areas of the ocean.

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Challenge 5
Engineering Ecological Resilience in Nearshore and Coastal Areas

THE PROBLEM

Coastal Ecosystems—coral reefs, mangrove forests, and coastal wetlands—are facing constant pressures, coupled with chance events, that threaten their survival. They face the stress of human development, including pollution from industrial and agricultural activity, pressures from tourism, and destructive resource extraction, which are magnified by the effects of climate change, including rising sea levels, increased storm energy, and acidification. Due to these stressors, the critical ecological functions of these habitats continue to be lost at alarming rates. How can we improve the capacity of these systems to respond to stochastic perturbations, in the face of increasing deterministic pressures?

THE CHALLENGE

Engineer resilience of nearshore & coastal ecosystems (coastal wetlands, mangroves, and coral reefs) against greater perturbations of stress, reduce & reverse proximate stressors, and restore degraded habitats through science, technology, and innovation.

Specifically, this challenge seeks innovations that:

1. Enhance ecological resilience to perturbation and accelerate adaptation to global climate change and local stressors through molecular and microbiological engineering;
2. Identify, reduce, and reverse proximate drivers for habitat degradation and destruction through new financial and infrastructure innovations;
3. Restore degraded coral reefs, coastal wetlands, and mangroves through ecological engineering.

PROBLEM STATEMENT

Coral reefs, mangrove forests, and coastal wetlands represent some of the most biologically diverse and productive habitats on earth. Coastal wetlands (which include salt marshes, sea grass beds, and mangrove swamps) provide critical habitat to wildlife, filter out pollutants, and serve as nurseries for fisheries. Coral reefs similarly provide habitat, spawning, and nurseries to multiple fish species and are immense warehouses of biological diversity. Coral reefs support more species per unit area than any other marine environment, including about 4,000 species of fish, 800 species of hard corals and hundreds of other species, with perhaps an even greater number of species yet to be discovered. These three coastal habitats are critical to humans as well. They offer food and livelihoods, provide coastal armament, store carbon, assist with nutrient cycling, provide important geophysical regulatory services and harbor novel pharmaceutical compounds that have provided treatments for cancer, HIV, and malaria.

However, these ecosystems are in danger due to human activities that are intense and increasing; 50% of salt marshes, 35% of mangroves, and 29% of sea grasses have been either lost or degraded worldwide. More than 60% of the world's reefs are under immediate and direct threat, and tropical reefs have already lost more than half of their reef-building corals over the last 30 years. Reefs are threatened by coastal development and habitat destruction, watershed-based pollution, marine pollution, and overfishing and destructive fishing through the use of explosives and cyanide. Thirty-five percent of mangroves have been lost due to clearance for aquaculture or agriculture, overharvest for firewood and construction, and pollution. Global climate change further stresses these

It is also prudent to explore the potential to augment the capacity of reef and coastal organisms to tolerate stress and to facilitate recovery after disturbances.

ecosystems, exacerbating local threats through changes in sea level, ocean temperature, ocean circulation, and acidity.

There is great concern that the high rates, magnitudes, and complexity of environmental change—including habitat degradation, pollutants, resource use, and climate change—are overwhelming the intrinsic capacity of corals, wetlands, and mangroves to adapt and survive. Although it is important to address the root causes of changing climate, it is also prudent to explore the potential to augment the capacity of reef and coastal organisms to tolerate stress and to facilitate recovery after disturbances. For all these ecosystems, the ability to understand the rate and drivers of change and reverse them, to adapt to changes under way, and to restore already degraded habitats is critical to ensuring long-term persistence.

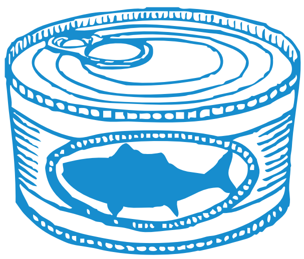
EMERGING SOLUTIONS

Reducing & Reversing Stressors. Attempts to conserve coastal habitats will be insufficient without understanding the state of the ecosystems and their health at scale, radically reducing existing stressors on these ecosystems, and incentivizing habitat protection over destruction. There are a number of new techniques that can be scaled to map, measure, and monitor the state of coastal and nearshore ecosystems. **XL Catlin Seaview Survey** provides systematically collected, high-definition imagery to monitor reefs globally, and shares the data through its public website, providing 134,759 **abundance records** of 2,367 fish taxa from 1,879 sites in coral and rocky reefs distributed worldwide. Future attempts will use citizen science to help analyze data. There are numerous off-the-shelf (e.g., **Deep Trekker**) or do-it-yourself (**OpenROV**) underwater rovers capable of visually photographing and monitoring the ocean. Satellites are capable of mapping and monitoring coral reefs, like **NOAA's Coral Reef Watch**, but for a closer look at the corals, higher resolution satellites or aerial photography is needed, from 1—40 meters. Nanosatellites, such as those deployed by **Planet Labs**, allow for global capabilities to monitor the status of ecosystems, including **mangrove forests**, on a daily basis and are emerging as potentially less expensive sources of remote imagery. Citizen science and advanced big data analytics can help analyze the terabytes of data generated by these systems.

Once baselines are established, we may use financial innovations including wetland banks, carbon markets through "blue" carbon sinks, and conservation finance to incentivize the protection of coastal habitats from further degradation, and incentivize the restoration of degraded habitats. **Green infrastructure** can reduce primary sources of ocean pollution, such as non-point source pollution (runoff). Pollutants in runoff include motor oil, trash, pet waste, fertilizers, pesticides, and dirt, all of which can harm marine life. Runoff can be diverted from the ocean through green infrastructure, or low impact development, like capturing rainwater in green roofs, bioswales, rain gardens, and other engineered permeable surfaces such as permeable pavement. However, adopting these designs on a large scale requires incentives to lower barriers, coupled with advances in technology to lower the cost of adoption.

Engineering Ecological Resilience & Accelerating Adaptation: Examples of engineering ecological resilience in corals have included **accelerated evolution** of resilient characteristics, acclimatization, transplantation of resilient populations, and active modification of the community composition of coral-associated microbes. Synthetic biology's gene editing breakthroughs (CRSPR) now allows for the programming of the very assembly and instructions for life, potentially increasing the speed by which species may adapt to changes in ocean temperatures, acidity, and salinity.

Advancing Restoration: Restoration of coral reefs and mangroves has involved direct interventions in rebuilding the ecosystems. Structural interventions that are in use and emerging include using novel materials to create scaffolding on which corals can form. One approach is through **Biorock technology**, which induces coral polyp settling via electrical impulses. As electric currents pass through salt water, calcium carbonate combines with magnesium, chloride, and hydroxyl ions around the cathode, forming a substance similar to natural reef substrates.



Challenge 6
Reducing the Ecological Footprint of Fishing through Smarter Gear

THE PROBLEM

Modern fishing practices often result in the unintended catch—and subsequent dumping —of millions of tons of fish, mammals, sea turtles, birds, and other creatures, resulting in destructive impacts from industrial and artisanal fishing on marine species. Innovators and scientists have developed a variety of technologies and innovations that lower the amount of by-catch from fishing and reduce the damage caused by fishing gear, yet few have been implemented at scale or adopted by policy makers or the private sector.

THE CHALLENGE

Create scalable and sustainable novel technologies that reduce the impact of fishing gear while enhancing the yield of desired species.

This challenge focuses on innovations for two different communities, and ways to bring the innovations to scale:

1. Reducing the impact of fishing gear and destructive fishing practices among artisanal communities without a diminishment in yield.
2. Reducing the impact of fishing gear and destructive fishing practices among industrial fishermen.
3. Improving the certification, adoption, and scaling of low impact fishing gear and fishing practices.

PROBLEM STATEMENT

The growing demand for seafood, a result of emerging middle classes and population growth, is putting tremendous pressure on fish stocks around the world. An estimated 80% of the world's fisheries are considered either fully exploited or overexploited (**FAO**). The global fishing industry captured $91.2 billion in first-sale seafood value in 2006, comprised of 92 million tons from both inland and marine waters.

Destructive fishing practices constitute a malicious side effect of the increased global demand for seafood and the decline in global fisheries. Such practices can include the use of gear or methods that are indiscriminate as to their target species, physically damage the habitat, or are unsustainable in their application. Both artisanal and industrial fishers may use destructive fishing practices.

Indiscriminate fishing results in bycatch, removing fish and other marine life from the sea without the intent to do so. In some cases, the bycatch is itself a valuable product (e.g., halibut) that is cast overboard and thus harms the livelihoods of other fishers in a region. Frequently, the bycatch includes species that play a critical role in the ecosystem, for instance top-predators and primary food-stock fish that have little to no market value but underpin the health of more valuable fish populations. **Destructive fishing practices** can include the uses of poisons such as cyanide (which also capture fish for the aquarium trade), blast fishing which utilizes explosives, muroami (which uses pounding devices to crush coral and encircling nets), and ghost fishing (the use of large scale pelagic driftnets). These practices may irreversibly destroy habitats, or indiscriminately kill non-target species. **Inadequate fishing practices** include standard fishing practices, whose misapplication may be damaging to an ecosystem. For instance, bottom trawling can severely damage the seafloor and benthic habitats. Finally, solutions exist, but they need incentives for adoption, and pathways to scale.

EMERGING SOLUTIONS

Reducing Indiscriminate Fishing: Bycatch reduction technologies can take a variety of forms based on the type of fishery, intended catch, and the available machinery and tools onboard fishing vessels. Primarily, bycatch reduction technologies can be classified as (a) mechanical and physical tools or modifications to equipment, (b) more accurate testing and controls for catch content, or (c) behavior-based solutions to attract only desired species (**FAO**).

Gear Modifications: A past Smart Gear winner, the **Yamazaki Double-Weight Branchline** sinks long-line hooks beyond the range of seabirds and has dramatically reduced seabird bycatch (89% reduction) while maintaining little-to-no impact on fish catch rates. A runner-up in the 2014 competition, **FRESWIND**, designed an escape device system for flatfish from industrial fishing trawlers so that only target species of round fish are caught. Both are examples of simple mechanical adjustments to fishing equipment that can limit the capture of undesired fauna from turtles to seabirds and small or unwanted fish species.

Testing and Controls: The 2014 winner of Smart Gear provides an example of the types of tools and technologies that can be used to aid specific fisheries in determining the bycatch content of a potential catch. The project, **Air-Powered Sampling for Purse Seine Fisheries** used a small air cannon and net to catch and view the contents of a purse seine catch when it is far enough away from its ship such that releasing the net will not harm the fish inside. The ultimate outcome is reduced mortality of non-target species. Growing opportunities in sensing and detection capabilities could also be areas of exploration to help provide fishers with better tools to manage and control what they ultimately catch and bring onboard.

Behavior-Based Solutions: Scientists have begun to capitalize on increasing knowledge of fish and megafauna behavior to develop tools that limit unwanted bycatch for fishers. **Super Poly Shark**, a Smart Gear 2014 runner-up, created a simple device for long-line fisheries that contained a slow-release, biodegradable, chemical shark repellant that reduced shark by-catch by 71%. Similar to the Super Poly Shark, a project called **Turtle Lights for Gillnets** used simple LED lights on commonly used gill-nets in Baja California to reduce sea turtle bycatch and entanglement by 60% with no effect on fishery yields. Identifying novel methods and technologies that can limit the bycatch of non-target species based on their behavioral traits has become an expanding focus in bycatch reduction.

Addressing Destructive Fishing. Techniques used to intercept illegal deforestation, gun shot detection in cities, or poaching may also work to reduce destructive fishing. **Triangulated underwater hydrophones** have been used to identify potential blast fishing at great distances (up to 30 km) with great accuracy (within 30 m), even in noisy underwater environments. WWF Hong Kong has installed such systems in Hong Kong. **Tank Watch** — The Good Fish/Bad Fish Tool for Saltwater Aquariums — is a mobile app providing global consumers the ability to easily identify popular aquarium species and distinguish those potentially bred in captivity from those that were wild-caught using cyanide or other harmful means. NOAA Fisheries scientists and partners like **Alaska Seafood Cooperative** and Bering Sea flatfish fishing industry members collaborated to **modify bottom-trawling gear** so it reduces the damage to important bottom habitat. These changes to the gear reduced seafloor contact by a whopping 90% and successfully maintained flatfish catch rates, minimized negative effects on bottom habitats, and reduced crab mortality rates.

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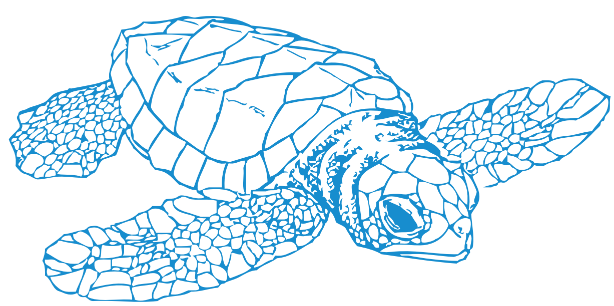
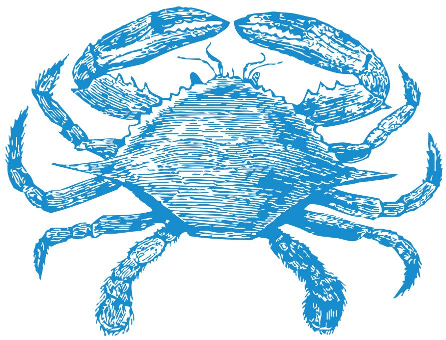




Challenge 7
Arresting the Alien Invasion: Combating Invasive Species

THE PROBLEM

Invasive species can spread quickly once introduced into a new ecosystem. Surveillance and detection remain key barriers to preventing their spread into new regions and water systems. Once established in a new ecosystem, invasive species often disrupt finely balanced ecosystems because they are free from the competition or predation that exists in co-evolved systems. For example, species like the lionfish have begun to disrupt food chains in many areas, preying on valuable species and critical members of the ecosystem while multiplying due to the lack of natural predators.

THE CHALLENGE

This challenge seeks new globally scalable systems, technologies, or financial innovations that aid the monitoring, prevention, and systematic removal of invasive species in ocean ecosystems.

This challenge focuses on:

1. Designing rapid, low-cost, immediate surveillance tools that can detect individual organisms in novel habitats and within carriers for such invasive species.
2. Creating novel technologies to prevent the introduction of invasive species at all scales (including microorganisms).
3. Developing innovations that could remove 95% of an invasive species in a novel habitat within five years, bringing the ecosystem back to pre-invasion baselines.

PROBLEM STATEMENT

Globalization and increased international trade have progressively removed the common and natural barriers to alien species introduction into ocean ecosystems, resulting in the loss of biodiversity and the homogenization of habitats. These sudden introductions brought about by the rapidity of global trade as well as the growing market for exotic aquarium species can lead to massive changes in the ecology of coastal and ocean ecosystems. Alien invasive species may compete with local species for limited supplies of food and habitat. They may serve as novel predators or introduce foreign diseases, driving native species locally extinct. The introduction of an alien invasive species to a coastal or ocean ecosystem can completely disrupt food chains, transform habitats, and drive down the abundance and health of keystone ecosystem species. Such invasive species may range from new apex predators, like lionfish, to invasive plants, to novel pathogens. Examples include the Chinese mitten crab, European green crab, Cladoceran water flea, zebra mussels, lionfish, and the North American comb jelly.

Invasive species may be introduced though novel connections between previously closed natural barriers (e.g., the Panama Canal, the Suez Canal) or through movement across traditionally natural barriers. Shipping carries 90% of internationally traded goods, and it is a significant conduit for invasive species. Many invasive species are spread through the ballast water of massive cargo ships along trade routes and then through natural waterways. As a result, many harbors around the world now share remarkably similar—and low biodiversity—ecosystems.

International trade in live marine organisms has also led to the expansion of invasive species.

The zebra mussel, now one of the most common freshwater shellfish globally, was accidentally introduced to U.S. waterways where it quickly out-competed endemic species.

International trade in live marine organisms has also led to the expansion of invasive species. The spread of personal salt-water aquariums stocked with exotic species has increased demand for charismatic species around the world, like the lionfish, and inadvertently, contributed to their release into novel ecosystems where they no longer have predators to keep their populations in check. After the highly voracious and fecund lionfish was introduced off the coast of Florida, it quickly expanded its range and abundance to the entire eastern United States, the Gulf of Mexico, and the Caribbean Sea within the span of 15—20 years. In the process, it has severely depleted juveniles of grouper and snapper and has taken up a dynamic position at the top of the food chain with few, if any, natural predators for healthy lionfish across the entire eastern seaboard.

Aquariums can also inadvertently harbor microorganisms—like algae—that can have a dramatic impact on local ecosystems. "Killer algae" (*Caulerpa taxifolia*), a species native to the Indian and Pacific oceans was released from aquariums in Europe and has become a massively destructive force throughout the Mediterranean, altering the structure of ecosystems throughout the sea. In California, where killer algae also became a problem, a large-scale campaign of poisoning the invasive species was successful in eradicating it from most habitats.

EMERGING SOLUTIONS

To date, the majority of solutions to marine invasive species have focused on either preventing their invasion by treating the source, or on eliminating the species once they have invaded.

Prevention: As ballast water is a major source of invasive species, innovations have focused on treating it. These include using damaging properties of light (UV radiation), filtration systems, oxidation, and chlorination. Unfortunately, no ballast water treatment method can completely eliminate the risk of introducing exotic species. Alternative solutions include changing fundamental hull designs to allow for continuous flow of water through the hull as ballast, or eliminating the use of ballast water altogether.

Surveillance: Advances in the efficacy and costs of molecular biology have enabled better detection and surveillance of invasions without having to isolate the targeted organism. This approach, termed **Environmental DNA** (eDNA), analyzes nuclear or mitochondrial DNA that is released from an organism into the environment. Sources of eDNA include secreted feces, mucous, and gametes; shed skin and hair; and carcasses. eDNA has allowed for breakthroughs in monitoring invasive species because it can detect species abundance at low densities, including upon an initial invasion by larvae or seeds. Early detection decreases both the costs of control and the impact on ecosystems.

Eradication: Eradication once a species has invaded is much harder than preventing the invasion. Biocontrol is the regulation of a pest species through the introduction of a natural predator. It has been proposed as a tool for controlling invasive species, however, it has had unintended consequences in terrestrial systems. Biocontrol proposals for marine systems include viral or microbial biocontrol of algal blooms, predatory control of ctenophores (comb jellies), parasitic regulation of the European Green crab, and introduction of sea slugs and plant hoppers to control green algae and salt marsh cord grass. The challenge of biocontrol is to guarantee host specificity—that the species being introduced will not prey on other

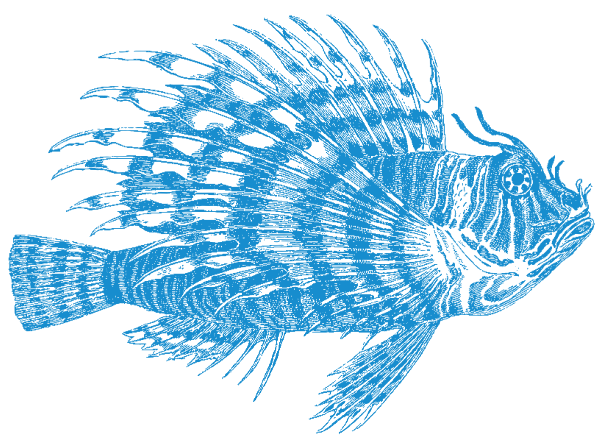
There may be further opportunity in greater financial incentives for the eradication of certain species.

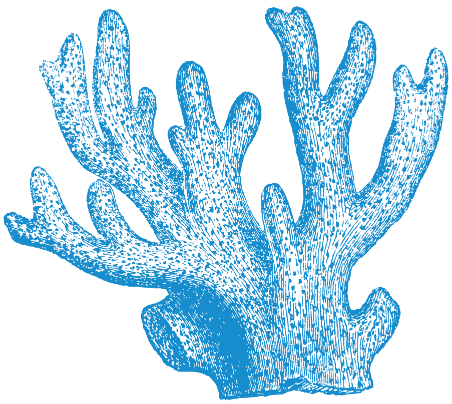
endemic species instead of the one it is intended to control.

Biocontrol isn't restricted to living animals anymore. The Queensland University of Technology developed an autonomous **star-fish killing robot**, which seeks out crown-of-thorns starfish through a computerized imaging system, and then gives them a lethal injection. Although the crown of thorn starfish is not an invasive species in Australia, the decline of its predators coupled with increased organic material flowing into the ocean from terrestrial sources has led to its massive overpopulation and the subsequent destruction of its ecosystem. This process is not dissimilar to the way invasive species often harm native ecosystems, providing a glimpse into a possible technological solution for other habitats.

Synthetic biology offers another set of potential solutions: the ability to edit genomes and encode lethal genetic instructions that could be turned on or off (kill-switch genes) as has been done with the mosquito, ***Aedes aegypti***, which is responsible for Dengue Fever and Chikungunya.

Changing Market Demand: Rather than directly addressing the number of species, we may seek to increase the demand for those species. We can increase financial incentives for the eradication of certain species by creating markets, providing incentives and bounties, and encouraging recreational harvest. For example, throughout the Caribbean a concerted effort was made to create a high-end market for lionfish.





Challenge 8
Combating the Effects of Ocean Acidification

THE PROBLEM

The oceans absorb approximately a quarter of the carbon dioxide emitted into the atmosphere by human activities. When dissolved in water, carbon dioxide (CO_2) forms carbonic acid. As a result, in the last 150 years—since the beginning of the industrial revolution—the oceans have become 30% more acidic. This increasing acidity disrupts the carbonate system upon which almost all marine organisms are dependent, from the phytoplankton at the bottom of the food chain, which produce the majority of the planet's oxygen, to the shellfish, coral, and even finfish that form marine food webs. While our ability to measure changes in ocean acidification has advanced rapidly, innovations to adapt and resolve the impacts remain woefully inadequate or non-existent.

THE CHALLENGE

Develop technologies and innovations that strengthen resilience and help habitats adapt to the effects of ocean acidification, and mitigate its effects. These may include techniques as wide-ranging as harnessing synthetic biology or microbiology, manipulating ecosystem dynamics, utilizing selective breeding, or geo-engineering ecosystems to change local pH.

PROBLEM STATEMENT

The ocean's chemistry facilitates conditions for species-rich biodiversity and sets the foundation for many of the cycles and systems that sustain all life. However, human-caused influx of carbon pollution into our atmosphere, which is deposited into our oceans, is drastically altering the chemical makeup of the oceans, threatening the physical, chemical, and biological processes that are necessary for life.

The ocean surface absorbs around 27% of the excess carbon dioxide from human activity, leading to a reduction in pH and shift in the carbonate chemistry of the seas. This particularly affects organisms with shells, including mollusks, corals, and many phytoplankton that form the base of the food chain. Calcification, the process by which organisms create their shells (such as the building blocks of coral), is greatly affected by acidification; as the saturation state of the necessary compounds for shell formation (calcium carbonate) decreases, organisms require more energy for shell formation and maintenance. In some cases, such as is seen with Northeast Pacific pteropods, even adult shells can dissolve in the more acidic water.

Ocean acidity is one of the first changes to be measurable as atmospheric CO_2 concentrations rise. Acidity is expected to increase a further 40—50% if CO_2 concentrations reach the projected end-of-century concentration according to current emission rates. The oceans have already become about 30% more acidic since the start of the Industrial Revolution, in tandem with a 39% decline in marine species populations in the past 40 years.

This fundamental and ongoing alteration of our ocean's chemistry threatens the survival of ecosystems in a way not seen in tens of millions of years. Such change will accelerate the rate of erosion for many shell-building creatures and will

Without reducing atmospheric CO_2, acidification will continue to cause widespread changes...

cause significant biodiversity loss as pH levels become increasingly more acidic.

In a preview of the types of impacts to come, an acidification event that occurred in the Pacific Northwest of the United States led to **widespread mortality in young oyster larvae**. With over 80% mortality in most oyster hatcheries, an entire industry was placed at risk as a result of more acidic waters. Without reducing atmospheric CO_2, acidification will continue to cause widespread changes in the fundamental processes that create the overall structure and function of marine ecosystems. However, the reality is that ocean acidification is an active process, and both natural systems and our communities will have to grapple with its impacts. Innovations to help us and our ecosystems cope with ocean acidification will be a necessary step to conserve marine biodiversity.

EMERGING SOLUTIONS

Mapping & Monitoring: The recently-awarded Wendy Schmidt Ocean Health XPRIZE has resulted in dozens of new and improved pH sensing devices providing unprecedented accuracy in environments ranging from coastal waters to the deep sea. The prize was awarded to ultra-high performance sensors as well as sub-$1,000 sensors that can be deployed with minimal effort. This prize has given the conservation community the opportunity to rapidly scale up the measurement of ocean pH. Coupled with advances in measuring the concentration of carbon dioxide, total alkalinity, and dissolved inorganic carbon, scientists' ability to measure changes to the carbonate system are advancing rapidly.

Scientists with the European Space Agency and several other institutions have recently demonstrated the ability to map surface ocean acidity remotely by using **satellite-based thermal and microwave sensors**. This **approach** had previously been limited to in-situ sensors, which are difficult to place and maintain in remote ocean locations. The newly demonstrated technique holds the promise of improved global measurements of ocean acidification, and may lead to the development of additional space-based sensors, though it is limited to the surface and open-ocean environments.

In addition to a diversity of useful sensors, some notable innovations in how monitoring can be accomplished were revealed during the Ocean Health XPRIZE. One notable example is SmartpHin, a surfboard-fin that includes pH, salinity, and/or temperature sensors. **SmartpHin** wirelessly downloads data after a surf session and integrates it into cloud-based analytics and data repositories. This type of citizen science application is critical for cheaply scaling up the global monitoring of the ocean.

Assimilating this increasing data stream on ocean acidification into both science and management remains an area of critical need. Moving from data to acidification forecasting systems, which would allow targeted interventions in local habitats, remains a rich opportunity for innovation.

Adaptation & Geo-engineering: Corals, like many shelled organisms, make their skeletons out of calcium carbonate, making them vulnerable to changes in ocean acidity. Recently, scientists have begun to identify species and populations of coral that are adapted to large fluctuations in pH, opening the possibility of selective breeding, transplants, or genetic engineering to produce more robust coral species in areas of high concern.

The Paul G. Allen Ocean Challenge identified several finalist projects that are now being funded to expand adaptation techniques. Leading innovations include modifying ecosystem dynamics through the use of seaweed that can mitigate local pH, human-assisted evolution by changing the species abundance and makeup in a habitat to produce greater ecosystem level resilience to acidification, and genetically engineering corals to extend their functional range and resilience to the more acidic and warmer conditions predicted for the oceans of the future.

Lawrence Livermore National Laboratory (LLNL) has recently demonstrated a chemical process for capturing CO_2 from the air, which results in the production of hydrogen and an alkaline solution (carbonate) [**Rau et al, 2013**]. Although the process requires energy input, if it were run with renewable electricity (possibly from off-peak periods), it could potentially provide a carbon-negative source of hydrogen, and an alkaline solution that could be added to the ocean as a de-acidification measure [**LLNL**].

Challenge 9
Ending Marine Wildlife Trafficking

THE PROBLEM

Illicit wildlife trafficking is valued at billions of dollars a year. An important element of such trade has been the luxury market for products from the sea. This includes demand for pets, health products, and food. In East Asia, population growth and the burgeoning middle classes have led to rising demand for exotic and luxury products, as well as for greater production of protein. The supply chain for seafood products involves a complex web of middlemen that facilitate the entry of illegally caught and sourced seafood into the mainstream market. Challenges for illegal fishing include monitoring fishing activity at the source, creating more efficient tracking and enforcement mechanisms to prevent illegal fishing, increasing barriers to entry for illegal fish products into global markets, and influencing consumer demand through marketing and behavior change.

THE CHALLENGE

Dramatically reduce demand for endangered ocean products through demand reduction, data & enforcement, and substitute products.

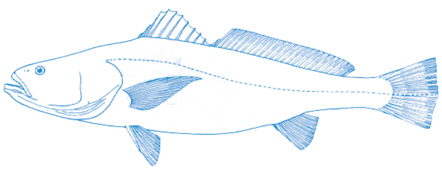
This challenge focuses on understanding the extent of illegal trade and enforcement, addressing demand for illegal seafood products:

1. **Consumer Demand Reduction Subchallenge**. This subchallenge focuses on harnessing marketing and behavior change for oceans conservation through financial incentives, social pressure, marketing, competition and gamification, and identity. Under this subchallenge, we are seeking solutions to reduce demand by changing cultural and societal norms around the perceived social status of luxury wildlife products from the sea. Potential innovations could borrow from behavior change approaches implemented in global health, as well as from marketing of consumer products.
2. **Enforcement Subchallenge**. This subchallenge looks at technologies and innovations that can improve governance and enforcement of illegal fishing. This includes improving data for measurement of the extent of the trade, surveillance of flows of wildlife products from the seas, and enforcement of regulations.
3. **Replacement Products**. Finally, this challenge will focus on creating substitute products for existing illegal seafood products.

PROBLEM STATEMENT

Wildlife trafficking is not only decimating the wildlife populations of critical species with spillover effects that disrupt entire ecological communities, it is driving some species to extinction. The business of trafficking has undermined the rule of law and promoted corruption, compromised national security of nations, and hindered economic development. The trade of trafficked wildlife has become extremely lucrative, with certain wildlife products even exceeding the value of gold, platinum, or diamonds in end markets.

The emergence of the middle class in Asia and other places in the developing world has placed new demands on fisheries. First, rising wages have increased pressure for cheaper and higher quantities of seafood. At the same time, growing wealth and a desire to demonstrate status is also driving demand for luxury seafood delicacies such as shark fin, sea cucumber, sea urchins, and fish swim bladders, particularly in South East and East



Asia. These twin pressures increase the incentive for illegal as well as over fishing. The developed world also contributes to marine wildlife trafficking and illegal fishing through the pet, curio, and food trade.

Globally, the expected financial loss due to unreported and illegal fishing ranges from $10 billion to 423.5 billion worldwide. Developing countries with poor governance records are more vulnerable to illegal activities, conducted by both their own fishers and vessels from distant nations. The solutions most often proposed to eliminate illegal fishing increase governance and the rule of law through better cooperation and data sharing between regional fishery management authorities, increased capacity for surveillance and enforcement, and reducing the economic incentives and demand to engage in illegal fishing.

Within the luxury seafood market, demand for one item—shark fins—is declining in China due to a series of successful campaigns focused on consumers. However, demand for other products, such as sea cucumber, marine turtles, sea urchins, manta gills, and swim bladders of the *Totoaba macdonaldi* (a species of fish endemic to the Gulf of California) is increasing. There is also a significant international trade in live marine animals. It is estimated that there are up to 30 million fish and 1.5 million coral colonies traded in any one year. Most of the demand comes from the United States, EU, and Japan, which account for over 80% of the trade. Other species are also kept as holiday curios, such as sea horses, which are also collected for the medicinal trade. Sixty-four million sea horses are taken from the wild every year, although some organizations claim the number is as high as 150 million killed annually. Sea horse fisheries have reported a decline of 50% in the last five years. Dried sea horses are sold in shops as curios within England, the United States, and Australia, but most originate in Asia.

EMERGING SOLUTIONS

Demand Reduction: Conservation marketing, behavior, and psychology are new fields within conservation. They have become more prominent (along with other social sciences) in the evolution of conservation as a multidisciplinary science, following the pathway of global health. However, there are few examples of behavior change or marketing innovations within marine conservation. Emerging techniques from social marketing include using incentives and rewards as well as self-identity and social pressures to change behavior. Some approaches tap into the competitive nature of humans by creating competitions or gamification to change behavior. Some of the best examples of these principles are with regard to energy usage and health. Residents in Brighton, UK, living on **Tidy Street**, agreed to track their daily energy usage publically on a website, and paint the street's average energy use against the Brighton average in a graph on the road outside their homes. Open-source software specially designed for the project allows each household to compare their energy use not only with the Brighton average, but also with the national average or even that of other countries. Residents' energy use has dropped by 15%, with some people cutting usage by as much as 30% in their households. Similarly, college campuses have demonstrated energy and water use reductions in dorms through competitions like "**Do it in the Dark**." Health and fitness apps, like MyFitnessPal, harness peer pressure to encourage maintenance of daily exercise, or maintaining a diet.

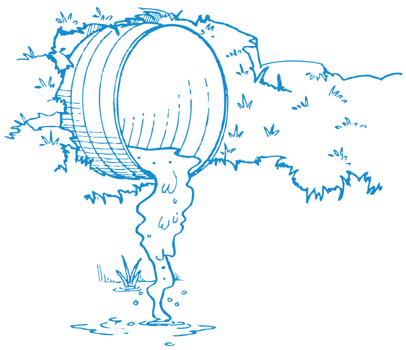
Marketing is one of the most data driven industries in the developed world. By studying patterns of production and consumption and the correlations between consumption patterns, marketers have been able to micro-target products to individual consumers. In much the same way, data can be harnessed to identify cultural norms and demographics that will be responsive to specific messages about conservation. As an example, **Wild Aid** had significant success targeting young Chinese women who were planning to be married about the nature of serving shark fin soup at their weddings. By combining demographic understanding about the audience's motivations and the nature of the consumption of shark fin soup as a traditional Chinese wedding meal, Wild Aid was able to reduce consumption significantly. Conventional methods of surveying people to gather information on opinions and consumption patterns can be expensive and time-consuming. However, social media and other large data sets gathered by online platforms are potential data sources that the conservation community can mine for information on consumption, attitudes, or opinions to provide insight into cultural norms and demographics. **Energy producers** are using Twitter and social analytics to track public opinion about their activities, and researchers have explored mining Twitter to track opinions on **climate change**. Researchers have used **geotagged Flickr images** to quantify nature-based tourism and recreation.

Financial incentives can also drive conservation behavior. Pay-for-performance in the field of conservation is a method where people or organizations are rewarded for meeting specific environmental conditions. The best-known example is that of **RecycleBank**, which harnessed technology that measured the amount of recycling for a specific residence, and then credits participants with reward points that can be used at local and national stores. The money came from avoidance of tip fees at landfills and through the sale of the recycled materials. The result was a dramatic uptake in recycling in cities that implemented the program. Similarly, direct payments for conservation programs have had some success. For example, the U.S. government pays farmers to set aside farmland to instead provide ecosystem benefits like wildlife habitat, enhanced water quality, or reduced soil erosion through the Conservation Reserve Program. Other investments can be made with the goal of capital protection through offsets or mitigation, such as wetlands and stream mitigation, bio banking, and conservation banking. Finally, eco-labels and certifications are intended as signals to consumers that purchases contribute to positive environmental outcomes. There are multiple marine eco-labels, including the **Marine Stewardship Council**, **FishWise**, and **Salmon Safe,** among others.

Surveillance and Enforcement: Improving capabilities of countries to monitor and enforce their waters can also help reduce wildlife trafficking and illegal fishing. As noted previously, **SoarOcean** and **Conservation Drones** are harnessing low-cost drone technology to improve conservation monitoring and enforcement for marine systems. **Skytruth**, working with Google's Geo for Good and Oceana, is harnessing satellite imagery, ship-based Automated Information Systems (AIS), and Synthetic Aperture Radar, to detect illegal, unregulated, and unreported fishing activities. Similarly, Pew has been working with Satellite Applications Catapult through **Project Eyes on the Sea** to analyze multiple sources of live satellite tracking data, link to information about a ship's ownership history and country of registration, and provide a dossier of up-to-the-minute data on vessels that can alert officials to suspicious behavior. Importantly for certifying legal behavior, WWF and navama created a vessel tracking tool and data sharing platform (**TransparentSea.org**) to offer good actors the ability to make their fishing activities transparent. With their registration, fisheries agree to share satellite-based AIS data, vessel monitoring systems (VMS) data or other location-based data for their vessels with independent experts from WWF, navama, other NGOs, governments, and science.

Not all of the efforts need to be highly technical or expensive. Moreover, they can harness the power of the crowd through citizen science. The **Turtle Island Restoration Network** has recently partnered with DigitalGlobe's crowdsourcing platform Tomnod.com to create a crowd-sourced digital patrol of the Cocos Island Marine Protected Area. The **Environmental Justice Foundation** used low cost cell phones and GPS-enabled cameras to help artisanal West African fishermen to protect local fisheries against piracy.

Replacement Products: Replacements are substitutes for illicit products or products whose removal or creation come at considerable cost to the ecosystem. One of the best-known examples is synthetic rhino horn, which has sought to provide an alternative to real rhino horn. One such company is **Rhinoceros Horn LLC**, which in December 2012 planned to fund the marketing of a new, ethically sourced keratin protein product via the crowd-funding site, IndieGoGo.com. Another company working in this area is **Pembient**, which describes itself as "The De Beers of Synthetic Wildlife Products". Pembient was quoted extensively in the media in January 2015, after it was chosen as one of 11 companies to benefit from an "accelerator class" held by IndieBio, after which each company will receive $50,000 in funding and access to the accelerator's lab for an entire year. Another company focused on a replacement product is **Stop Poaching Through Synthetic Rhino Horn**. Artificial substitutes for shark fin also exist, commonly known as "**mock shark's fin**", which uses gelatin, soy, pig's skin, and sometimes even cellophane noodles. The challenge of the replacement product approach is in the possibility of it not decreasing demand for the original, illicit wildlife product, but instead increasing consumer's desires for the "real thing."



Challenge 10
Reviving Dead Zones: Combating Ocean Deoxygenation and Nutrient Runoff

THE PROBLEM

Nutrient pollution in coastal areas, which primarily results from agricultural fertilizer runoff and sewage, has led to a rapid increase in hypoxic zones in the ocean. In the last half a century, the number of dead zones in the world's oceans has increased over ten-fold. The paucity of oxygen in these areas results in aerobic marine life dying or moving away. Habitats once rich in life become dead zones, the equivalent of deserts in the ocean. This problem is accentuated by warming and worsened by acidification. The triple threat of deoxygenation, warming, and acidification has been associated with past major extinctions.

THE CHALLENGE

End deoxygenation by disrupting and redesigning systems of agriculture and wastewater management on land:

1. ***Redesign the farm-to-sea relationship to remove anthropogenic nutrient runoff;***
2. ***Design scalable innovations for storm water and wastewater treatment and removal of excess nutrients such as phosphates and nitrogen.***
3. ***Develop new ways to restore dead zones.***

PROBLEM STATEMENT

Nutrient runoff and waste from agriculture and sewage has contributed to widespread instances of dead zones—regions of widespread hypoxia (areas without oxygen). This hypoxia either kills marine life, reduces their reproductive potential, or forces species to move to new habitats. Dead zones commonly occur near inhabited coastlines, where marine biodiversity is often highest, and where communities and ecosystems depend upon healthy habitats. The extent of the losses from such dead zones can be economically and biologically significant. In the Black Sea in the 1970s and 1980s, an estimated 60 million tons of bottom-living aquatic life perished from hypoxia, resulting in dramatic impacts on fisheries and biodiversity.

During the 20th century, the rapid industrialization of agriculture, coupled with human population growth and urbanization, has led to a massive increase in number and size of dead zones globally. In 1960, there were 10 documented dead zones, but by 2007 scientists had identified 169. Currently, scientists estimate there may be over 1,000 dead zones around the world, including many that are undocumented. Concentrated in areas with high human activity, these dead zones are a result of disrupting natural biogeochemical cycles.

The mechanism by which these dead zones occur—rapid eutrophication—also offers opportunities for intervention. The excessive supply of nutrients, mainly phosphates and nitrogen, spark the growth of phytoplankton and lead to algal blooms. The water becomes more opaque as phytoplankton populations boom, and the shade they cast deprives the plants living below them of sunlight. Sea grasses in shallow bays also become covered with small epiphytic algae and can ultimately be smothered and die. Algae can also envelop and kill off coral reefs. The critical shift happens when the massive blooms of phytoplankton and other organisms die. As organic matter

Untreated sewage causes the majority of dead zones in Africa, Asia, and South America.

accumulates, bacteria digest the organic matter and consume the oxygen present in the water during the decomposition process, creating hypoxic conditions.

This hypoxia is caused primarily by the intensive use of agricultural fertilizers, particularly in the developed world. Globally, farmers spend $60 billion annually for 150 million tons of fertilizer to nourish their fields. Much of this may be wasted. Farmers often apply excess fertilizers or have poor systems to keep fertilizers in the soil. Rain and irrigation then washes excess fertilizer into inland waterways, and ultimately to the ocean. Currently, less than half of the fixed nitrogen generated by farming practices actually ends up in harvested crops, and less than half of the nitrogen in those crops actually ends up in the foods that humans consume. Much of the remainder ends up fertilizing phytoplankton and algae in the ocean.

Additional drivers of greater nutrient emissions into watersheds include fossil-fuel use (which releases nitrogen into the atmosphere), effluent from the mass breeding of food animals (especially pigs and chickens), and sewage systems that empty directly into the sea. Untreated sewage causes the majority of dead zones in Africa, Asia, and South America. The presence of large-scale aquaculture in Southeast Asia may also contribute to hypoxia

EMERGING SOLUTIONS

Transforming Inputs: With burgeoning global populations, understanding how we can increase plant productivity while decreasing its environmental footprint will usher in the second green revolution. The ability to harness **nitrogen-fixing microbes** for widespread agricultural practices could allow for more efficient use of nitrogen as a fertilizer, or even lead to its elimination. One sterling example is the current effort to transfer ***Gluconacetobacter diazotrophicus***, a bacterium found in sugar cane that fixes nitrogen from the air into the cells of plant roots such as maize, rice, wheat, oilseed rape, and tomatoes. This type of approach could obviate the need for nitrogen fertilizer in much of the world's agricultural land. A similar approach involves synthetically engineering the genome of certain crops, such as rice, to take up nitrogen directly. Precision agriculture, the use of nitrogen-fixing cover crops, and traditional breeding techniques can also increase nitrogen efficacy in soils. The National Academy of Engineering has called for research and discovery of novel technological methods for applying fertilizer more efficiently to ensure that a much higher percentage of the fertilizer ends up in the plants as organic nitrogen. Other critical innovations are needed in soil management and design to reduce runoff, leaching, and erosion, which carry much of the nitrogen fertilizer away from the plants and into groundwater and surface water.

Addressing Pollutants: Grassroots entrepreneurs are beginning to use the natural by-products of excessive nutrient outflows, namely macro-algae and seaweed, as harvestable resources. Approaches that unify land-based and marine farming practices in a closed-loop system have been designed to capture nutrient runoff for use in growing marine macro-algae that can be used in local agriculture. A Washington, D.C.-based startup, **Kegotank Bio**, has begun to plant and harvest macro-algae at the source of excessive nutrient outflows in freshwater and saltwater systems and then converts the harvested material into marketable products, from natural fertilizer to thickeners for a variety of mainstream products. Other approaches, such as **Janiki Bioenergy Omniprocessor**, turn sewage into potable water, electricity, and fertilizer, and turn sewage treatment for developing countries into a source of revenue.

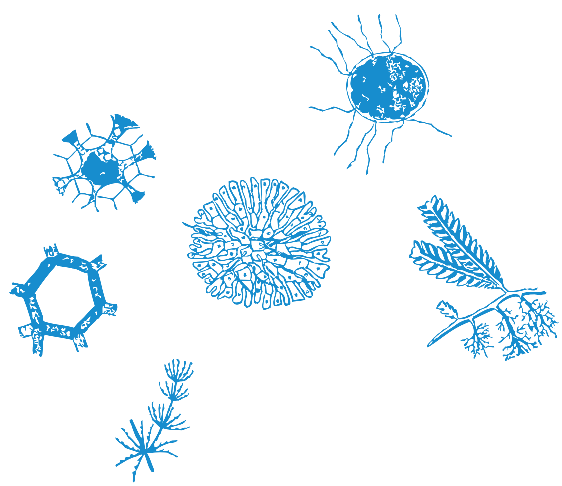
New Open Innovation Challenges for Reducing Pollutants: As nutrient flows have caused a growing dead zone in the Gulf of Mexico and affected the wetlands in and around the Mississippi River Delta, a set of challenges and prizes have been launched to advance detection and reduction efforts. The **Tulane Nitrogen Reduction Grand Challenge**, launched in

2014, has begun identifying promising solutions to reduce nutrient pollution and manage dead zones. The **ACT-EPA Nutrient Sensor Challenge**, launched in 2014, is seeking low-cost,

real-time sensors that can measure dissolved nitrogen and phosphorous concentrations. The **Everglades Foundation** recently announced a $10 million prize for innovations that can remove excessive phosphorus from waterways and recycle it into fueling the world's food supply. While several incentives in the form of prizes and challenges have arisen in the areas of detection and removal of nutrients, the timelines of the challenges are such that the potential recipients remain many years away from scaling their work into viable solutions.

Financial Mechanisms: Nutrient trading has become a popular market-based tool to attribute monetary values to point source pollution and non-point source runoff from wastewater and agricultural activity, enabling a market to trade and manage those nutrient flows. States including **Maryland**, **Pennsylvania**, and **Virginia** have launched online nutrient trading platforms to calculate values of sources and facilitate more efficient and cost-effective processes for managing nutrient pollution that ultimately ends up in coastal waters like the Chesapeake Bay. Expansion of these programs, as well as refinement of their models, can better harness emerging tools and technologies in managing nutrient flows at their source.

Approaches that unify land-based and marine farming practices in a closed-loop system have been designed to capture nutrient runoff for use in growing marine macro-algae that can be used in local agriculture.



Designing *the* Next Generation *of* Technologies

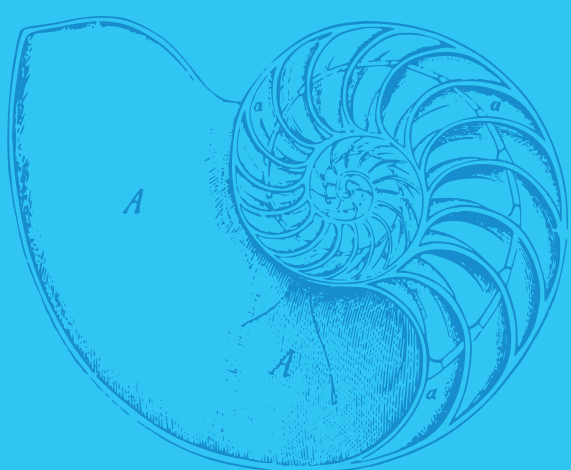
In the previous section, we reviewed ten potential grand challenges for ocean conservation. For each challenge, we summarized the problem, sought to understand the core constraints for which a breakthrough would be particularly transformative, and reviewed examples of promising emerging solutions. We will determine which of these ten challenges holds the greatest potential to launch as our first grand challenge for oceans conservation.

The solutions to these grand challenges, however, will not be found in traditional conservation science. We need to open conservation to new disciplines, novel ways of solving problems, new ways of leveraging exponential technological advances, and new solvers. Although traditional experts will play an important role in defining the problem, they do not hold all the solutions.

Much of the opportunity for innovation lies in cross-pollinating disciplines—applying innovative thinking from other disciplines and attracting new solvers and new solutions. We can achieve this by opening up the field of conservation to others, and bringing in experts who work in the fields of design, technology, internet and communications technology, engineering, global health, data science, genomics, microbiology, finance, behavioral science, marketing, agriculture, and supply chains. We will focus on engaging those who have the potential to contribute, but have not yet had the opportunity.

As science & technology emerges, so may conservation's efficacy and impact.

The following is a brief survey of emerging technologies and approaches that hold promise as breakthroughs for ocean conservation, whether or not they are currently in use.



DATA AND ANALYTICS

Many ocean challenges stem from the fundamental inability to easily see the size of the challenges—what we call ocean blindness. Our lack of data on oceans and our inability to visualize its changes and threats, or to quantify our impact on it, hamstrings our ability to address these grand challenges of oceans conservation. On the whole, we know frighteningly little about ocean ecology and the associated human impacts. This lack of knowledge has profoundly inhibited ocean conservation efforts.

Moreover, there are an abundance of specific challenges that require better data and predictive analytics. Ocean systems are in state of constant dynamism and flux, with greater, less predictable changes underway due to global climatic disruptions. Too often, regulations such as designating marine protected areas (MPAs) are painstakingly established only to see migration patterns shift unexpectedly, limiting their effectiveness. Pirates on the high seas transport contraband like illegally caught fish and modern-day slaves without fear of being caught and brought to justice. Real-time location data for whales is not integrated into routes for cargo ships, resulting in the collision and maiming of migrating whales.

Many of the technologies to address these problems are currently available or just over the horizon. A wide array of applicable sensors and analytics are currently being used in a variety of industries. The democratization of science, technology, and innovation, documented through advances in processors, memory & storage, connectivity, and mobile technology, have rapidly driven down the prices and increased the utility of sensors and analytics. They have given us tremendous new abilities to understand the abundance, distribution, and change of species, communities, and ecosystems; their interconnections; and their underlying proximate and ultimate threats.

We now have the capacity to monitor entire ecosystems and the changes they are undergoing in nearly real time. New nanosatellite constellations, like Planet Labs, have greatly improved the cadence and scale of our ability to image the entire planet at higher resolution, and their use of consumer technology and low cost allow for continual iteration and improvement of their technology. These may prove particularly useful in monitoring marine protected areas, tracking changes in surface water chemistry, and monitoring fishing activity on the high seas. Initiatives such as Esri's ocean mapping and Google Ocean and offer a giant leap into ocean awareness and exploration, and may be used in the future to create a Global Forest Watch for our oceans. Companies like PlanetOS (formerly Marinexplore) offer analytic tools and big data architecture to make sense of such vast troves of data for search, analysis, and discovery for real world sensor networks in oceans, in the atmosphere, on land and in space.

Advances in big data allow for predictive analytics that can help us understand threats before or while they occur. The expansion of mobile platforms (phones, tablets, laptops) has created new methods of tracking demand by analyzing changes in specific behaviors. The **UN Global Pulse** has used mobile data and purchases of airtime credits to better understand food security and seasonal migration patterns. Conservation can also harness new tools from the private sector, including social media hypertargeting and predictive analytics. **Target** famously used "predictive analytics" to predict when women were entering their second trimester of pregnancy, based on their shopping habits, in order to better market to them. Such big data analytics could help improve our scientific understanding of the interactions between organisms and their habitat across large spatial and temporal scales, and well as predict where ocean ecosystems are most at risk from human activity. However, conservation science will also increasingly confront challenges with big data regarding data quantity, quality, integration, and information extraction, as well as the cost, robustness, and ease of use of technological solutions.

By understanding and quantifying the problems more effectively, we can better direct resources to the areas that need it the most. Current methodologies in data analysis combined with vast increases in computing power have enabled capabilities in data fusion and collaboration that could fill many of these information gaps. By connecting previously disconnected data sources and combining them with mapping and sensing technologies, we can attain an understanding of our oceans at a scale that was previously out of our reach.

CONNECTED ECOSYSTEMS

The democratization of information technology, coupled with the global spread of mobile platforms, particularly smartphones, allows for revolutionary new approaches in conservation that were impossible a decade ago. There are now 7 billion mobile subscriptions around the world, which serve as gateways to knowledge, sensors for the environment, and platforms for research, education, and capacity building.

In Africa, it took 20 years for the first 100 million subscribers, but less than 3 years to attract the next 200 million. By 2015, there will be nearly 1 billion mobile phones in Africa, while the number of landlines stays fixed at 13 million. The percentage of those phones that are smart phones (currently 18%) is increasing at 19% per year. Mobile data use in sub-Saharan Africa doubled between 2012—2013, and is projected to double every year for the next 6 years. With software and mobile sensors designed inclusively with user-centric incentives, coastal people and maritime workers the world over can contribute to and directly benefit from gathering data for the ocean. A shift in perception around citizen science from a voluntary hobby to building a valuable community resource will grow with the increased efficacy of these tools.

The connected ecosystem leverages the innovation seen in "smart devices", which are network-connected physical objects with embedded microprocessors, sensors, and software, to benefit efforts in science and conservation. The work currently underway in the creation of the connected home or "smart cities" has bigger implications than many realize. It is not a large leap to go from a smart city to a smart ecosystem. In addition, the hardware created to support the smartphone industry (smaller/faster/cheaper microprocessors, sensors, storage & memory, batteries, and communications equipment) has created opportunities to miniaturize and spread the Internet of Things capabilities.

Current conservation and science efforts could work to create connected nature reserves instead of connected toasters and thermostats. By watching over the appropriate variables in an ecosystem, we can ensure that any impacts to biodiversity and ecosystem health are quickly identified and that the appropriate mitigation efforts are taken.

There are a number of fundamental technological benefits that come from the use of sensors and low-power computing/communication hardware. Persistent monitoring of an area is now possible, whereas it is not feasible with traditional sampling and testing methods. Commercial sensor development efforts are more active than ever, offering a wide variety of parameters to measure what is important for a particular region. There are significant efforts underway by telecom and tech companies (like Google and Facebook) to connect the entire planet. Since such devices use similar hardware to that used in smartphones, we can use those same networks for connected ecosystems in areas where communications previously relied on expensive satellites or ground infrastructure.

Imagine a marine protected area with autonomous underwater vehicles patrolling the habitat, networked sensors on strategically placed moorings that monitor ocean chemistry and environmental DNA, satellite data that assess both activity and surface-water chemistry, and numerous other sensors (hydrophones, current monitors, weather stations) that integrate all of this data through advanced data analytics. A system for monitoring, assessment, and surveillance could be created using existing tools. And not only could officials patrol and protect the MPA more effectively, our knowledge of how the species are faring in this MPA would be advanced, making conservation outcomes measurable.

Moreover, if the systems are created with the appropriate sensors and deployment plans, we can start to identify changes in the environment years (or even decades) before our current capabilities. Under our current monitoring approach, scientists typically monitor conservation efforts through periodic assessments of limited parts of an ecosystem. By watching the declines in animal populations or plant health, we deduce that something is damaging that population.

In contrast, if we create low-cost sensor systems to provide persistent monitoring, we can start to observe such changes much sooner by monitoring trends or setting thresholds. Alarms can be set on specific parameters and logic within the computer that can determine risk levels and send notifications. We would be able to see the threats the instant they occur. The low cost and ease-of-build could help to open up new possibilities for scientific data collection and environmental protection (from poaching, overfishing, and resource exploitation) on a magnitude that has never before been possible

THE POWER OF CROWDS

The democratization of technology and popularity of crowdsourcing has created an opportunity to expand conservation efforts far beyond the capabilities of a single organization or government. The collaboration inherent in open, networked approaches to conservation creates possibilities for environmental protection that is more effective than traditional methods in science and conservation. Museum collections, for instance, offer the highest quality of species records, with carefully curated voucher specimens verifying each datum. However, this curation limits the pace and scale of what can be collected. We are recognizing that much more data is needed to document the pace of change in the Anthropocene, and to be able to address it. We need to harness the power of crowds.

The fastest growth in conservation data comes from large numbers of amateurs. New citizen science tools, such as eBird, the Reef Life Survey, and i-Naturalist, allow a division of labor between amateur observers uploading mystery field observations from smartphones and skilled identifiers who catalogue the photos provided. Cooperation between amateurs and experts now produces high volumes of quality data for diverse taxa. eBird went international in 2010 and now has >100,000 observers and >100 million observations. Novel approaches have been used to identify and count wildlife on Serengeti camera traps, to assess populations of African and Antarctic penguins, and to assist rangers in Namibia through collaborative micromapping. Wildbook has used recreational divers and instructors to improve the understanding of whale sharks' ranging behavior and distribution. Through their website (**www.whaleshark.org**), they have collected more than 53,000 images of whale sharks (*Rhincodon typus*) and 25,000 sighting reports, resulting in collaborative tagging of 5,200 whale sharks, from 4,000 divers, 365 days per year. Apps like iNaturalist—which has acquired one million observations in a few years—feed data to Global Biodiversity Information Facility. Leafsnap automatically identifies tree species using photos of their leaves. These tools provide democratization of assisted expertise tools, coupled with curation for quality control. The possibility of offering incentives for data collection also exists. Gigwalk, a company who pays users small amounts of money to upload photos of store shelves on behalf of retailers that need customer data, could be applied to generating data from under-studied and unmonitored marine habitats. Recognition and competition may be as effective as financial rewards.

Prizes and challenge competitions focus attention on a problem, without being constrained by existing practices. The Grand Challenges programs, for instance, do not purport to know the solutions to the world's most pressing development issues—but they are willing to take risks and invest to create new solutions. When problems at the core of a prize or a challenge are well defined, they efficiently focus research and development efforts to engage and capture the imagination of the world's best researchers and innovators. A prize can focus on a specific breakthrough, while a challenge could result in a community of possible solutions. With well-developed problem statements and identified characteristics of a solution, we may use a challenge or prize to rapidly develop deployable solutions which are selected not only for technical excellence, but for their potential for scale, translation of research, and impact. The philanthropic community has extensively used competitions in the last decade (USAID and Gates' Grand Challenges for Development, as well as the X Prize, are examples). Such tools of open innovation will encourage disruptive breakthroughs that allow the conservation community to find novel solutions.

Greater degrees of global connectivity have enabled greater data collection, analysis, and collaboration across borders than ever before. Open Source Drug Discovery (OSDD) created a platform for collaborative, early-stage research to develop new drugs for neglected tropical diseases such as tuberculosis and malaria. OSDD collaboratively aggregates the biological, genetic, and chemical information available to scientists to hasten the discovery of drugs. It uses a translational platform for drug discovery, bringing together informaticians, wet lab scientists, contract research organizations, clinicians, hospitals, and others who are willing to adhere to the affordable healthcare philosophy by agreeing to the OSDD license. The OSDD approach is to conduct early stage research in an open environment in a highly collaborative fashion involving the best minds from around the world.

This approach could facilitate global assessments of biodiversity loss and ecosystem change, new ways of encouraging collaborative translational research that will support the resilience of coral species, or development of replacement products for endangered species such as sharks or for meeting the growing demand for protein. Similarly, open source efforts that have been built around the Arduino/Raspberry Pi/microcontroller communities, 3D printing and software, and in creating technology like drones, OpenROV, and other hardware projects have brought a wealth of open engineering expertise that can be mined to create new systems for conservation. Similarly, data software hackathons/codefests, in which computer programmers, design experts, and subject matter experts collaborate together within a specific event, could be used to engineer solutions for conservation problems, such as wildlife diseases, or improved sensors, or finding ways to better protect species against environmental change.

Finally, crowdsourcing has provided new opportunities, not only for participating in science but for funding it as well. In addition to major crowdfunding platforms like Indiegogo and Kickstarter, many smaller, science-specialized platforms exist, such as **Medstartr**, **Experiment**, **Crowdrise**, **Razoo**, and **Rockethub**. Crowdfunding allows for higher risk, higher reward science that overcomes the conservatism of government funding and forces scientists to build an audience for their work, which is essential to the public understanding of science.

INCENTIVES, BEHAVIOR, AND DESIGN

Prevailing cultural norms, institutional inertia, and ingrained notions of the environment can be barriers to systemic change toward sustainable use of the oceans and restorative ocean ecology. Every conservation or development issue involves humans, and, therefore, involves human behavior. Many of the widespread threats to marine life are the result of individual human behavior. This means that addressing the root cause also involves modifying individual behavior, but this reality is underappreciated in conservation.

Behavior is the cutting edge of adaptation. It can be the fastest way to meaningful change and also the biggest barrier to it. These challenges of behavior can also provide solutions. Conservation can harness behavior to bring change and break down barriers. This suite of tools includes incentives and rewards, harnessing competition and gamification, knowledge gaps, social pressure and networks, fear, self-identity and self-worth, and altruism, among others.

Similarly, financial innovations tied to human behavior also provide opportunities to bring large-scale change. They include pay-for-performance mechanisms such as direct payments for conservation, advance market commitments, social impact bonds, conservation finance, conservation and credit trading platforms, as well as harnessing new tools and platforms such as crowdfunding, microinsurance, microcredits, peer-to-peer lending, pay-as-you-go mechanisms, and franchise schemes. Global health and education have pioneered many of these approaches for social good and offer examples and failures from which conservationists can learn.

Design is the application of behavioral science and anthropology to products and systems. When done well, design can integrate the needs of people and species; the possibilities of technology; and the demand for impact, sustainability, and scalability. As nearly half of the world's population lives within 200 kilometers of a coastline and the majority of those people are in developing nations, we must consider the use cases; potential unintended impacts; cultural and social suitability; cost; environment; maintainability; education levels; and manufacturing, distribution, and supply chains for the development of new behavioral, financial, and technological innovations for the oceans. Artisanal fishers, for example, battle with commercial fishing operations and oftentimes cannot afford the technology or systems improvements that would aid them in the long run. How might we make vital technology like vessel tracking and traceability software an advantage to a fisher instead of a financial burden to avoid??

SYNTHETIC BIOLOGY AND PROGRAMABLE LIFE

Current advances in molecular biology are rivaling—and in some cases overtaking—the remarkable breakthroughs we have seen in computing and information technology. The human genome experiment in 1990 cost 2.7 billion dollars and took 13 years to create a reference genome of the human species. By 2014, commercial technology could sequence 55 genomes a day, at $1,000 per genome. Concordant with information technology, the efficacy and speed of sequencing efforts have been accompanied by miniaturization and portability. The modern synthesis of biology, technology, and data science has created the entirely new field of synthetic biology. Synthetic biology focuses on the design and fabrication of novel biological components and systems that do not already exist in the natural world, and on the re-design and fabrication of existing systems.

This technology will provide new opportunities to protect ocean ecosystems. Specifically, it may help accelerate adaptation to a changing environment due to climate change and increase the resilience of ecosystems against human degradation and invasive species. It can also be used for controlling invasive species, including halting the spread of novel pathogens that threaten ecosystems. Synthetic biology could provide substitutes for resources that are the underlying drivers of environmental change—from protein to plastics—changing demand for products that are currently illegally harvested from protected areas (e.g., meat, timber, non-timber forest products). It will also help with the restoration of existing degraded lands and regions, enabling crop production on lands currently viewed as marginal, thereby reducing the need for ecosystem conversion from forest to farmland.

Synthetic biology is not without controversy. Just as with genetically modified organisms, synthetic biology faces many of the challenges of biocontrol, our ability to ensure that natural systems and species are not disrupted by technological intervention into biological processes, as well as concerns over human and ecosystem health. Moreover, synthetic biology techniques are being proposed for use in recreating extinct species (e.g., the mammoth, Tasmanian tiger, and the passenger pigeon), and have significant ethical concerns. These activities are overly mechanistic, failing to incorporate an understanding of development, reproductive biology, and ecology, and may ultimately distract from the positive uses of synthetic biology for conservation.

ENGINEERING BIOMES, SPECIES, AND SYSTEMS

Recent advances in genomics have opened up our understanding of microbiology. Bacteria and other microbes are the most diverse organisms on earth and play a pivotal role in planetary cycling of nutrients and energy. Within the human body alone, there are over 100 trillion microbial symbionts, which constitutes up to an order of magnitude more non-human cells than human cells. Moreover, the collective microbial genome contains 100 times more genes than the human genome. Microbes control the composition of gases in the atmosphere, and are major agents of nutrient cycles on the planet.

Yet much remains to be learned about the ecological role of microbiota. Emerging research suggests that microbes play a significant role in maintaining ecosystem functions over the long term. We do not, however, understand the extent to which microbial communities follow the same rules of community ecology and organization at the microscale, as larger organisms do at the human scale; nor do we understand the extent of the role microbes play in generating and maintaining the earth's ecological services. Our knowledge of the marine microbiome is also incredibly thin. What we do understand suggests the hidden power of microbiota for conservation.

Emerging research suggests important links between the diversity and makeup of an individual's microbiome (the typical human microbiome is made up of 1,000 species, with considerable variation between individuals), and their physical and mental health, nutrition, immune response, and response to drugs. Disease can result not just from the presence of pathogens, but from the absence or altered composition of organisms in the microbiome. The increase in novel diseases around the world that are decimating species, like the devastating effect of Chytridiomycosis on amphibians, may be a result of imbalance in microbial communities.

The power of the microbiota is just beginning to be understood for applications in global health and agriculture, yet there are few applications for conservation—much less for marine conservation. Microbiology, despite borrowing heavily from the foundations of conservation biology and ecology, has been largely ignored by conservation science until recently. Yet, advances in microbiology offer great promise for conservation applications. Within farming systems, which have a significant impact on our oceans, we could potentially reduce the ecological impact of meat production by increasing the efficiency of nutrient extraction in the gut, or alternatively, reducing the need for antibiotics. For plants, microbiological engineering promises novel ways of reducing pesticides to better shape plant health and productivity. Finally, we could create probiotics for conservation, to help with the restoration of natural systems and communities that have been disturbed by human activities and global environment change.

BUILDING THE TRIBE

We need to build a community of practice for the next generation of conservationists to accelerate and substantially increase conservation's impact. We will build a novel community from the existing conservation movement, but also incorporate technologists, biological engineers, designers, makers, innovators, hackers, marketers, financiers, and anthropologists. We must serve as a catalyst, connector, amplifier, and mobilizer within the conservation community, relying on an ecosystem of institutions and individuals that enable us to effectively understand, source, test, and accelerate conservation solutions. We call this community our 'Tribe.'

By creating mechanisms for communities to tell their stories, share conservation successes, fundraise, and collaborate globally, environmental engagement will reach people that it has not previously reached. Many conservation challenges around the world share similarities despite their disparate locations. If the global community had more effective communication approaches and connection to their tribe of solvers, stories would emerge to unite these conservation challenges and solutions, helping the people who are impacted most. Social media initiatives like **StoryCorps** have been very successful in putting a human face on issues. Conservation, and associated technological solutions, should leverage the importance of story to raise the profile of these issues and create a culture of change.

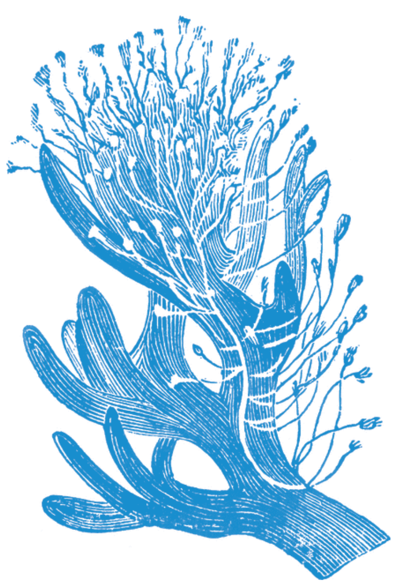
Creating *the* Pipeline

INTRODUCTION

In the twentieth century, innovation was primarily driven by the government, large corporations, or universities investing heavily in internal research and development to advance research. Such directed innovation, utilizing internal processes and research and development partnerships between research institutes, universities, corporations, and the federal government, were vital to the creation of the technologies that now power modern life. However, with advances in information and communication technologies, coupled with exponential technological advancement driven by consumer products, and a new Maker's movement that prioritizes creation and innovation, the opportunity gap between those large companies and individual citizens around the world has begun to close.

This unprecedented series of technological, financial, and social forces have now made it possible to transform conservation for exponential success. By harnessing the democratization of science and technology and accelerating connectivity, we can allow conservation to operate at the pace and on the scale necessary to match the planet's most intractable environmental challenges. There is a clear need to accelerate conservation solutions, harness new technologies, and draw upon new solvers and new solutions (especially within biodiversity-rich countries) to help us co-design and co-create a different set of solutions to improve the efficacy, speed, cost, and scale of global conservation efforts for our oceans.

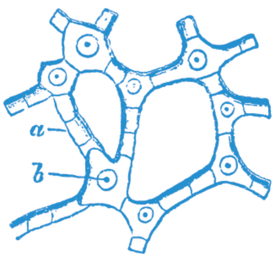
A variety of models for innovation sourcing, development, and acceleration/incubation exist in the startup ecosystem that provide a roadmap for Conservation X. Harnessing the best practices from accelerators and innovation challenges and prizes, we will create a 'Tribe' for conservation innovation and a pipeline through which the most promising breakthrough technologies that solve key conservation challenges will be sourced, developed, and accelerated to scale.



OPEN INNOVATION AS A TOOL FOR CONSERVATION

Open innovation is a modern approach to an old problem. At the highest level, it is an open and collaborative process that expands the pool of talent and creativity to create, incubate, and accelerate effective and impactful solutions that address complex challenges. While there are many manifestations of these types of programs, openness and participation are the catalysts for open innovation. By thoughtfully opening up organizational and industry-wide challenges to the masses, we can unleash creative potential that has the promise to make lasting positive impact as people contribute their own talents to issues they care deeply about.

I. SOURCE



Innovation can and should come from anywhere

Sourcing is a first step in the process of creating sustainable and transformative solutions, and relies heavily on the execution of the program in order to succeed in attracting breakthrough solutions to complex challenges. The fundamental preconditions for open innovation require not only a shared solution to a problem but also a shared definition and understanding of that problem to facilitate a co-creative process. Instead of simply harnessing the power of the crowd to validate ideas, we will utilize mass collaboration to access the talents of a broader community in forming those ideas to reach the best outcomes across institutions and platforms.

Through open innovation, we will focus a massive community of solvers against the core constraints of these problems, bring in new entrants, technologies, and innovations into conservation, and create an ecosystem of solutions, solvers, and resources that will transform the field and change the view of what is possible. Our goal is to take a high risk, high reward approach to investment in the best ideas early on, allowing for revolutionary over evolutionary advances, and then to scale those companies (and innovations) that have proven success in their impact.

The sourcing of innovations and technologies can come from two primary drivers in the open innovation space: (1) competitions, challenges, and incentive prizes or (2) collaborative events and co-design spaces. In each case, we harness the collective knowledge and expertise of the crowd to understand and begin to solve a problem. The process requires interdisciplinary experts, members of the private and public sector, and input from everyone from citizen scientists to Nobel laureates to create novel technologies, models, or systems.

Collaborative events and sessions can serve a broader purpose in conjunction with prizes to increase public knowledge and recognition of the prize and galvanize activity around the challenge space. Although not as likely to produce a specific scalable solution as a competition, these co-design sessions can serve a valuable purpose in expanding the reach and role of the challenge as a whole and building the broader tribe working on that set of issues or problems. Longer processes or competitions that incorporate iterative models, mentorship, and a scaled-down acceleration process beyond funds can contribute heavily to competitor success once the challenge is complete and also enable sustained engagement around the challenge areas and solutions.

Finally, we will partner with universities to incentivize students and faculty to help us co-design and solve the Conservation Grand Challenges, source breakthrough ideas, license promising intellectual property, and help commercialize innovations and bring them to market. We have ties with leading engineering schools, including Duke's Pratt School of Engineering, Stanford University, Carnegie Mellon University, the University of California, Berkeley, and the Massachusetts Institute of Technology, and environmental schools, including Duke's Nicholas School of the Environment, Yale School of Forestry, and Stanford's Wood's Institute. We will also work closely with Singularity University, Google, and Microsoft on technology development.

RECOMMENDATIONS

Create a set of conservation challenges that incorporate an incentive prize and co-creative programming to inspire new entrants to the space, harnessing the resources of multi-sector partners to identify the most promising breakthrough solutions and innovators.

- **Engage** multi-sector stakeholders and partners to expand reach including government, civil society, NGOs, the private sector, and the startup community.
- **Design** the program and develop internal capacity to provide the proper resources and staff to support the challenge and help create a budding conservation innovation community.
- **Create** a collaborative, solutions-driven tone for the challenge.
- **Identify** the specific barriers and key constraints that—once solved—could lead to the most transformative impact and ignite a breakthrough solution.
- **Create** the necessary platforms and facilitate access to key resources that are necessary to solving the identified challenge.
- **Host** a large gathering for the completion of the challenge, and a series of co-creative programs to galvanize interest and action in the space.
- **Plan** for what follows the challenge, having a clear path and the necessary resources for participants to develop and accelerate their ideas into viable solutions.

SELECTION PROCESS

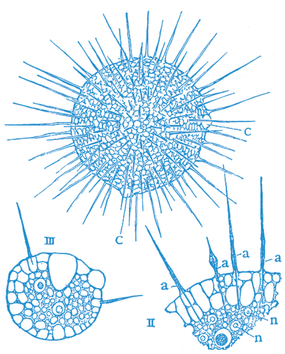
In making potential investments, we will determine whether the companies and innovations are transformative, impactful, scalable, sustainable, feasible, and potentially profitable. As our goal is to build a platform of long-term sustainability, we will seek to construct a portfolio of diversified risk, impact, novelty, and profitability.

Based on results from the Big Think, challenge design, systems mapping, and innovator outreach, we will establish a detailed set of judging criteria based on the following qualities:

- **Transformative**: whether the idea is revolutionary, novel, or questions fundamental assumptions in its approach;
- **Impactful**: whether the proposed idea will make a significant contribution in advancing conservation efforts through dramatic improvements in efficacy, speed, efficiency, or cost;
- **Scalable**: whether the proposed idea is replicable and scalable to different communities, species, and contexts;
- **Sustainable**: whether the proposed idea is sustainable in both its design and tenure;
- **Feasible**: whether the proposed solution is realistic with an acceptable degree of risk, and noting where it sits on the development spectrum, from idea to deployment;
- **Profitable**: whether the proposed solution will be profitable within conservation or through secondary markets outside of conservation, or will lead to intellectual property with the potential to be acquired.

Finally, as individuals are significant to the success or failure of a company, we will make an assessment of the leadership potential of the innovators, and our ability to assist them in developing their skills.

II. DEVELOP: PROTOTYPE, INCUBATE, *and* ITERATE



PROTOTYPE
TRANSFORMING IDEAS INTO REALITY

Once identified, licensed, or co-created, every idea enters a stage of development that is critical to its future as a potential sustained innovation. This stage encompasses the creation of an innovation that could blossom into an actual solution to a problem. At the close of any open innovation approach—be it a prize, hackathon, or co-design session—teams are often left with the backbone of a solution but need additional resources, mentorship, and time to develop it into a viable solution or product that could be scaled to enter the market. The main requirement is a clear idea, model, or product that can be iterated, modeled, and refined over time. The licensing of intellectual property requires a similar pathway toward the development of prototypes.

As potential solutions have been sourced, we shift from a competitive environment to a more collaborative one. At this stage, the goal is the creation of a minimum viable product or prototype. This requires an environment that fosters interaction and feedback, and builds momentum. This stage is also integral to creating the business case for the innovation—a justification for the expected commercial benefit, and pathway to scale and sustainability.

Prototype Recommendations:

- **Build** a community of innovators & entrepreneurs in the program that can support and aid each other throughout the process. Although most incubators focus on mentorship, peer-to-peer learning among entrepreneurs can be even more powerful and useful.
- **Engage** and **create** the tribe or community around the challenge areas for co-design and co-development through tech demos and makers faires.
- **Provide** and **facilitate** access to physical resources for innovators to model, iterate, test, and refine solutions into viable products. This may include fab labs and makers' spaces, app design and testing resources, and wet labs and biohacking tools. This may be through partnerships (e.g., with Green Town Labs outside of Boston), or through building our own dedicated design and engineering studios.
- **Mentor** innovators with a curated list of technical experts and design professionals who have committed to providing specific assistance or resources to participants.

INCUBATE
SUPPORTING COLLABORATION BY DESIGN

The best incubators involve a combination of physical space coupled with programmatic tools and resources, a robust community of fellow startups at different stages, and access to mentors and finance. Our goal is to build not only a library of intellectual property and financially successful companies that will transform conservation, but to harness the collective ideas and wisdom of this community to maximize the success of each innovation for impacting conservation at scale. These efforts would effectively map out the landscape of conservation technology.

In the incubation phase, we will build an ecosystem where the incentives encourage collaboration over competition. This will be a one- or two-year program, with both residence and virtual training components. We will host companies within an incubator space, potentially in partnership with the Global Impact Hub network, which has sites in San Francisco, Berkeley, New York City, Philadelphia, and Washington, D.C., as well as world-wide, which would enable us to create a global community of practice, share the best ideas, and promote collaboration across our portfolio of conservation solutions. This may be combined with resources for prototype development.

Through our programming, we will bring in expertise in finance, design, engineering, and business to support and work with the teams. We will also use our own digital training program, *Innovation & Design for Global Grand Challenges*, developed in partnership with Duke University and the on-line course company **Coursera** — to help companies and innovators get the expertise they need to scale as social enterprises. We will partner with some of the best programs for social impact globally: Duke's innovation and entrepreneurship program, Santa Clara University's Global Social Benefit Incubator, and Further by Design and SecondMuse's Launch Accelerator to provide further content and programming for training innovators.

Recommendations

- **Educate** innovators in entrepreneurial skills including business strategy, pitching their product to investors, and customer acquisition.
- **Provide** financial and legal resources to fledgling companies to expand and further develop their product and determine the correct course of action for their product.
- **Expand** the publicity and marketing for innovators and provide access points to the right media or contacts to reach customers and the general public.
- **Identify** and recruit entrepreneurs who are a step ahead in the process to guide innovators, as well as a broader network of experienced and expert mentors and investors that can help facilitate scaling and market entrance.
- **Provide** physical office space and business resources including technological tools to run an effective company and adapt to specific company needs through consistent communication.
- **Locate** incubators in hubs of the innovation, startup, and conservation communities in multiple locations including San Francisco, Washington, D.C., and the developing world.

ITERATE
ENGINEERING AND DESIGN FOR CONSERVATION

We will work with a wide range of partners, including those in the conservation community such as WWF, WCS, and the Smithsonian, to take promising technologies and solutions that we invest in or create, from the lab or the garage to the marketplace. To do so, we will work with innovators to field-test and rapidly iterate prototypes across multiple locations, in different socio-cultural contexts, evaluating technologies for cost, environment, function, suitability, reliability, efficacy, manufacturing and distribution.

Recommendations

Create a product development pathway and resources for sourced ideas and innovators that facilitates the development of novel technologies and harnesses the power of a conservation tribe to refine, iterate, and develop ideas into viable solutions.

- **Partner** with the scientific and conservation communities to test new technologies or approaches, assess their effectiveness and suitability for their user communities given education levels, operating environments, cost, maintenance & reliability, distribution channels, and manufacturing and assembly.
- Harness **crowdfunding** as a means of measuring market readiness, engaging the larger community in design and development, capturing user response and feedback, and expand the market.

III. ACCELERATE ENGINEERING *and* DESIGN *for* CONSERVATION

Scaling solutions for transformative impact and long-term sustainability

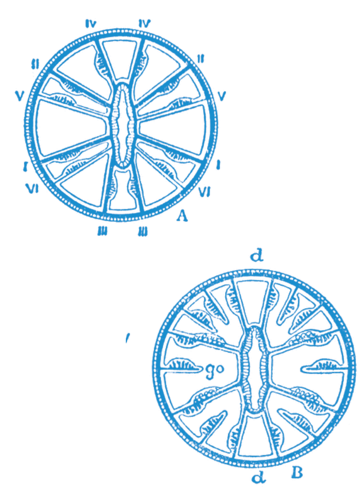
Acceleration functions primarily to provide key resources and capacities to refined products or ventures so that they can quickly and effectively break into new markets, expand within an existing market, or franchise the core technology.

Scale is a metric of both sustainability and impact. Without widespread application, innovative solutions will not help solve conservation problems. To ensure ideas get to scale, we will bring together social innovators and serial entrepreneurs, venture capitalists, angel investors, donors, and foundations to provide innovators with services such as seed funding, grants, incubation and accelerator services, networking opportunities, operational business support services, knowledge exchange, and technical assistance. We will also facilitate access to equity, debt, and other capital, in addition to our own investments.

Recommendations

- **Host** large kickoff event, progress updates, and pitch events that can mark the timeline of the incubator's annual schedule and allow innovators to measure and share progress with investors and the broader community.
- **Showcase** innovators' products to investors and the broader conservation community to garner support for their scaling and adoption through an annual conservation tech fair and conservation technology conference (potentially in partnership with a major innovation conference, such as SXSW Eco).
- **Assist** conservation entrepreneurs in raising capital to achieve scale through direct investments, grants, financing, and acquisition.
- **Connect** innovators to companies and investors who can help bring their innovations to scale.

We will create a 'Tribe' for conservation innovation and a pipeline through which the most promising breakthrough technologies that solve key conservation challenges will be sourced, developed, and accelerated to scale.



INVESTMENT MODEL

Our approach in funding new innovations will be to partner with a variety of institutions to de-risk individual investments and leverage additional capital. Moreover, we will use a tiered investment model to support innovators who may be at different points along the pipeline.

INITIAL INVESTMENTS

Drawing inspiration from product development enterprises, venture capital, and the Grand Challenges for Development program at USAID, we may use a three-tiered finance model to maximize cost-effectiveness and minimize the risk of testing new ideas. This approach will be used to determine the initial level of investment into an enterprise in exchange for equity.

STAGE 1
PROOF OF CONCEPT:

Stage 1 grants support prototyping and the introduction of a solution in a conservation context to gain an early, real-world assessment of the solution. This includes testing for technical, organization, distribution, and financial viability. Key activities could include initial field testing, assessing user feedback or demand, willingness to pay, and product design, as well as documenting social outcomes and real-world costs to implement the solution.

Stage 1 funding levels range from $25,000 to $100,000 per project.

STAGE 2
TESTING AND POSITIONING FOR SCALE:

Stage 2 grants support testing for conservation impact, improved outcomes and/or market viability, as well as operational refinement to build paths to sustainability and scale. Stage 2 applicants should have already met all the requirements of a Stage 1 project described above. Stage 2 projects range from $150,000 to $500,000.

STAGE 3
TRANSITIONING PROVEN SOLUTIONS TO SCALE:

Stage 3 grants support the process of transitioning proven approaches to scale, which could include adaptation to new contexts and geographies. Operational challenges for scaling should be identified and addressed, allowing for refinement and iteration along defined pathways to scale. Stage 3 applicants must explain how they will use investment funds in a catalytic fashion so that they can leverage additional needed resources from outside sources. Stage 3 funding and support provides a runway for applicants to grow by preparing them for outside investment, while engaging additional partners who will help scale the project beyond our support, but for whom more evidence of success and track record are needed. Stage 3 grants range from $500,000 to $2.5 million. Most funding would be done in partnership with other sources, including development agencies, impact investors, and foundations. Public funding would be used to de-risk other potential investments.

CAPITAL FUND

Beyond the initial challenge investments, we may set up a flexible, higher risk capital fund to de-risk second-stage investments and make the deals competitive. The capital can be structured as needed to stimulate private investment. This fund could provide both grants and financing.

Grants may be used to fund supply-side interventions such as improving the innovation, capacity building of the management team, facilitating production, improving distribution models, gaining operational efficiency, and expanding access to capital to finance the growth strategy. Demand-side interventions may include improving market linkages, securing contracts, building partnerships, enabling penetration of new markets, and providing support in attracting a larger customer base.

The fund could also provide a first-loss loan that would be ranked junior to the commercial investor. Alternatively, the impact-first investor could receive a fixed return (e.g., principal plus low interest), allowing any remaining profits to be distributed to the commercial investor. Private investors will be more willing to support the businesses when they are more "investment-ready" and the management team is proven. In addition to lowering risk for private investors, this structure helps to increase transaction size for private investors, since more-developed business opportunities tend to require larger amounts of capital for growth compared with those in the seed-stage phase.

Who **we are**

CONSERVATION X LABS

Conservation X Labs is a conservation technology and innovation firm based in Washington D.C. that seeks to create a new model for conservation. At its core, it is an innovation platform focused on developing new disruptive breakthroughs in technology, behavior change, and financial incentives, using the power of open collaborative problem solving, directed research and development, and the market. It focuses on developing innovations that improve the efficacy, speed, cost, and scale of global conservation efforts with the aim of ending human induced extinction. CX Labs' goal is to create the platforms, coupled with the scientific and technological tools, that empower the larger conservation community.

FURTHER by Design

FURTHER is a collaboration and innovation company working with governments, companies, non-profits, and investors to accelerate the development of effective partnerships to address systemic design challenges. FURTHER is not a big box consultancy or a traditional research company. Our team of connectors - who specialize in innovation through collaboration - approach a design challenge by profiling and assessing the landscape then engaging the most influential and resourceful players, both internal and external, to co- design, incubate and implement a strategy or solution. Through collaborative processes and tools that help both internal teams align and execute, and organizations to work better with external partners, we have been bringing a systems perspective to designing and accelerating innovations and solutions across a wide range of issues, including zero waste, affordable housing, agriculture supply chain sustainability, space exploration, breast cancer in the developing world, mobile banking, and alternative energy systems, to name a few.

SecondMuse

SecondMuse is an innovation and collaboration agency that runs some of the world's largest mass collaborations to date, including the International Space Apps Challenge, the White House's National Day of Civic Hacking and Random Hacks of Kindness. We co-create prosperity by applying the science of collaboration to solve complex problems. We believe that the key to human prosperity is the coming together of diverse thinking and coordinated action to solve the really tough challenges. We create and facilitate this process. Our team builds capacity in people to think about challenges in a different way and create alternative solutions. We help facilitate this ongoing process using the principles of design thinking, curated collaboration, and open innovation, creating opportunities for change across organizations and industries.

World Wildlife Fund

WWF's mission is to conserve nature and reduce the most pressing threats to the diversity of life on Earth. One of world's leading conservation organizations, WWF works in 100 countries and is supported by 1.1 million members in the United States and close to 5 million globally. WWF's unique way of working combines global reach with a foundation in science, involves action at every level from local to global, and ensures the delivery of innovative solutions that meet the needs of both people and nature.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