# Breakthrough Aquaculture

Uncovering solutions that drive ecologically sound and commercially viable models for farm-raised seafood

FUTURE of FISH

This report was prepared for Commune, LP

by Future of Fish

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"If you are going to innovate something, having a purpose beyond financial gain is a very powerful motivating force in aligning people from disparate fields to focus on one thing."

*—Beau Perry, Executive Director*
*Olazul*

# EXECUTIVE SUMMARY

More than three billion people on the planet depend on seafood for a critical portion of their diet's protein. In the US, we import nearly 90% of our seafood, reaching across the globe to the waters of developing nations to buy their tastiest and most exotic fish. Worldwide, the voracious appetite for fish has shamefully depleted our oceans, overexploiting stocks and destroying marine habitats. To keep pace with the growing demand for seafood—predicted to rise 8% during the next decade—the world must increasingly rely on aquaculture, the farming of fish.

Unfortunately, though it is a prevalent and important solution to the shortage of wild fish, aquaculture in fact creates new problems, which include ecological damage, water pollution, antibiotic overuse, high rates of freshwater and energy consumption, and numerous potential health issues for farm workers. As stewards of a future without food scarcity and environmental plunder, our critical challenge is to find new ways to produce more fish—without causing more harm.

Forward-thinking fish farmers, other entrepreneurs, and scientists are already working on exemplary systems and practices to raise fish without negative impacts. Yet, scaling these efforts to a level that can meet growing demand for seafood requires overcoming significant financial, political, social, and logistical challenges. That conundrum, however, can also represent a significant business opportunity.

Using that lens of potential opportunity, Future of Fish used a **discovery framework** to analyze the "stuck points" in the systems supporting what we're calling "breakthrough aquaculture" to better understand how to shift this particular sector of the industry into a high growth phase. We've defined "breakthrough" as a significant innovation that reduces the environmental impact of farming or makes progress in furthering the economic viability of these eco-friendlier farming techniques. Our launching point was this question: How might we foster a business landscape where ecologically sound and innovative aquaculture can actually scale and thrive?

Our research identified and distilled the experiences of 50 experts and entrepreneurs working to build ecologically sound models of aquaculture. We solicited information about the challenges they faced, and the innovative ways they had overcome those challenges. From this discovery process, we looked for patterns that pointed to overarching problems ("barriers") and the underlying strategies ("design principles") used to solve them.

The five **barriers** identified were:

- Hostile Public and Regulatory Environment. Formal regulation as well as public perception makes starting and operating a farm challenging and costly.
- Chokehold on Raw Materials. The resources required to establish and operate an aquaculture facility are controlled by a small number of source outlets or are simply scarce.
- Lack of Market Differentiation. A premium, high-value market for farmed fish does not yet exist.
- Underdeveloped Risk-Mitigation Strategies. As a relatively nascent industry, aquaculture has yet to adopt best practices in order to predictably reduce failure rates in biomass production.
- Immature Operational Models. Fish farming that is both ecologically and economically beneficial is too new to have well-tested and developed operational models.

The five **design principles** identified were:

- Focus on More Than Fish. Diversify business activities and revenue streams to increase profitability and hedge risks.
- Draft Off-Aligned Stakeholders. Take advantage of like-minded players who can surmount marketing, public acceptance, and regulatory hurdles.
- Pioneer Custom Solutions. Invent and test new methods and strategies to overcome challenges.
- Share Responsibility. Build strategic partnerships to facilitate business development, distribute risk, and maximize potential for success.
- Mimic the Ecosystem. Leverage basic ecosystem principles such as zero waste and minimal inputs to boost productivity and profitability.

The barriers and design principles form the **Discovery Map™**, a subjective qualitative tool that helps identify and illustrate how forces of change are already at work within a system, as well as where innovators are falling short. Based on interviews with innovators, we mapped 42 unique solutions being employed to overcome challenges to scaling ecological breakthrough aquaculture. Through this process we inferred the following **system insights** about the state of aquaculture innovation and scaling potential:

- Aquaculture is home to a plethora of individual innovations, none of which alone are capable of systems-level problem solving.
- The very custom solutions that farmers invent often have the unintended consequence of making their businesses harder and riskier to operate.
- Constant attention to daily needs prevents the development of long-term strategies.
- Collaboration is necessary yet nearly impossible for individual players to broker.
- Risk management is overwhelmingly poorly addressed.

The insights led us ultimately to a set of five **opportunity areas** for further exploration that could potentially shift the aquaculture industry landscape toward less environmental impact, greater efficiency, lower risk, reduced costs, and increased scalability.

Opportunity 1: Enable businesses to share knowledge and information in order to lower the difficulty of farming and allow time and attention for more creative and growth-oriented strategies.

Opportunity 2: Engage the insurance and financial sectors to develop better strategies for risk mitigation and improved dialogue for how fish farming can lower its risk profile.

Opportunity 3: Beat the bad reputation of farmed fish.

Opportunity 4: Build distribution networks that help producers access bigger markets.

Opportunity 5: Develop secure pipelines for raw materials and operational know-how.

The narrowing of one or more of these opportunities into viable solutions—with outcomes and goals—is the next step in our process, which includes convening diverse players in and outside the system to contribute to the evolution of this framework. As more stakeholders are invited to participate, we fully expect the ideas to shift (based in part on feasibility) and a deeper exploration into execution to follow.

Thimble Island Oyster Co.

"The aquaculture revolution, the blue revolution, has not always been green. We have to make the blue revolution greener. We need a turquoise revolution!"

*—Thierry Chopin, PhD, Professor*
*University of New Brunswick*

# INTRODUCTION

The ocean is the largest source of wild food on the planet, and demand for fish is ever on the rise. Seafood provides critically important animal protein to an estimated three billion people. Unfortunately, the seas are unable to sustain current consumption needs—much less future ones—as fish populations are already fished to their limits. Thirty percent of wild fisheries are actively overharvested or significantly depleted, and 90% of the biggest fish are gone. Myriad issues related to bycatch, illegal fishing, mislabeling, forced labor, and habitat-damaging gear further complicate the future of fish.

In order to keep pace with the escalating need for more seafood, the world must rely increasingly on aquaculture. Aquaculture has for many years been the fastest-growing food production system on the planet, and it has expanded by a factor of 12 since 1980. Taking place in approximately 190 countries and involving cultivation of roughly 600 species—from salmon to oysters to sea urchins—aquaculture supplies more than half of all seafood produced for human consumption.

Despite its prevalence and importance as an alternative to wild fish, aquaculture is not without problems. Some forms of conventional fish farming are associated with serious ecological damage related to fish feed, water pollution, habitat loss, antibiotic use, genetic contamination, land conversion, and ecosystem disruption, as well as high rates of freshwater and energy consumption. In addition, some farming methods expose workers to unsafe levels of disinfectants and other chemicals used to treat disease, clean ponds, and process products.

**A CRITICAL CHALLENGE FOR THE CURRENT GENERATION IS TO FIND NEW WAYS TO PRODUCE MORE FISH WITHOUT CAUSING MORE HARM.**

Forward-thinking fish farmers, other entrepreneurs, and scientists are already working on exemplary systems and practices to raise healthful fish without negative impacts. Those innovations include enclosed recirculating tanks, fishmeal-free feeds, and cultivating native and multi-trophic species. We've also seen the emergence of integrative aquaculture, which, in mimicking natural systems, can actually reverse ecological destruction by improving water quality, restoring stagnant lands, and increasing biodiversity.

Most of those nascent improvements are small scale, high cost, and high risk. Nearly all are managed by resource-strapped start-up companies or university programs dependent on limited funding from government grants and, to a small degree, private capital. Bureaucracy hampers many, while others struggle with public perception. Scaling these efforts to a degree commensurate with growing demand for seafood requires overcoming significant financial, political, social, and logistical challenges.

But the constraints of the present may well prove to be the opportunities of the future for the right investor or business. With that lens—using opportunity as a lever for problem solving—Future of Fish has conducted a thorough analysis of the "stuck points" in the systems that support what we're calling "breakthrough aquaculture"; our analysis serves to better understand how to shift this particular sector of the industry into a high-growth phase.

This report represents the first stage of Future of Fish's approach to solving complex systemic problems in aquaculture. The insights we gleaned through this research and analysis then will allow us to recruit and convene a working group of entrepreneurs, existing businesses, field experts, and investors to collaborate on resolving the barriers that prevent breakthrough aquaculture ventures from scaling. This analysis points us toward the specific business opportunities that can become the basis of an initial business design workshop, as well as an ongoing collaboration that benefits individual participants and the system as a whole.

"There are major environmental issues with a number of industrial aquaculture operations. If it was commercial terrestrial farming that we were supporting—if it was the same level of contamination and unsustainable practices, and it affected 50% of our terrestrial consumption—there would be major concerns more frequently seen in the major news outlets."

*—Barry Costa-Pierce, PhD, Director*
*Marine Science Center, University of New England*

Fair Share CSF

"Basically, we still have a lot to learn. It's easy to say conceptually we should do this or that...but it's what we shall learn individually and collectively through our real experiences that will create the learning and the know-how."

*—Tama Matsuoka, Founder*

*Meadows and More*

# THE DISCOVERY FRAMEWORK

## UNDERSTANDING THE WISDOM OF INNOVATORS

The discovery framework is an integrative approach to understanding the multifaceted nature of a problem, and how the different components of that problem are being addressed and solved by innovators through different strategies and approaches.

To develop the discovery framework, we identified more than 60 unique solutions addressing various challenges to the development and scaling of ecologically sound and economically viable aquaculture models. Those solutions came from 50 interviews: 17 interviews conducted with owner/managers of aquaculture enterprises, ranging from early-stage start-ups to large-scale commercial operations; 21 interviews with on-the-ground participants in government agencies, academia, research institutions, and nonprofit organizations; and 12 interviews with value chain players as well as fish feed companies and investors. Each offered a perspective that reflected their personal experience designing solutions to particular problems they encountered. In all, we were able to name 75 distinct problems in the system, which we grouped into a set of core challenges to be analyzed.

The discovery framework analysis includes the following components:

**CONTEXT** The snapshot of the current landscape. Context comprises static conditions that will always shape the climate, as well as the historic (and possibly changeable) influences and facts that explain the status quo.

**TENSIONS** Social, political, economic, and behavioral trends and biases that perpetuate a problem, but could unlock potential levers for change if reframed.

**BARRIERS** The core challenges of a problem, which, if successfully resolved, could pave the way for real progress. Barriers are not immutable conditions; they must be moveable and changeable.

**DESIGN PRINCIPLES** The underlying ideas or observations of a solution. These principles are not tools or solutions themselves, but ways to understand the mechanism a solution is addressing. They reveal truths about a system and insights to address long-standing stuck points.

**DISCOVERY MAP™** Subjective qualitative tool that helps identify and illustrate how forces of change are already at work within a system, as well as where innovators are falling short.

**PROJECT PROFILES** Brief descriptions of the solutions, the barriers they address, and the organizations behind them.

**SYSTEM INSIGHTS** Observations of patterns, trends, and holes that lead to our subsequent recommendations and identification of opportunity areas.

## The Discovery Framework

The effectiveness of our methodology comes from our team's combined 25 years of experience in complex systems analysis. Its strengths include:

**Inherent optimism.** We begin our analysis by identifying what is succeeding in a given space. We then look for opportunities to build on that success.

**Reliance on wisdom from those on the ground.** A significant gap exists between the theoretical and the practical when it comes to the front lines of solving an environmental or social problem. Within that gap are insights and adaptations—flashes of brilliance—that are often missed when relying only on high-level views of the system.

**Detection of patterns not otherwise apparent.** Those insights and adaptations from the field, when knit together, provide new possibilities: ways for players working on entirely separate aspects of a multidimensional challenge to potentially collaborate; ways to address segments of the problem that have been inadvertently ignored; ways to make successful strategies more widely applicable.

**Reframed challenges allow for new thinking and new participants.** The definition of a problem shapes not only the types of approaches applied, but also the expertise invited to the conversation. Ultimately, multiple framings are necessary and compelling. For example, seafood sustainability is a marine science issue. But it is also an investment issue and a business issue. Without investors and entrepreneurs in the room, important voices are left out of the solution set.

**Qualitative in nature, not quantitative.** Our methodology is meant to generate a framework for understanding and a set of viable assumptions to shape the path forward, rather than a statistically derived proof.

# THE QUESTION

How might we foster a business landscape where ecologically sound and innovative aquaculture can actually scale and thrive?

# CONTEXT

**The snapshot of the current landscape. Context comprises static conditions that will always shape the climate, as well as the historic (and possibly changeable) influences and facts that explain the status quo.**

Aquaculture takes place in nearly every country in the world, and for some cultures has been practiced for millennia. Yet, in the US, fish farming is a relatively small and nascent industry, accounting for less than 1% of global production. Of the farmed fish consumed domestically, 90% is imported. Due to a number of economic, ecological, social, and regulatory issues, the US aquaculture industry has lagged behind the rest of the world in terms of new technology, business-friendly policies, cutting-edge research, public and private investment, and mature market demand.

From an economic perspective, commercial-scale aquaculture is expensive. Start-up costs are high due to the need for land, physical infrastructure, and sophisticated technology. Inputs such as water, feed, and brood stock are pricey, and operations costs—including skilled labor, energy, and insurance—can inhibit profitability. Add to that the fact that raising fish, especially on land, is hard work. Fish farming requires both scientific and operational expertise, constant maintenance and monitoring, and above all, precision. Fish lack the resilience of crops or other livestock and are vulnerable to changes in ambient conditions. For that reason, fish farmers must be sharp troubleshooters to react quickly when something goes wrong, or risk losing an entire cohort of fish.

Aquaculture is further challenged with resistance from many people who are opposed to having fish farms established in their neighborhoods or along their coastlines. Regardless of how benign the farms might actually be, the popular perception is that they will be ugly, noisy, smelly, polluting, or otherwise unpleasant enough to spoil the neighborhood and reduce property values. Citizen complaints often drive laws and regulations that prohibit or effectively prevent aquaculture from growing as an industry in the US. Although some legislation rightly aims to protect public health and preserve natural areas by establishing strict guidelines with respect to farming fish, many laws lack flexibility and, thus, hamper innovation and entrepreneurship. Appendix I (page 33) outlines aquaculture regulations for a number of key states.

The ecological issues associated with aquaculture depend on myriad factors related to species, production system, management regime, inputs, geography, and the surrounding environment, among other dynamics. Full descriptions of those issues, as well as definitions of common production systems, are outlined in Appendix II (page 39). Of specific concern are water use and pollution, feed, sources of brood stocks, land conversion and habitat loss, antibiotics and chemical inputs, escapees, and disease. Opponents to farmed fish tend to magnify those negative impacts, which further taints aquaculture in the mind of the consumer and toughens efforts to grow demand, build markets, and attract investment.

Given the issues currently plaguing aquaculture in the US, the core question underlying the framework we've developed is: How might we foster a business landscape where ecologically sound and innovative aquaculture can actually scale and thrive?

## TENSIONS

**Social, political, economic, and behavioral trends and biases that perpetuate a problem, but could unlock potential levers for change if reframed.**

Tension 1: Urban centers have economic engines to drive innovation. / Urban centers have stricter regulations that stymie innovation.

Cities are hubs of intellectual capital, market diversity, and easy methods of localized distribution; in that sense they are a product-development dream. If you are a fish farmer looking to grow your business—and can get some expertise on how to do it—locating your farm near a city center can be hugely beneficial. But urban aquaculture can also lead to enormous roadblocks in the form of permitting, safety inspections, and other regulatory hurdles. If permits are secured, they tend to be strict, limiting farmers' ability to experiment, test, and refine their designs, models, and operations. However, the growing interest in locally sourced food, along with rising concern over urban food deserts, could provide the social and political support needed to create a more hospitable urban aquaculture environment.

Tension 2: Successful fish farmers need to develop markets. / Marketing steals valuable time, making farming less successful.

The seafood industry is built on long-term, trusted relationships between buyers and sellers. Thus, new ecologically responsible fish farmers often struggle to find markets for their quality product. Even more difficult is finding buyers willing to offer prices reflective of the value of the fish. Due to staffing expenses, most fish farmers have no choice but to be their own marketers, courting buyers (e.g., chefs, high-end retailers) and building demand. Unfortunately, time spent away from the farm has the potential to increases risks, reduce efficiency, and hinder success. But the alternative is to sell into the commodity market, get gouged on price, and hope to make up for it in volume—which is usually a losing proposition for small-scale operations.

Tension 3: Economically viable fish farms need high-value fish. / High-value fish tend not to be environmentally sustainable.

Fish farming is an expensive venture, both in the sea and on land. Feed, infrastructure, insurance, maintenance, labor, and energy costs are all high. To make the model work, farmers need to grow high-value fish, maximizing the return per unit effort. Consumer demand is greatest for fish high on the food chain: tuna, snapper, salmon, and sea bass. However, growing these species requires lots of wild-caught forage fish such as anchovies, menhaden, and herring to make feed. That demand contributes to overfishing and depleted stocks of these smaller fish. Raising vegetarian fish, such as tilapia, is far more environmentally friendly and cost effective, but not nearly as lucrative.

Tension 4: In terms of resource consumption, fish are a "better" protein than land animals. / Fish are the hardest species to grow on land.

While discussion in the marine science world focuses on the negative impacts of fish farming, in truth, farmed fish actually have a lighter environmental toll compared with beef, pork, or even chicken. Fish convert energy into edible protein far more efficiently than mammals. But growing fish on land requires extremely high-energy inputs that can offset those gains. Further, land-based fish farming is risky. With other forms of husbandry, animals are relatively resilient to changes in their surrounding environments. Fish, on the other hand, live and die based on the water conditions in their tanks. A slight variation in temperature, pH, dissolved oxygen, or any number of other factors can be catastrophic. Thus, not only does land-based aquaculture require sophisticated technology to provide constant aeration, filtration, and monitoring, but back-up systems must also be in place.

Tension 5: Science expects private industry to scale their models. / Private companies don't have the financial or resource capacity to run test pilots.

Government grants and small experimental fish farms can take an idea only so far. Eventually, researchers need to test their ideas on a larger, more commercial scale. But often the companies that would realize the most gain from such projects are the least likely to participate. With small margins and already high-risk operations, these companies cannot afford to spend time or funds engaging in experimentation. The mutual need for commercial-scale pilot projects to demonstrate proof-of-concept in aquaculture offers fertile ground for collaborative models that can address industry limitations while exploiting the facilities and permitting structure that industry brings to the research table.

## BARRIERS

**The core challenges of a problem which, if successfully resolved, could pave the way for real progress. Barriers are not immutable conditions; they must be moveable and changeable.**

Hostile Public and Regulatory Environment. Formal regulation as well as public perception make starting and operating a farm challenging and costly. In some cases, regulations are so strict that new types of aquaculture are not permitted; in other cases, the lack of any regulation makes it impossible to grow and market a product. Meanwhile, the NIMBY attitude among home owners creates strong opposition to even low-profile coastal farms, while local fishing communities voice opposition out of fear that farms will limit access to fishing grounds or introduce disease. A reputation for pollution, environmental harm, and disease associated with certain types of aquaculture (mostly shrimp and salmon) taints public perception of all aquaculture, driving resistance to even the most environmentally friendly models.

Chokehold on Raw Materials. The resources required to establish and operate an aquaculture facility are controlled by a small number of source outlets or are simply scarce. For example, there are few marine fish hatcheries or kelp seed banks in the US to provide fingerlings or seed to developing farms. Likewise, vegetarian feed is limited and expensive. Aquaculture companies must compete with developers for high-demand coastal sites or appropriately zoned land-based facilities, both of which are hard to find. Depending on location, freshwater and energy may be expensive. Finally, technical expertise is lacking within the labor force, and compared with Asia in particular, labor costs are high.

Lack of Market Differentiation. A premium, high-value market for farmed fish does not yet exist. The most environmentally friendly species, such as shellfish and seaweeds, are relegated to niche markets; superior farmed fish (ecologically and quality-wise), simply by virtue of being farmed, cannot garner price premiums. That is in part due to the fact that buyers need volume and diversity of product, something a new farm pioneering a new method may not be able to provide. A new farmer introducing a new product to a supply chain steeped in tradition and regimented by tightly knit, trust-driven relationships presents another challenge. The result: the vast majority of farmed fish must compete in commodity markets, even if the farmed fish represents a higher-quality or more environmentally friendly product.

Underdeveloped Risk-Mitigation Strategies. By nature, fish farming is high risk. Seasons, storms, disease, parasites, and other biological or environmental factors all threaten the health (and bottom line) of an operation. Technical and mechanical failures are also common with any new production method. The more species and the more complex an operation, the more that can go wrong—and the harder it is to know what went wrong. As a relatively nascent industry, aquaculture has yet to adopt best practices in order to predictably reduce failure rates in biomass production. Without this refinement, the financial risk also remains high, deterring investors.

Immature Operational Models. Fish farming that is both ecologically and economically beneficial is too new to have well-tested and developed operational models. Farmers lack facilities and government support for large-scale demonstration projects; there are few trained technicians or farm managers with the know-how to run demonstration- or commercial-scale operations; and no processing infrastructure exists to deal with the large volume of product that a thriving, restorative aquaculture industry would produce. These factors—plus a history of failure and low return on investment—lead to a catch-22: investors are hesitant to enter the space and want to see a scalable demonstration model before committing, while farmers need investment in order to create such demonstration-scale projects.

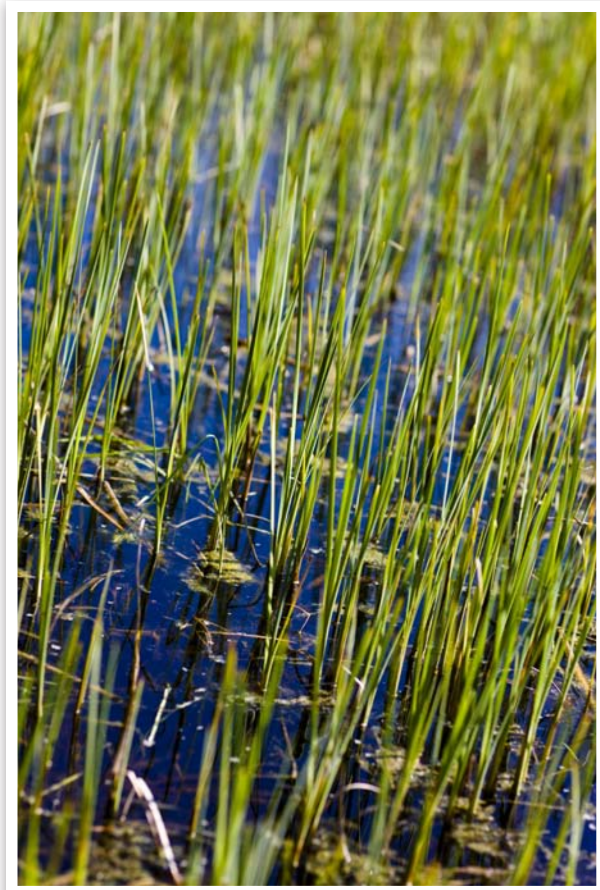
## DESIGN PRINCIPLES

**The underlying ideas or observations of a solution. These principles are not tools or solutions themselves, but ways to understand the mechanism a solution is addressing. They reveal truths about a system and insights to address long-standing stuck points.**

Focus on More Than Fish. Significant potential exists in reframing the aquaculture business model—in terms of revenue streams, product diversity, and marketing—to make a farm more economically resilient and scalable. This could mean turning waste into a high-value product, converting feed costs into for-profit feed products, or designing a fish farm as a water-treatment facility.

Draft Off-Aligned Stakeholders. Fish farms can progress faster by associating with others who demonstrate similar or overlapping values and who have already created robust markets, gained acceptance with the public, or developed relationships with regulators. Whether it is recruiting partnerships with local/slow-food organizations, aligning with wildlife conservation initiatives, or integrating product into existing markets, aquaculture entrepreneurs are finding ways to take advantage of the openings made available by others in order to leapfrog barriers to growth.

Pioneer Custom Solutions. Farmers relentlessly invent and test new ways around feed, fingerling, grow-out, market, and financing challenges. Take the fish farmer who deploys five different species to filter the water and preserve the environment or the recirculating aquaculture company that moved half their operations from tanks back into the ocean to make the system work. These solutions help individual farms survive; the challenge is how to share these insights and address the underlying systemic problems so that such tailor-made solutions don't continue to drain resources from companies.



Share Responsibility. Deep partnerships in scientific development, operations, or business management limit the direct risk to farmers and reduce the need for them to become jacks-of-all-trades. From long-term academic-business partnerships that share intellectual and financial capital, to cooperative processing models, to outsourcing the grow-out of fish to rural farmers, these mutually beneficial relationships accelerate start-up and growth of aquaculture enterprises.

Mimic the Ecosystem. Efficiency and opportunity exists in the elegant integration of species, production systems, and waste cycles of natural ecosystems. Models that use marketable species to filter water and waste, those that convert excess heat into fuel for growing fish, or those that grow fish that don't need to be fed—all of these leverage basic ecosystem principles such as zero waste and minimal inputs to boost their productivity and profitability.

# DISCOVERY MAP

*Each circle represents the number of solutions employing the given design principle to address the specific barrier.*

| DESIGN PRINCIPLES / BARRIERS | Hostile Public and Regulatory Environment | Chokehold on Raw Materials | Lack of Market Differentiation | Underdeveloped Risk-Mitigation Strategies | Immature Operational Models |
|---|---|---|---|---|---|
| Focus on More Than Fish | | 1 | 2 | 1 | 4 |
| Draft Off Aligned Stakeholders | 2 | 2 | 2 | 1 | 1 |
| Pioneer Custom Solutions | 1 | 6 | 1 | 1 | 2 |
| Share Responsibility | 1 | | | 2 | 2 |
| Mimic the Ecosystem | 5 | 5 | | 1 | |

# PROJECT PROFILES

## Design Principle 1:
## Focus on More Than Fish

*Diversify business activities and revenue streams to increase profitability and hedge risks.*

Harvest Food and Fisheries (HFF), LLC, Michigan, USA. HFF has found a way to simplify land-based fish farming: just grow fewer fish. In an effort to help save small family farms in Michigan, HFF has created a model whereby fish are the add-on. The income from fish sales is a bonus to the farm's revenue stream, not the main source of livelihood. Without the pressure to grow thousands of pounds of fish, farmers don't have to optimize their systems, which is where much of the complexity and failure in aquaculture happens. It's a lower risk model for the farmers, who can exploit the opportunity to whatever level they choose. (Barrier: Underdeveloped Risk-Mitigation Strategies)

Kingdom Aquaponics, New Hampshire, USA. Recirculating aquaculture systems (RAS) can mitigate many of the common environmental impacts associated with fish farming, but they are expensive to operate. By growing vegetables coupled with vegetarian fish, Kingdom Aquaponics reduces feed costs, eliminates dependence on unsustainable wild fish–based feed, and earns additional revenue from high-value herbs and greens. However, making a profit is still difficult, as the fish most suited for a vegetarian diet (in this case, tilapia) tend to garner low market prices. To cover the costs of operation as well as ongoing research and development, Kingdom Aquaponics developed and sells a high-quality fertilizer derived from fish waste. Through that product, Kingdom Aquaponics provides farmers with an alternative to chemical fertilizers, which serves to reduce the agricultural runoff harming coastal marine environments. (Barrier: Immature Operational Models)

Klein Eden Tropenhaus-am-Rennsteig, Upper Franconia, Germany. A research development site, this novel greenhouse utilizes the low-temperature waste heat from a nearby glassworks production to grow organic tropical and subtropical fruits and fish in colder climates. A visitor greenhouse—constructed specifically to cater to educational and ecotourism needs—brings revenue in addition to that from the sale of fish and tropical fruits. (Barrier: Immature Operational Models)

Mariculture Technologies International (MTI), Florida, USA. Commercial feed is expensive and is often over half the operating costs of a farm. In what originally started as a way to reduce his own costs and control quality of feed, MTI owner McMaster started to grow his own line of microorganisms, brine shrimp, and algae for his larval fish. He then turned this cost savings into revenue production by selling those products to other hatcheries, zoos, and aquariums around the country. The additional revenue supports the research and development of MTI's true focus: environmentally friendly and economically sustainable farming of pompano, a high-value fish in high demand. (Barrier: Chokehold on Raw Materials)

Oko Farms, New York, USA. Striving to be known as "the" fish farmers of Brooklyn, this early-stage venture is building a model based on diversified revenue streams in order to support their mission to bring healthy, local, environmentally friendly food to urban areas. By growing fast-turnover herbs and vegetables, Oko Farms can produce a constant revenue stream to support the grow-out of lower-value but highly sustainable tilapia. Farm tours to out-of-town visitors, locals, and classrooms generates additional revenue to keep the farm operating. (Barrier: Immature Operational Models)

Pemaquid Mussel Farms, Maine, USA. In 2007, four mussel farmers joined forces to purchase an at-sea processing barge, the Mumbles, and formed Pemaquid Mussel Farms. This vertically integrated company provides farmers with the reliable processing capacity they need for large-scale cultivation of mussels. Using only locally based materials for their ropes and rafts, Pemaquid Mussel Farms grows dense clusters of native mussels in relatively small areas compared to other forms of mussel farming. Seed is harvested from the wild, and there are no feed inputs. (Barrier: Immature Operational Models)

TwoXSea, California, USA. A unique seafood distribution company, TwoXSea has established a reputation among chefs and consumers for having the strictest sourcing standards for both environmental impact and quality. By prioritizing the taste, texture, health, safety, and overall quality of the product as much as the sustainability, TwoXSea is able to sell responsibly farmed seafood at wild-fish prices. (Barrier: Lack of Market Differentiation)

Veta La Palma, Seville, Spain. More than a fish farm, Veta La Palma is an example of a truly integrated operation that combines food production with ecosystem restoration and conservation. From the start, 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. Now a hub for both local and migrating birds, the wetland habitat created by Veta La Palma supports some of the largest flocks of flamingos in Europe. The naturally and semi-fed fishponds produce the high-quality fish, known for their taste and texture. This premium-level product, combined with the conservation and ecotourism opportunities the farm provides, elevates the Veta La Palma brand in the marketplace. (Barrier: Lack of Market Differentiation)

## Design Principle 2: Draft Off Aligned Stakeholders

*Take advantage of like-minded players who can surmount marketing, public acceptance, and regulatory hurdles.*

'Namgis Closed Containment Salmon Farm, SOS Marine Conservation, British Columbia, Canada. This project seeks to replace net-pen salmon farming with an environmentally friendly land-based alternative. With such a lofty goal, SOS Marine Conservation needed a partner that could provide community support, resources, and attract funding to the table. Although initially wary of involvement with any kind of salmon farming, The 'Namgis First Nations chief and council recognized the aligned values of this venture with their own long-term goals: to save their wild salmon and provide lasting economic opportunities to their community. They joined with SOS Marine Conservation to establish a partnership that attracted support from a diversified funder base (conservation and First Nation causes) and provided leadership, community engagement, and critically, the land necessary to launch a project of this scale. (Barrier: Chokehold on Raw Materials)

Aonori Aquafarms, LLC, Baja, Mexico. Developing a market for the enormous potential volume of ulva seaweed produced from its desert pond system presents a significant challenge for Aonori. Getting a fair price for the high-quality food that ulva offers is even more difficult. Instead of trying to create new markets, Aonori is working to integrate its seaweed product as a nutritious value add into one the highest volume markets already existing in Mexico: corn tortillas. By processing their ulva into a flour and incorporating that flour into corn tortillas, Aonori has shown it can increase the health benefits of corn tortillas, in terms of fiber, gylcemic index, and other critical factors. Drafting off public health concerns and existing markets, Aonori is positioning itself to tap into huge traditional market potential with their untraditional product. (Barrier: Immature Operational Models)

Culmárex, Spain. Growing certified organic sea bream and organic sea bass is one way Culmárex is attempting to distinguish itself in the marketplace. They are also experimenting with the addition of non-finfish species (e.g., scallops, mussels, and oysters) to boost revenue of their farm sites. Sea bream and sea bass are both higher-value species, but getting people to pay higher prices is not always easy. Culmárex is participating in the European Union project Oraqua, which seeks to establish scientific standards and push the growth of organic aquaculture in the EU with the hope that organic seafood will drive price premiums. Such standards would include strict, and greener, sourcing protocols for feed, disease control, and fingerling/seed sourcing. (Barrier: Lack of Market Differentiation)

Dr. Alejandro Buschmann, Universidad de Los Lagos, Chile. In Chile, there are few regulations, and thus no effort by industry or government to measure the full environmental impacts of salmon farms—or the potential benefits accrued by farming additional species (e.g., filter-feeders) as a way to minimize those impacts. Salmon farms are struggling to overcome a disease crisis and have neither the interest nor the resources to explore seaweed or shellfish as remediation tools. But there is some geographical overlap among existing salmon farms and mussel farms. Taking advantage of this arrangement, Dr. Buschmann is conducting studies to measure the effects of seaweed on the environment in and around salmon and mussel farms. Although not integrated into a single-farm system, the three species are colocated within small bay systems, and thus some effects can be determined. (Barrier: Underdeveloped Risk-Mitigation Strategies)

Global Aquaculture Alliance, Global. The Global Aquaculture Alliance was founded in response to growing pushback on the destructive and harmful practices that characterize many fish farms. As part of their commitment to promote the “good side” of aquaculture, the GAA developed a set of standards and a certification process to incentivize farms to engage in more environmentally friendly practices in return for recognition (and potentially better prices). The Best Aquaculture Practices (BAP) program builds on the growing popularity of sustainable seafood certification and eco-labeling programs in the hopes of satisfying consumer concerns for safer, healthier product. (Barrier: Hostile Public and Regulatory Environment)

**Meadows and More, New Jersey, USA.** Chefs are the key to opening up markets for new food products. Tama Masuoka relies on years of trusted relationships with top chefs to bring often-overlooked local plant species to the attention of New York's foodie community. Her success depends in large part on her attention to quality. When exploring locally grown seaweed as a potential resource for her chefs, Masuoka turned to research scientists to verify the safety, health, and sustainability of the species grown. By aligning herself with respected scientists working to develop seaweed aquaculture, Masuoka has positioned Long Island Sound seaweed as a safer, higher-quality alternative to imported seaweed. This approach gets better prices for local seaweed growers and puts seaweed on the menu of established restaurants in the tristate area. (Barrier: Lack of Market Differentiation)

**Oko Farms, New York, USA.** Oko Farms is on a mission to bring local, healthy food to needy communities in urban centers. By aligning with the Brooklyn Economic Development Corporation (BEDC), this new venture has set up a demonstration project on a vacant lot in the heart of the community. For Oko Farms, the secret to success started by embracing a farm site in what others considered a less-than-ideal location: next to a liquor store and across from a fried chicken joint. But the heavy local foot traffic allowed Oko farms to build a strong volunteer base that provided labor, lumber, and other resources. Because of lobbying from the BEDC, the City Parks and Recreation Department has now rezoned the lot as a park, allowing Oko Farms to lease the land for about $1 a year. (Barrier: Chokehold on Raw Materials)

**Olazul, Baja, Mexico.** Olazul knew that shrimp farming—reinvented as a sustainable business—could provide the job opportunities and additional income local fishing communities desperately needed. Unfortunately, local fishing communities hated shrimp farms and mistrusted NGOs. To overcome this barrier to engagement, Olazul decided to make itself valuable to the community by offering dive-safety trainings free of charge. (Commercial diving is one of the main employment opportunities in the region, but it is notorious for poor safety standards.) Olazul's classes slowly gained traction, with instructors becoming a trusted resource for divers. Olazul then hired divers from the local community and invited them to participate in the entire design and management process for the shrimp farm. By providing a quality service to the community, creating a unique codesign approach to farm development, and applying a business model that eventually hands ownership of the farm to the local community, Olazul has gained the full support of the local community and built a positive reputation across the region. (Barrier: Hostile Public and Regulatory Environment)

## Design Principle 3: Pioneer Custom Solutions

*Invent and test new methods and strategies to overcome challenges.*

**Aquacare Environment Inc., Washington, USA.** Finding and sourcing suitable materials for the appropriate land-based tank system can be overwhelming, not to mention expensive. Aquacare assists its fish-farmer clients by building tanks from prefabricated glass-coated steel panels that are mass-produced for other industries (e.g., agriculture). Panels are made from recycled material and are welded together to create different tank kits, which allows scaling for specific client needs while still providing the availability and reduced cost associated with a prefabricated product. (Barrier: Chokehold on Raw Materials)

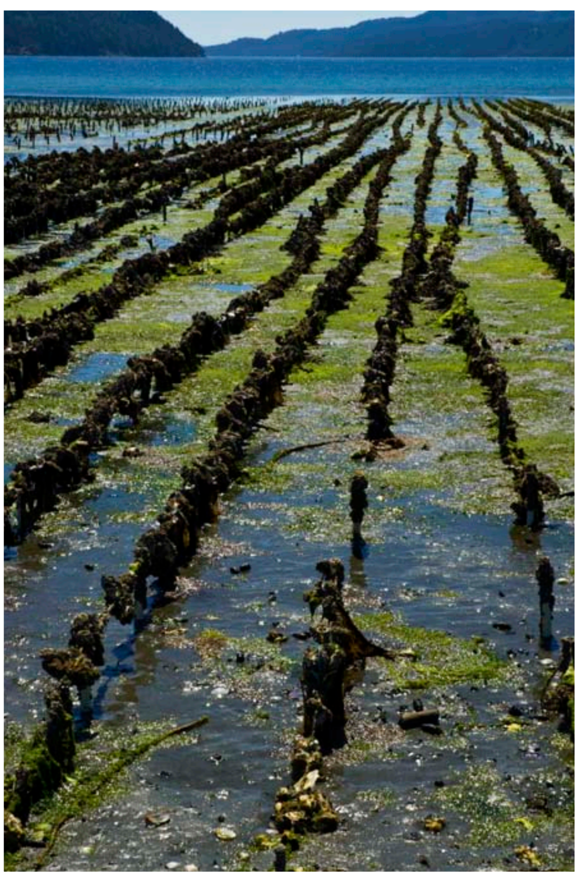
**Australis, Massachusetts, USA.** A pioneer in closed-containment aquaculture, Australis is the only vertically integrated barramundi-farming operation in the world. Australis has developed a hybrid closed-tank/net-pen farming operation in order to overcome the inherent cost barriers to growing larger fish in closed-containment systems. By using closed containment to raise advanced juveniles, they reduce the risk of escapees into the environment and produce a healthier fish to transport offshore; by growing out juveniles to adults at low densities in ocean pens, they minimize ecological impacts and improve profitability. (Barrier: Immature Operational Models)

**Cryoocyte, Massachusetts, USA.** Aquaculture production is limited by seasonal spawning in fish. Eggs are viable only for a short period of time after a spawn, so farms cannot spawn new "crops" year-round. Cryoocyte aims to change that through a patented freezing technology that will allow surplus eggs to be stored and then safely shipped to hatcheries around the world when needed. Based on technology originally developed for NASA, a frozen "egg bank" could open the market for year-round production of multiple species of fish, helping increase production and stabilize revenue streams for fish farmers. (Barrier: Chokehold on Raw Materials)

Charles Yarish, PhD, Connecticut, USA. Growing seaweed from seedlings is easy for a farmer; getting seaweed to produce seedlings is not. Extensive research into seaweed life cycles and development of reliable seed banks takes time, money, and know-how. In order to help launch a seaweed industry, Dr. Yarish at the University of Connecticut has built a seed bank/hatchery to provide high-quality, reliable seedlings to local seaweed farmers. (Barrier: Chokehold on Raw Materials)

Harvest Food and Fisheries (HFF), LLC, Michigan, USA. HFF has developed a business model built on distributed aquaculture production. HFF partners with small-scale growers, providing them with access to fingerlings as well as affordable feed, which is purchased in bulk at wholesale prices. HFF then buys the fish from the farmers at contracted prices and handles all processing, distribution, and marketing. Through this model, HFF provides a streamlined process for rural farmers to secure the resources they need at the front and back ends of a new aquaculture business. (Barrier: Immature Operational Models)

Inland Shrimp Company, Ohio, USA. Inland Shrimp Company aims to bring fresh, local saltwater shrimp to the Midwest. By utilizing a unique design for how the shrimp are physically housed within a recirculating system, they can grow ten times as many shrimp using two-thirds less space and two-thirds less water. By locating their facility centrally within developed urban areas near Cincinnati, they can provide fresh, high-quality shrimp to a large urban population. (Barrier: Chokehold on Raw Materials)



Kyuquot SEAfoods Ltd. (KSL), British Columbia, Canada. KSL has constructed a seafood production system that uses unique technology and design to grow multiple species while minimizing the farm-energy footprint and reducing harmful effects on the environment. Unlike many integrated multi-trophic aquaculture (IMTA) farms—where species are often added post hoc to a traditional fish farm (such as mussels added near salmon pens)—KSL kept all potential species in mind to optimize their farm design, including site selection and layout of rafts and cages. Instead of numerous boat trips to haul shellfish cages, they use solar-powered hydraulics to life cages, reducing pollution and costs from diesel expenses. (Rotating fish-cage technology allows cages to dry out and fouling organisms to fall off, without the need for harsh anti-fouling chemicals.) Building an IMTA facility from scratch has helped KSL increase efficiencies and reduce risks associated with introducing new species or equipment in a piecemeal fashion. (Barrier: Underdeveloped Risk-Mitigation Strategies)

Maine Sea Grant Extension, Maine, USA. Fishers are often the first to protest new aquaculture leases. Hostility stems from a range of concerns, from reduced access to fishing grounds to environmental impacts. But in Maine, changes in fishing regulations are leaving increasingly more fishers struggling to make a profit. In an effort to "marry the capture and culture of seafood," Maine Sea Grant Extension developed Aquaculture in Shared Waters, a hands-on training program to teach fishers how to farm shellfish and seaweeds. In addition to the training program, Sea Grant officers have developed informal community outreach efforts around sensitive issues, such as new lease applications as well as uncertainties with infrastructure and processing. Through these educational and informal sharing platforms, Maine Sea Grant has witnessed growing interest in aquaculture among fishers, and greater community support of established shellfish farms. (Barrier: Hostile Public and Regulatory Environment)

Menon International, California, USA. A sustainable alternative to commercial fish feed must be (a) independent of wild fishmeal and fish oil, yet still contain the omega-3s, fats, and protein content that give fish their health advantages and quality taste; (b) cost competitive with commodity fishmeal-based feeds; and (c) produced in large-enough volumes to feed a growing aquaculture industry. Menon International has developed a bacteria-based fermentation process that may meet all three criteria. Under the right conditions, bacteria in enormous tanks can convert organic waste—such as byproducts from sugar processing—into protein, fat, and vitamin-rich food pellets for fish. Because the process relies on microorganisms and low-value waste products, and because it can be conducted at large scales, the final product is proving cost competitive with commercial feeds. (Barrier: Chokehold on Raw Materials)

**TwoXSea, California, USA.** In their quest to provide a truly sustainable farmed fish, TwoXSea partnered with American Trout to develop a vegetarian feed that could produce good-tasting, healthy, sustainably farmed trout. They succeeded. McFarland Springs Trout are fed a 100% vegetarian diet, have higher omega-3 content than wild salmon, and hold up in taste tests with the toughest chefs. By developing their own feed source, TwoXSea helped create a supply of high-demand farmed trout for their distribution business. (Barrier: Chokehold on Raw Materials)

**Whole Foods, USA.** A reputation for high-quality, environmentally friendly, and safe food choices distinguishes Whole Foods in the marketplace for conscious consumers, and allows the company to charge premium prices. In order to keep their reputation intact, Whole Foods had to develop a way to carefully and consistently source aquaculture products. By hiring a full-time seafood standards expert, Whole Foods has invested in multi-stakeholder, multiyear processes to develop separate and specific sourcing criteria for finfish, shrimp, and mollusks. Through extensive research, site visits, and consultation—not to mention at significant financial cost—Whole Foods has preserved its high bar for sourcing and provided a market for aquaculture products that seek premium prices based on their high quality and superior environmental practices. (Barrier: Lack of Market Differentiation)

## Design Principle 4: Share Responsibility

*Build strategic partnerships to facilitate business development, distribute risk, and maximize potential for success.*

**Thierry Chopin, PhD, New Brunswick, Canada.** Although he was convinced that integrated multi-trophic aquaculture (IMTA) could provide enormous environmental and economic benefits, Dr. Chopin faced policies that prevented the simultaneous production of different species within close range. At the same time, his research to prove the benefits of IMTA was limited to the scale of his university lab. Partnering with Cooke Aquaculture, one of the largest salmon farming companies in the world, gave Dr. Chopin the industry buy-in and demonstration-scale facility he needed to convince the Canadian government to change their regulatory structures. Four years later, IMTA is permitted in certain coastal provinces. (Barrier: Hostile Public and Regulatory Environment)

**Increasing Industrial Resource Efficiency in European Mariculture (IDREEM), Europe.** The IDREEM research project pairs academic mentors with medium-size aquaculture businesses to help introduce integrated multi-trophic aquaculture (IMTA) to established fish farms. With a business-centered approach, academics help guide the process of integration, and conduct studies to monitor environmental impacts and fish health. Participating aquaculture companies receive research knowledge and financial support—50% of the cost of added species. Through this supportive structure, the IDREEM project is successfully developing models for how to efficiently and effectively expand IMTA throughout Europe, while minimizing risks incurred by farmers. (Barrier: Underdeveloped Risk-Mitigation Strategies)

**'Namgis Closed Containment Salmon Farm, British Columbia, Canada.** To develop a large-scale, commercial RAS salmon system, 'Namgis and their partner, SOS Marine Conservation, needed funds. They turned to Tides Canada, a nonprofit that "connects donors with doers" to launch a fund to support land-based salmon farming. The Salmon Aquaculture Innovation Fund became active in 2010. This fund provides support for 'Namgis and other projects, including marketing research, to help fuel growth of a land-based salmon farming industry that could bring an end to open net-pen farming and help save wild salmon. (Barrier: Immature Operational Models)

**Acadia Harvest Inc., Maine, USA.** Taking advantage of one of the few research centers with marine recirculating aquaculture technology, Acadia Harvest (formerly RAS Corp) moved on-site as a tenant at University of Maine's Center for Cooperative Aquaculture Research (CCAR) to develop new approaches to growing high-value fish in a zero-waste system. The expertise and facilities at CCAR have been instrumental to

Acadia Harvest's ability to successfully conduct (with minimal risk) the research and development required in order to scale. (Barrier: Underdeveloped Risk-Mitigation Strategies)

Thimble Island Oyster Co., Connecticut, USA. From the decks of industrial fishing fleets to farming shellfish in Long Island Sound, Thimble Island Oyster Co. founder Bren Smith recently turned to seaweed as the latest addition to his restorative farm model—growing species that help, rather than harm, the environment. Strands of kelp and mussels are grown along vertically hung ropes, dangling above oyster and clam cages below. Developing this 3-D aquaculture approach takes experimentation and funds. To secure both, Smith turned his farm into a research lab. Additional financial support through grants helps Smith optimize and test grow-out methods. He is also working with researchers to determine the effect of his 3-D farm on the local ecosystem. (Barrier: Immature Operational Models)

## Design Principle 5: Mimic the Ecosystem

*Leverage basic ecosystem principles such as zero waste and minimal inputs to boost productivity and profitability.*

Aonori Aquafarms, LLC. Baja, Mexico. Aonori Aquafarms turns the coastal Baja desert into a verdant food production system. Long rectangular ponds filled with saltwater pumped from the nearby Pacific are covered by living mats of bright green ulva—a native seaweed. The seaweed serves as a protective cover—and an all-you-can-eat buffet—for native brown shrimp, which thrive below. The ulva shields shrimp from changes in water temperature, produces oxygen within the ponds, and provides a high-nutrient diet, which improves shrimp health. Aonori is the only farm to successfully grow this most popular wild-caught shrimp species; their unique cocultivation system produces disease-free, high-quality shrimp and seaweed-based products. They use 5% of the energy consumed by equivalent shrimp farms, without any freshwater input in a nonfertile desert habitat. (Barrier: Chokehold on Raw Materials)

Cooke Aquaculture, New Brunswick, Canada. Cooke Aquaculture, a family-run company, is the world's largest fully integrated salmon farming company, with operations in Canada, Chile, the US, and Spain. In a move unique among large-scale commercial salmon operations, the company is engaged in efforts to test the effects of mussel and seaweed farming as a nutrient-mitigation strategy to meet increasingly stringent regulations. By trialing an environmentally friendly approach to waste management, Cooke sets itself apart from other competitors in the market and helps build a reputation as a "more sustainable" company. (Barrier: Hostile Public and Regulatory Environment)

Charles Yarish, PhD, New Haven, CT. Long Island Sound faces a problem of excessive nutrients, a form of water pollution. Long Island Sound fishers face the problem of too few fish and lobsters. Dr. Yarish believes seaweed-shellfish farming could solve both. Seaweeds absorb inorganic nutrients from the water column, while shellfish filter out the organic nutrients. Together, they offer a chance to grow food while cleaning up the ocean. By emphasizing the benefits of seaweed-shellfish farming as a nutrient management tool, Yarish garnered critical support from coastal managers for new legislation that governs seaweed production in Connecticut waters (shellfish laws were already in place). The bill, which Yarish helped write, passed in July 2013 and now serves as a model for other states. (Barrier: Hostile Public and Regulatory Environment)

Green Desert Project, Middle East. Still in concept phase, the Green Desert Project is the brainchild of the recently deceased researcher Guillermo Garcia-Blairsy Reina. It envisions a massive integrated multi-trophic aquaculture (IMTA) system to green the Sahara desert by using natural processes to convert saltwater into freshwater. Seawater would be gravity-fed from the coast to subsea-level dry-lake beds to successively grow fish, crustaceans, mollusks, seaweed, fruits, and vegetables, with evaporated freshwater recapture watering freshwater plants. Salt will also be collected as an end product. (Barrier: Chokehold on Raw Materials)

Klein Eden Tropenhaus-am-Rennsteig, Upper Franconia, Germany. This novel greenhouse employs several technological advancements to capture low-temperature waste heat from a nearby glass manufacturer and repurpose it for growing tropical fruits and fish in colder northern climes. Specialized glass, rainwater recapture, and gabled-ceiling design all work to maximize freshwater and light, while minimizing heat loss. Through tight coupling of fish and fruits, tropical plants can flourish under lower light levels (just as they do in a rainforest) in return for being bathed in nutrient-rich waters, thanks to the waste from fish. (Barrier: Chokehold on Raw Materials)

**Kyuquot SEAfoods Ltd. (KSL), British Columbia, Canada.** Kyuquot SEAfoods is the first licensed SEA-farm in Canada. SEA stands for sustainable ecological aquaculture, which is a polyculture approach to growing seafood. Organic and inorganic wastes from the fish, which are the only fed component of the system, filter down to other living organisms that are placed below and around the floating fish farm. These species naturally use the waste materials as food. Producing fish, seaweed, shellfish, sea urchins and sea cucumbers, KSL—like nature—makes sure nothing goes to waste. The different species all utilize different types of nutrients (solid particles, dissolved, organic, inorganic), maximizing the productivity of the farm while minimizing costs, space, waste, and energy footprint. (Barrier: Chokehold on Raw Materials)

**Mariculture Technologies International (MTI), Florida, USA.** Pompano is a high-value marine fish that eats mostly crustaceans and shellfish. MTI's pond-reared pompano graze on a native mussel that was introduced to the ponds through the action of a hurricane. Recognizing the mussels as a boon rather than a nuisance, MTI left them to flourish. From this small colony, a thriving population now serves as the preferred prey of the pompano. To round out the fishes' diet, MTI has seeded the ponds with native glass shrimp—which, like the mussels, thrive in the ponds. Natural blooms of algae feed the shrimp and mussels, which feed the pompano, reducing external feed inputs on the farm. (Barrier: Chokehold on Raw Materials)

**Acadia Harvest, Inc., Maine, USA.** Black sea bass and yellowtail are high-value marine fish. But growing marine fish in net pens raises concerns over environmental pollution and escapees; growing marine fish on land presents many other challenges, especially the salt-laden waste material. Acadia Harvest (formerly RAS Corp) has developed a unique biological filtering system—including the use of worms coupled with other species—to remove and repurpose fish waste in order to create a near zero-waste recirculating aquaculture system. These advancements, along with new feed formulations and plant-design innovations, could distinguish Acadia Harvest products as some of the most energy-efficient, green, and high-quality marine fish on the menu. (Barrier: Hostile Public and Regulatory Environment)

**Sunrise Capital, Hawaii, USA.** Fish farming in Hawaii is particularly challenging, due to strict environmental wastewater regulations. Sunrise Capital has designed a system that produces very little effluent with minimal waste product, all using natural processes. Utilizing the naturally occurring phytoplankton present in the cold, deep, nutrient-rich waters off the island of Kauai, Sunrise Capital grows shrimp in large round ponds that encourage algal growth. The algae oxygenate the water and serve as a food source for the shrimp, which are also minimally supplemented by a soy-based feed. The algae and nutrients in the water also sustain filter-feeding clams, which help keep the ponds clean, reducing the need for water replacement and discharge. Finally, native saltwater tilapia are reared in sandy outflow ditches, where they act as natural biofilters, consuming the vast majority of organic material in the wastewater. (Barrier: Hostile Public and Regulatory Environment)

**Thimble Island Oyster Co., Connecticut, USA.** Oyster farming on its own is a risky business, with a relatively long grow-out period (up to a year or more)—and an entire year's crop can be wiped out in a matter of days by disease or a storm. To help diversify product and revenue streams, and thus stabilize income, Thimble Island Oyster Co. owner Bren Smith added seaweeds to his product list. Seaweed and shellfish are the perfect complement: they grow easily without external feed inputs, drawing their sustenance from the nutrients in the water. With little additional technology and no feed costs, this combination provides Thimble Island Oyster Co. with stable revenue and natural insurance, while helping to clean the local waters. (Barrier: Underdeveloped Risk-Mitigation Strategies)

**Veta La Palma, Seville, Spain.** The poster child for ecologically friendly aquaculture, Veta La Palma harnesses the natural flows and nutrients of a wetland to grow fish. Located within the Doñana Biosphere Reserve, the family-run farm had to accommodate strict conservation and regulatory requirements as they sought to transform a failed cattle ranch back into the wetland it once was. The pumping system for the enormous ponds works with the natural tidal flows and allows for thriving populations of native crustaceans, fish, and birds. Over six species of fish (sea bream, sea bass, meager, mullets, sole, and eels), as well as shrimp, feast off the natural food supply. A select few species are provided a supplementary diet, creating an aquaculture model that combines extensive with semi-intensive approaches. The result is high-quality, delicious, fresh fish raised in a restored wetland that provides habitat to native species and jobs for local residents. (Barrier: Hostile Public and Regulatory Environment)

## SYSTEM INSIGHTS

The Discovery Map is a subjective qualitative tool that helps identify and illustrate how forces of change are already at work within a system. It shows where innovators are finding traction, as well as where they are falling short or overlooking critical aspects of a given complex challenge. Often, the map reveals areas where collaboration might be necessary or useful for the system to overcome particular barriers. Mapping is the starting place of critical conversations about where to focus energy, effort, and investment in innovation.

Here are our insights and interpretations of what the map shows about the state of aquaculture innovation and scaling potential:

### 1. Aquaculture is rife with individual innovations, none of which alone are capable of systems-level problem solving.

Aquaculture entrepreneurs are relentless innovators, constantly overcoming diverse challenges in order to make their operations work. Unfortunately, the majority of problems they solve are not unique to their farms. The problems are systems-level issues that are impossible for individual players to resolve at scale. For example, while one farm might successfully battle to get its products into a small local grocery, that victory doesn't move the needle on market access for farmed fish as a whole; it doesn't build systems that resolve that problem for more than one player. Scaling individual solutions to systems-level interventions requires collaboration and the intent to design for groups and aggregated transactions. That intervention also requires different insights, different strategies, and a different level of investment than one system participant is positioned to supply.

"Much more applied, cooperative experimentation has to happen for aquaculture to develop...We need less of years-of-farmer-trial-and-error. We need cooperative, multi-institutional, multi-disciplinary team science."

*—Barry Costa-Pierce, PhD, Director*
*Marine Science Center, University of New England*

### 2. The very custom solutions that farmers invent often have the unintended consequence of making their businesses harder and riskier to operate.

Hence, the "Pioneer Custom Solutions" design principle wound up in many cases being a case of swapping, for example, the "frying pan" of undiversified revenue streams for the "fire" of integrated species complexity. Not enough collective effort or knowledge has emerged to create standards and best practices that save farmers from this innovation doom loop.

"Salmon farmers—they're really good at doing salmon and do it very well. They are brilliant at what they do, but they don't want to do anything else that might distract them from their core business."

*–Adam Hughes, PhD, Principle Investigator in Sustainable Aquaculture*
*Scottish Association for Marine Science*

### 3. Constant attention to daily needs prevents the development of long-term strategies.

The bulk of innovators' attention (15 solutions) targets the chokehold on raw materials and resolving the immature operational models. This emphasis makes sense, as these are the primary hurdles fish farmers need to tackle simply to enter and remain in business. Day-to-day challenges don't particularly require forward thinking or system alignment. The least amount of energy (four solutions) was invested in market differentiation. This pattern tracks to what we heard from interviewees about the lack of marketing skills present in the industry and the difficulty of overcoming common negative perceptions about farmed fish. It may also reflect a bafflement—also present the wild-fish sector—about how to differentiate fish in ways that consumers value, as opposed to ways that environmentalists value.

Popularizing the good health effects of good environmental practices within fish farming will remain an uphill battle as long as the simple "organic" label cannot be applied to fish in the US. That said, the story of integrated multi-trophic aquaculture (IMTA) as a way to both feed fish with minimal inputs and remove waste products naturally has the potential to develop into a compelling pitch with a "small and elegant" versus "factory farm" positioning that has worked for farmed meat products. Interestingly, despite the richness of the IMTA story, we found only a single fish farm that was successfully using the novelty and ecological friendliness of their system to build market differentiation.

"It was a really good lesson. Regardless of money, time, effort, and having pioneers to do it and who succeeded...it didn't work because of basic connections to a fuel/energy system that wasn't sustainable."

*—Michael McMaster, President*
*Maritime Technology International*

### 4. Collaboration is key.

Two design principles involved collaboration: Draft Off-Aligned Stakeholders and Share Responsibility. The former seems most effective for overcoming start-up barriers (e.g., building on groundwork laid by others), while the latter appears to be useful for distributing costs and risks when scaling. The examples in the related profiles can be compelling illustrations for other groups to consider collaboration.

"We would be lost without Nick Brown and his team [at CCAR]. We could not afford to build and develop a facility like that. That is why we laud them long and loud. CCAR has benefited from lots of federal and state money, and they have incubated other businesses in the past. Our experience with them is awesome. If we succeed it will be because of their help."

*—Ed Robinson, Chief Business Officer*
*Acadia Harvest, Inc.*

### 5. Risk management is overwhelmingly poorly addressed.

Ecologically sound aquaculture is a start-up industry plagued by nascent models, sparse infrastructure, unproven methodology, small margins, weak market demand, and unfamiliar products. That's not the pedigree of an investible business. The few entrepreneurs who have secured investments have done so by minimizing perceived risk through product diversification and partnerships. We did not see any significant involvement from the financial sector in either creating risk-mitigation products or offering loans that provide risk-mitigation incentives. That lack of participation is a clear opening to explore in future phases of work. It's not the domain of farmers to design financial instruments to make their work more investable. We need other players addressing this part of the conundrum.

"Financial barriers are real. People are worried about being pioneers—they're the ones to get the arrows stuck in their backs. They'd rather wait and see who is making money."

*—João Ferreira, PhD*
*Universidade Nova de Lisboa*

"In science, innovation is siloed, and the same is true with the corporate world…people don't share. But if people are seeing a profitable business model that can help change the world in a way we all agree needs to happen, and fisher communities are asking for it, that organizes people and gets them excited and engaged in innovating with a mentality of sharing and an open posture. That is powerful."

*—Beau Perry, Executive Director*
*Olazul*

# OPPORTUNITY AREAS

Based on the Discovery Map and the system insights, we looked for the most pressing challenges and the changes that might yield the greatest impact. We returned to our core question and brainstormed ideas—some mundane and obvious, others more far reaching and unexpected—that could help foster a business landscape where ecologically sound and innovative aquaculture can actually scale and thrive. We settled on five broad opportunity areas, summarized in the following pages. In each summary we describe the contextual landscape of the core challenge being addressed, and then consider three essential questions: What forces could push this opportunity forward? What are the sources of pushback? And what is the potential for this opportunity to gain traction if the challenge is met with innovation, public and organizational support, and adequate resources?

## OPPORTUNITY 1

### Enable businesses to share knowledge and information in order to lower the difficulty of farming and allow time and attention for more creative and growth-oriented strategies.

Landscape: Fish farmers attempting to develop ecologically sound methods of aquaculture tend to be stranded innovators. Outside of a few small programs, there is no centralized hub where practitioners can access advice or information about best practices, running a business, securing insurance, funding, marketing expertise, or troubleshooting. As a result, fish-farming novices are continually reinventing wheels, repeating mistakes, and suffering the same inefficiencies as their predecessors. Because knowledge and information are not shared, some of the competitive advantage in aquaculture is simply competency, which lowers the bar for the whole industry. The lack of transparency—as well as the nascence of innovative aquaculture—is a red flag for investors, who are not only unfamiliar with how to evaluate and set expectations for returns, but are also understandably gun-shy based on the historically dismal track record of many aquaculture companies. A knowledge platform could solve many of these issues. (By "platform," we do not necessarily mean an online tool. A platform could comprise a membership group, conferences, in-the-field technology, or multiple other methods of knowledge exchange. We are identifying the need for this exchange, not the specific method most appropriate for this target audience.)

The Push: A platform for sharing expertise, experiences, successes, and mistakes would benefit individual fish farmers and the industry as a whole. Practitioners would be armed with a tool for making appropriate business decisions when faced with given conditions and limitations. Increased knowledge transfer would accelerate the development and implementation of best practices, reduce the need for constant experimentation and wheel reinvention, improve efficiencies and cut costs. Such a resource could streamline the process for starting and operating a farm, as well as reduce risk by providing basic knowledge about contingency planning and available financing. A similar platform could serve to educate the investor community, providing reliable information upon which to base financing decisions.

The Pushback: Innovative fish farmers often mistakenly assume any knowledge they have is protectable intellectual property and therefore may be loath to share it. They also may fear that their generosity might transfer advantage to a competitor. A natural human resistance to disclosing mistakes and admitting failure is a possible deterrent to participation as well.

The Potential: Strategic information sharing could free up direct resources (e.g., time, capital, knowledge), reduce start-up costs, accelerate innovation, and increase the success and scalability of ecologically sound aquaculture.

"My main role to farmers is as propagandist. Farmers are told about what we do, and the technology transfers happen between farms. The farmers talk to each other, to be honest, and they share. Our recirculation system had small test areas, and a farm nearby heard about our small study and wanted to see if it could apply."

*—John Bolton, PhD*
*University of Cape Town*

## OPPORTUNITY 2

### Engage the insurance and financial sectors to develop better strategies for risk mitigation and improved dialogue for how fish farming can lower its risk profile.

Landscape: Aquaculture that is both ecologically sound and commercially viable is still in its infancy, and lack of capital is impeding growth. One of the impasses to investment is risk, both real and perceived. Farmers often omit risk mitigation as a problem to tackle; they might come up with an operation that functions, but it may not have back-up systems, tank segregation, or contamination plans that could help meet a potential investor's risk-management criteria. Additionally, few investors understand aquaculture well enough to evaluate risk accurately. While that may lead some investors to avoid all opportunity, the very real opposite scenario is equally damaging: ill-informed investors taking chances on faulty designs or poorly managed projects perpetuate the perception that aquaculture is a bad investment. Finally, the insurance industry, which has plenty of crop insurance available for farmers of plants, has to date steered clear of particularly the small and local models for aquaculture. Helping insurers find the opportunity in this market could also contribute to investment readiness.

The Push: Financial tools and instruments (such as insurance) can be designed to reward better risk planning by farmers and to stabilize cash flow, therefore making the sector a more appealing investment. Creating these tools requires a dialogue between farmers and financiers. The dialogue can also benefit from participation from impact investors and possibly philanthropy to absorb some of the risk through loan guarantees or other support.

The Pushback: The biggest risk factors remain imbedded in the farming process and the fragility of the nature of the crop. Financial instruments can't change the basic biology of the challenge.

The Potential: An influx of financing and insurance support designated for ecologically sound aquaculture could unleash a flurry of innovation, provide practitioners with the space to experiment on larger scales, and accelerate the growth of this segment of the industry.

"The number one hurdle holding back development of large scale sustainable aquaculture in the USA is access to finance. That is the hold back. We see Chinese companies hiring Western consultants to study our systems, and then they go and build them themselves. They go to incredible scale. But in the USA, and to a lesser extent in Canada (though they have a little more government support), that access to finance is a real dilemma."

*—Henning Gatz, Owner*
*Aquacare Environment Inc.*

## OPPORTUNITY 3

### Beat the bad reputation of farmed fish.

Landscape: The negative impacts of aquaculture tend to be emphasized by environmental advocacy organizations and hence the US media, giving the false impression that farmed fish is always inferior healthwise and more environmentally destructive than other sources of animal protein. Even shrewd consumers concerned with how and where food is produced apply that assumption to all forms of aquaculture without regard to production method. As a result, the high-end consumer base most likely to drive the market for high-quality, low-impact, local, farm-raised fish opposes it on principle. Perpetuating the problem is the fact that, unlike grass-fed beef, organic chicken, or pastured eggs, there is no market differentiation for fish raised using ecologically sound methods. Thus, innovative fish farmers face the uphill battle of building demand for a product that has a relatively high market price and a bad reputation.

The Push: Building positive branding around ecologically sound aquaculture could both free it from the negative stereotype and tap the growing consumer base focused on high-quality, fresh, local, healthy animal protein. By presenting products in terms chefs and foodies get excited about—flavor, texture, versatility, novelty, and reliability—innovative aquaculture could harness the enthusiasm of those most willing to experiment and most eager to be seen as driving trends. Incorporating ecotourism, community enhancement, and art could also reinvent the face of aquaculture. With the right marketing strategy, the array of benefits that ecologically sound aquaculture can offer should appeal to—and garner support from—a number of diverse interest groups.

The Pushback: Aquaculture currently lacks the cohesion, money, and lobbying power enjoyed by other industries. Thus, launching a national campaign to rebrand aquaculture the way the beef, pork, and egg industries have done could be quite challenging. In addition, the NGO community—a natural ally—may be the toughest to get on board, given their history of extreme resistance to traditional aquaculture endeavors.

The Potential: A successful rebranding campaign could grow demand enough to make ecologically sound aquaculture commercially scalable and investible.

"We always viewed it as the story. We have to be effective messengers to help the public understand that smart aquaculture—aquaculture done well—is a critical part of a secure and sustainable food system, which also promotes human health. The most important thing we do is marketing—creating demand for the products which help to realize that vision."

*—Josh Goldman, Co-founder & CEO*
*Australis*

## OPPORTUNITY 4

### Build distribution networks that help producers access bigger markets.

Landscape: Seafood buyers make purchasing decisions based on consistency, quality, quantity, and price. While most ecologically sound fish farms can deliver consistency and quality, many are limited by land area, lease size, or tank capacity, and they produce volumes too low to be competitive. Because the coordinated logistics to source product from multiple distributed farms are lacking, poor market access continues to be a barrier to new aquaculture start-ups.

The Push: The development of distribution networks for small-scale fish farmers would allow them to sell into existing markets at fair prices, without having to spend their own scarce time or financial resources building a customer base. Those networks could include product aggregation, forward contracting, or community-supported fishery models, all of which are currently utilized for wild fish. The addition of traceability and branding could further drive demand and potentially garner a price premium.

The Pushback: Coordinating distribution of farms raising different species with different grow-out cycles is complex, and building the infrastructure (e.g., delivery trucks, cold storage, processing facilities) and traceability technology for such disperse production systems will be a challenge.

The Potential: Fish farmers across a range of scales could add their production to an established, traceable value chain to deliver fresh, local, healthy, environmentally friendly products to diverse end users.

"Unless you're pushing to maximize profits by densely populating your system, growing the fish is not your biggest challenge. The challenges for yellow perch are getting fingerlings when you need them and finding a market that will pay premium prices for small quantities. Those are the tough issues."

*—Diane Durance, Founder & CEO*
*Harvest Food and Fisheries*

## OPPORTUNITY 5

### Develop secure pipelines for raw materials and operational know-how.

The Landscape: In their efforts to achieve ecologically sound models of aquaculture, many fish farmers are faced with underdeveloped sources for raw materials and a scarcity of experienced practitioners to manage operations. As self-reliant, serial innovators, most fill those gaps themselves: they develop hatcheries to secure a reliable, healthy supply of fingerlings or seed; formulate their own fishmeal-free feed; become expert water chemists, waste managers, and civil engineers, mastering pipes, pumps, and energy use; and find markets for their fish. That jack-of-all-trades strategy is taxing, inefficient, and risky—for the farm and the farmer alike. Vertical integration can be a good business strategy, but building the entire value chain into a farm's operations is a recipe for failure.

The Push: In order to succeed as a viable alternative to conventional fish farming, ecological breakthrough aquaculture needs a mature support-service industry to provide a reliable supply of farm inputs (e.g., equipment, feed, fingerlings), a pool of experienced practitioners with the intellectual and technical capacity to manage daily farm operations, and a cadre of experts in specialized areas (e.g., water chemistry, animal nutrition, marketing) for outsourcing troubleshooting. That could mean scaling and replicating existing services, creating brand-new businesses to meet industry needs, or simply developing a platform to match farmers with support-service providers.

The Pushback: Building a support-service industry takes time, and many of the fish farmers are forced into these roles and side projects because they cannot afford to wait. Also, depending on how the industry is structured, paying for these services could increase operations costs for an already expensive endeavor.

The Potential: A fully functioning support-service industry for breakthrough aquaculture would reduce inefficiencies and risk, release innovators from the burden of constant troubleshooting, and create a more mature value chain and a more attractive industry for investors.

"When considering growing sea vegetables, a few questions remain: Where will it be grown? Where will a grower land it? Will it be trucked over the road wet or will it be dried? And if so, where? Who will buy it? How will it be processed? The infrastructure necessary to support the growth of this emerging industry has a few challenges to sort out."

*—Hugh Cowperthwaite, Fisheries Project Director*
*Coastal Enterprises Inc.*

"Integration to me, and to lots of others in the state, doesn't just deal with physical growing of fish next to plants. It is really the integration of a seafood production method into traditional harvesting, inclusive of location, time, markets, infrastructure and, most importantly, identity and social-cultural aspects."

*—Dana Morse, Marine Extension Associate*
*Maine Sea Grant*

# NEXT STEPS

Our goals for this report go beyond merely offering a field survey. We designed our process to support action, and the opportunities we've named represent a road map for next steps in fostering a business landscape where ecologically sound and innovative aquaculture can actually scale and thrive.

The diversity of innovation we identified can be viewed from two different angles, both of which offer hope and opportunity, but also involve risk and the need for trusted partnerships. On one hand, multiple models offering various approaches to growing ecologically sound—and even restorative—seafood provide for a potentially more robust and resilient industry in the long term. These models lay fertile ground for continued experimentation and refinement of ideas. However, unless those innovations can be coordinated, supported, and scaled, the dispersed and disparate state of affairs will continue to sap limited resources and prevent the establishment of a truly thriving aquaculture industry.

The overarching insight this report supports is that the system's current need is not to focus investment and support on any one farm model. Instead, the need is to help the landscape evolve to support all approaches. That means looking to the industries that supply raw materials to farms, the sectors that finance them, and the buyers who purchase from them as potential partners in building the opportunity for breakthrough aquaculture to thrive.

It is worth noting that the opportunities identified represent areas for exploration. The specific ideas we have suggested are merely examples of how various areas might be targeted; they are by no means the only options. The narrowing of one or more of these opportunities into viable solutions, with outcomes and goals, is the next step in this discovery process. We hope that this report will spark fruitful and impassioned discussions in the field about the opportunities outlined here, and also about this approach to effecting change. Ultimately, any insights we have discovered here can be traced back to the hard work and expertise of those involved in on-the-ground restoration. The hallmarks of their approach—noticing what's working and why, building on experience, and moving from a standpoint of what is possible (rather than what is broken)—could prove transformative for the industry in very practical terms.

We look forward to convening and shepherding this ecosystem of players, in partnership with our sponsors as well as others in the field.

“A diversified industry away from finfish monoculture, towards a more cyclic approach at different trophic levels, and more product for less impact, is what success will look like.”

*—Adam Hughes, PhD*

*Scottish Association for Marine Science*

# APPENDICES

## Appendix I • Regulatory Climate Affecting Aquaculture in the US

### FEDERAL AGENCIES AND REGULATIONS

A combination of federal and state agencies oversee aquaculture in the United States. At the federal level, six agencies (representing five different US Departments) exercise some level of jurisdiction relevant to aquaculture:

- US Department of Agriculture (USDA)
- US Environmental Protection Agency (EPA) within the US Department of the Interior
- National Oceanic and Atmospheric Administration (NOAA) within the US Department of Commerce
- US Fish and Wildlife Service (USFWS) within the US Department of the Interior
- Food and Drug Administration (FDA) within the US Department of Health and Human Services
- US Army Corps of Engineers (USACE) within the Department of Defense

Selected key federal policies, plans, and regulations are outlined below.

**US Department of Commerce Aquaculture Policy (June 2011).** This brief document states that it is the policy of the Department of Commerce (DOC) to encourage and foster innovation and aquaculture development in the US in an environmentally sustainable manner while creating jobs and economic opportunity. In implementing this policy, the DOC will work in partnership with a range of other federal and state agencies, provide technical assistance, and enhance and accelerate research and pilots.

**Magnuson-Stevens Fishery Conservation and Management Act.** This act grants authority to NOAA's National Marine Fisheries Service over aquaculture development within the nation's exclusive economic zone (EEZ), which stretches 200 miles off the coast.

**NOAA Marine Aquaculture Policy (June 2011).** Although "marine" is in its title, this policy applies to all of NOAA's aquaculture authorities and activities, and simply outlines NOAA's aquaculture priorities with regards to sustainability, science and research, regulation, innovation, partnerships and outreach, and international cooperation.

**National Offshore Aquaculture Act of 2007.** Currently, there are no commercial finfish or shellfish aquaculture operations in US federal waters. This act provides authority to the Secretary of Commerce for the establishment and implementation of a regulatory system for offshore aquaculture in the US Exclusive Economic Zone. NOAA is the lead authority.

**Fisheries Management Plan for Offshore Aquaculture in the Gulf of Mexico (2009).** The first fishery management plan for offshore aquaculture based on the National Offshore Aquaculture Act of 2007 was submitted for the Gulf of Mexico in 2009 and is still under review. NOAA may be able to begin receiving permit applications in 2014. The plan includes requirements related to environmental impact monitoring and assessment, recordkeeping, reporting, and operational requirements. It prohibits the farming of nonnative, genetically modified, or transgenic species.

**The Rivers and Harbors Act of 1899.** This act establishes US Army Corps of Engineers permit requirements to prevent unauthorized obstruction or alteration of any navigable water in the US. Alteration of wetlands can fall under this act, and thus permits from the Army Corps are applicable to fish farmers producing in wetland areas.

**The Clean Water Act (1977).** This act authorizes the Army Corps of Engineers to issue permits for discharge of dredged or fill materials into US waters (relevant to shellfish growers), as well as for activities "that have minimal individual and cumulative adverse environmental effects." It also grants jurisdiction to the EPA to require point source pollution discharge permits from aquaculture operations under the National Pollution Discharge Elimination System.

# REGULATIONS AND PERMITTING REQUIREMENTS BY KEY STATES

The process of obtaining permits from the multitude of state and federal agencies exercising authority over aquaculture-related activities is daunting. Below we outline the regulatory climates for a few selected states (focusing on the Gulf of Mexico) in order to provide a snapshot of the types of state policies currently governing aquaculture. Any new or existing fish farm must comply with all applicable policies at both the federal and state levels.

## Alabama

The Alabama Department of Environmental Management (ADEM) is the primary agency responsible for regulations and permitting that affect aquaculture in the state, and is the first point of contact for a fish farmer seeking to site an operation in Alabama and wishing to clarify permitting and licensing requirements. ADEM has a Coastal Area Management Program responsible for permitting, monitoring, and enforcement activities in the coastal zone. ADEM also coordinates most EPA programs in the state and administers water discharge permits through the National Pollutant Discharge Elimination System. Additionally, the Alabama Department of Conservation and Natural Resources (DCNR) has authority over the leasing of state lands. However, a leasing program specific to aquaculture does not currently exist.

More than 20 species are currently produced in Alabama, including channel catfish, tilapia, crawfish, and freshwater prawns. The Alabama Department of Natural Resources authorizes which exotic species are allowed to be produced in aquaculture operations in the state. Currently it appears that the only exotic species permitted are red claw crawfish, tilapia, and freshwater prawns.

**Key link for Alabama:**

- Aquaculture Permitting Guide for Coastal Alabama

  http://nsgl.gso.uri.edu/masgc/masgch97001.pdf

## Florida

In Florida, aquaculture is considered agriculture and falls under the jurisdiction of the Florida Department of Agriculture and Consumer Services, which has a Division of Aquaculture. There is also an advisory council, called the Aquaculture Review Council, as well as an Aquaculture Interagency Coordinating Council. Although Florida has made an effort to streamline the permitting process for commercial aquaculture operation, farms still need to obtain a number of relevant permits from different agencies:

Certificate of registration (Florida Department of Agriculture and Consumer Services)

- Approval of collection of brood stock from natural populations (Fish and Wildlife Conservation Commission)
- Permits related to solid and hazardous waste disposal, worker safety, and zoning considerations (Florida Department of Environmental Protection)
- Surface water discharge permit (Florida Department of Environmental Protection)
- National Pollution Discharge Elimination Permit (Florida Department of Environmental Protection)
- Water or Consumptive Use Permit (Florida Department of Environmental Protection)
- Florida sovereign land use permit, or a sovereignty submerged land and water column lease (Florida Department of Environmental Protection)

Aquaculture in Florida is governed by the following key regulations, policies, and plans:

- Florida Aquaculture Policy Act: Chapter 597
- Aquaculture Best Management Practices Rule: Chapter 5L-3
- The Florida Aquaculture Plan for Fiscal Year 2014–2015

Florida permits the cultivation of a range of native and nonnative species including, but not limited to, clams, shrimp, crayfish, tilapia, catfish, bass, sturgeon, bream, carp, cobia, pompano, redfish, sunfish, and trout.

**Key links for Florida:**

- Florida Department of Agriculture and Consumer Services: Division of Aquaculture

  http://www.freshfromflorida.com/Divisions-Offices/Aquaculture

- Florida Department of Agriculture and Consumer Services: Aquaculture Leasing

  http://www.freshfromflorida.com/Divisions-Offices/Aquaculture/Agriculture-Industry/Aquafarm-Program/Aquaculture-Leasing

- Florida Department of Agriculture and Consumer Services: Aquafarm Program

  http://www.freshfromflorida.com/Divisions-Offices/Aquaculture/Agriculture-Industry/Aquafarm-Program

## Louisiana

Within Louisiana, the Department of Natural Resources, the Department of Environmental Quality, and the Louisiana Aquaculture Coordinating Council play a role in the development and implementation of regulatory frameworks for aquaculture. The Louisiana Department of Wildlife and Fisheries provides fish farmers licenses and permits, including tilapia culture permits. The Louisiana Department of Natural Resources issues coastal use permits, while the Louisiana Department of Environmental Quality has authority over water quality and administers National Pollutant Discharge Elimination System permits, which are needed for commercial aquaculture activities.

**Key links for Louisiana:**

- Louisiana Administrative Code: Wildlife and Fisheries
  http://doa.louisiana.gov/osr/lac/76v01/76v01.pdf
- (Louisiana) Tilapia Culture and Live Holding Permit Rules and Regulations
  http://www.wlf.louisiana.gov/sites/default/files/pdf/permit/6687-Tilapia%20Culture/tilapia_rules_and_regulations_ldwf.pdf

## Maine

According to the Maine Aquaculture Association, six state agencies are involved in the regulation of aquaculture production in the state. The Maine Department of Marine Resources has jurisdiction over the farming of marine species within the coastal waters of the state.

The types of permits needed vary by the production method and the species being produced. Permits are obtained from several State agencies. These include:

- Lease or aquaculture license (for marine species, Department of Marine Resources.)
- Discharge license (for finfish, Department of Environmental Protection)
- Gear permit (US Army Corps of Engineers)
- Site marking requirements (US Coast Guard Private Aids to Navigation program)

A range of species are cultivated in Maine, including several being raised in experimental facilities. Species raised include Atlantic salmon, Eastern oysters, Blue mussels, halibut, scallops, and shad.

**Key links for Maine:**

- Department of Marine Resources: Marine Aquaculture in Maine
  http://www.maine.gov/dmr/aquaculture/index.htm
- Maine Aquaculture Association
  http://www.maineaquaculture.com/

## Massachusetts

The Department of Agricultural Resources is the lead agency for the regulation of aquaculture in Massachusetts. The Department has a designated Aquaculture Coordinator, an aquaculture resource library, and the state has three regional aquaculture centers to provide technical information.

Several permits and licenses may be required for fish farmers in Massachusetts, each of which is obtained from a specific state or local agency:

- Discharge permit (Department of Environmental Protection and/or US Army Corps of Engineers)
- Shellfish grant (granted by the municipality)
- Fish Propagation Possession Permit (Division of Fisheries and Wildlife)
- Special permit for cultivation of marine finfish species (Division of Marine Fisheries)
- Aquaculture permit (Division of Marine Fisheries)
- Water withdrawal permit (Department of Environmental Protection)
- Federal Consistency Determination – CZM Consistency (Office of Coastal Zone Management)

Aquaculture is governed in Massachusetts by the following key regulations, policies, and plans:

- Part I, Title XIX, Chapter 130 of the Massachusetts general law (section 17B, section 57)
- Part 1, Title XIX, Chapter 131 of the Massachusetts general law (section 23)
- Massachusetts Aquaculture White Paper and Strategic Plan
- Division of Marine Fisheries aquaculture regulations for the Management of Marine Aquaculture (322 CMR 15.00)
- Massachusetts Office of Coastal Zone Management Policy Guide

Massachusetts permits the cultivation of a range of native and non-native species. Restrictions are placed on the type of production system that can be used for non-native species under 322 CRM 15.00.

**Key links for Massachusetts:**

- Energy and Environmental Affairs (EEA): Aquaculture
  http://www.mass.gov/eea/agencies/agr/about/divisions/aquaculture-program-generic.html
- EEA: Aquaculture Industry
  http://www.mass.gov/eea/agencies/agr/about/divisions/aquaculture-industry-generic.html
- EEA: Aquaculture White Paper and Strategic Plan
  http://www.mass.gov/eea/agencies/czm/publications/pages/aquaculture-white-paper-and-strategic-plan.html
- General Laws: Marine Fish and Fisheries
  https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIX/Chapter130

## Mississippi

The Mississippi Department of Agriculture and Commerce is the lead authority for aquaculture regulation in Mississippi. The Mississippi Department of Marine Resources has authority to regulate activities that affect coastal wetlands, and the Mississippi Department of Environmental Quality is responsible for regulating discharges, including the administration of National Pollutant Discharge Elimination System permits.

Several permits and licenses are required for fish farmers in Mississippi, each of which is obtained from a specific State agency:

- Exotic species permit (Dept. of Agriculture and Commerce)
- Cultivation/aquaculture permit (Dept. of Agriculture and Commerce)
- Wetlands permit for activities below the high tide line or in coastal wetlands (Dept. of Marine Resources
- Aquaculture Lease for any aquaculture activity using the water column or sea bottom (Secretary of State)
- Water discharge permit (Department of Environmental Quality)

**Key link for Mississippi:**

- Mississippi Code: Guidelines for Aquaculture Activities
  http://www.mdac.state.ms.us/agency/regulations_laws/reg_%20pdfs/Subpart%204/11%20-%20Guidelines%20for%20Aquaculture%20Activities.pdf

## New York

The New York State Department of Environmental Conservation (DEC) is responsible for overseeing permits related to most major environmental regulatory areas related to the state's water and biological resources.

The DEC should be the first point of contact for a fish farmer seeking to understand the permitting and licensing system in the state. The DEC issues licenses and permits related to hatcheries, marine area use, on/off-bottom culture, and pollutant discharge.

Species raised in New York include rainbow trout and brown trout, primarily used for stocking of recreational fisheries, shellfish, and crawfish.

**Key links for New York:**

- Marine Permits and Licenses
  http://www.dec.ny.gov/permits/6084.html
- Special Licenses
  http://www.dec.ny.gov/permits/359.html
- New York State Aquaculture Association
  http://nysaquaculture.org/

## Texas

In Texas, aquaculture is regulated through multiple state agencies, though primarily through the Texas Department of Agriculture (TDA), the Texas Commission on Environmental Quality (TCEQ), the Texas Parks and Wildlife Department (TPWD), and the Texas General Land Office (GLO). To operate a commercial aquaculture operation in Texas, farms need to obtain a number of relevant permits from these different agencies:

- Aquaculture license: required of persons who produce and sell cultured species raised in private facilities. (TDA)

- Fish Farm Vehicle license: required if vehicles are used to transport cultured species from a private facility and the species are sold from the vehicles. (TDA)

- Wastewater Discharge permit: required if the aquaculture facility discharges into state waters or is located adjacent to state waters. (TCEQ)

- Mariculture Permit: required for operations using brackish or marine water for land-based mariculture activities. (TCEQ)

- Water Use Permit: required to divert freshwater from a surface source such as a river. (TCEQ)

- Stocking permit: required to introduce any fish, shellfish, or aquatic plant into state waters. (TPWD)

- Exotic Species permit: required for the importation or possession of any nonnative fish, shellfish, or aquatic plant. (TPWD)

- Fish Dealer's License: different licenses may be required for retail versus wholesale, and whether sales are from the establishment or a vehicle. (TPWD)

- Permit, easement, or lease: required for fish farmers using state-owned coastal land (GLO).

Aquaculture in Texas is governed by the following key regulations, policies, and plans:

- Fish Farming Act of 1989

- Texas Water Code

- Texas Agriculture Code

**Key links for Texas:**

- Texas Commission on Environmental Quality (TCEQ)
  http://www.tceq.state.tx.us

- TCEQ: General Permit Requirements for Water Discharge from Aquaculture
  http://www.tceq.texas.gov/permitting/wastewater/general/TXG13_steps.html

- Texas Department of Agriculture: Aquaculture
  http://texasagriculture.gov/RegulatoryPrograms/Aquaculture.aspx

- Texas Parks and Wildlife
  http://www.tpwd.state.tx.us

"Right now, the state is debating if my kelp is a noodle or not. Depending on how they determine that makes a huge difference for me. Last year they decided kelp was to be regulated as an animal, not a vegetable...They stop me at every step. It's a war. Yet, everyone is now claiming that seaweed farming is the big promise for economic development in Long Island Sound. They've been giving me hell for two years."

*—Bren Smith, Owner*
*Thimble Island Oyster Co.*

## Appendix II • Ecological Issues and Production Systems

Through the course of our research, we discovered a number of state policies that served to support reef restoration efforts, and several that hindered them. Below is an outline of those findings, along with examples. This summary is not a comprehensive overview of all policies relevant to restoration, but rather a sample of how current laws on the books can not only substantially affect the success of restoration endeavors, but also how they vary from state to state. Specific permitting rules and procedures were beyond the scope of this synopsis.

## ECOLOGICAL ISSUES

There is general scientific consensus about the key negative outcomes of aquaculture production, although debates surrounds the extent of those effects and their degree of severity. As such, it is not appropriate to paint all production in the same light, and customized solutions must be implemented to manage risks and mitigate relevant impacts. Below are descriptions of issues associated with conventional fish farming. Where applicable, mitigation techniques are also mentioned.

**Water Pollution** Excess (uneaten) feed and fecal waste contributes to nutrient loading in surrounding water, which can lead to harmful algal blooms and local dead zones where native plants and animals are no longer able to survive. With land-based systems, improper wastewater management can contaminate groundwater, local streams, and farmland. ***Mitigation:*** Suitable site selection for inland farms and the filtering of effluents can minimize freshwater pollution. In semi-open systems (flow-through or ponds), effluent treatment can be highly effective.

**Feed** Feed is viewed as both a major impact of aquaculture and a major constraint to aquaculture development. Many farmed species—regardless of whether they are naturally carnivorous—are fed fishmeal or fish oil derived from wild fish. The capture of forage fish (e.g., anchovies, menhaden, herring) for those purposes contributes to overfishing and the depletion of wild fish stocks. Conventional fish feed can also contain these unsustainable and/or unsavory ingredients: GMO soy and corn, poultry byproducts, feather meal, meat meal, and blood flour. ***Mitigation:*** Large feed manufacturers have for years been investing in developing and testing diets low in fishmeal and fish oil, with specific attention to how those diets impact fish growth rates and health qualities, especially omega-3 content. Sourcing fishmeal and fish oil from the trimmings of seafood processed for human consumption is one method of reducing dependence on wild forage fish. Alternative feed sources include algae, yeast, insect meal, and fish processing byproducts. It is important to note that approximately one-third of aquaculture production is of un-fed species. Filter-feeding bivalves and seaweeds require no feed inputs, nor do some species of carp or shrimp if produced in low-intensity systems.

**Capture of wild fish for grow-out** Direct harvest of wild juveniles for stocking fish farms is common for oysters, shrimp, grouper and tuna, and can threaten the health of wild populations. For example, the practice of capturing wild bluefin tuna before they are able to spawn is linked to the continued decline of already depleted stocks.

## Land Conversion and Habitat Loss

Some farmed species are associated with the destruction of coastal wetlands or mangroves, disrupting habitat and lifecycle processes for fish, birds, amphibians, and mammals, and diminishing biodiversity. Cage or net-pen production can similarly damage benthic habitats on river or ocean floors. ***Mitigation:*** In the case of mangroves, the trend of land conversion has slowed due to increased awareness; also, mangrove forest soils were deemed unsuitable for long-term production. Wetlands can sometimes be spared by siting fish farms on land that was previously cleared for agriculture. Benthic impacts have lessened as technology and stronger cages have allowed production to move to the open ocean, where nutrients are bettered dispersed and diluted. (Open-ocean aquaculture has its own problems, however.) Finally, integrated multi-trophic aquaculture (IMTA), which involves the cocultivation of multiple species (e.g., finfish, oysters, mussels, seaweeds) can reduce the nutrient load on the environment by mimicking natural ecosystems.

## Antibiotics and Chemical Inputs

The use of antibiotics to treat and prevent disease outbreaks is prevalent in dense, single-species aquaculture operations. Chemicals (some of which are banned) are also applied commonly to prevent the growth of algae, bivalves, and other unwanted pests on nets and cages. These inputs can be toxic to both marine organism and human health alike, affecting the well-being of farm laborers as well as consumers. ***Mitigation:*** There is a lot of research into anti-foulants to create ones that are nontoxic, and some companies experimenting with cage materials to reduce need for chemicals. There are also methods for physical cleaning of nets instead of chemicals. With regards to antibiotics, appropriate stocking density and siting can effectively reduce and even eliminate their use.

## Water Use

Land-based aquaculture is water intensive, and freshwater is an increasingly scarce resource facing growing demand. According to current estimates, freshwater shortages in the US have been declared for 36 states, and worldwide, demand for freshwater is projected to exceed supply by 40% by 2030. The site selection of new aquaculture facilities must take freshwater availability into consideration, as without proper conservation measures, land-based systems can deplete aquifers and/or can salinize groundwater—negative impacts for communities, farmland, and livelihoods. ***Mitigation:*** Recirculating systems effectively reduce the need for freshwater, though they require significant energy inputs. These systems have proven economically viable for the production of high-value species, but more work is needed to make them a realistic option for more general production.

## Escapees

Farmed species that escape into open streams, lakes, or oceans can compete with naturally occurring organisms for food and habitat, disrupt the ecosystem balance, or contaminate the gene pool of wild stocks of the same species.

## Disease

In any production system where water is exchanged between the farm and the natural environment, there is a risk that the water carries pathogens, viruses, or parasites harmful to wild populations. In the case of net pens and cages, farmed fish can acquire disease and parasites from the environment and amplify a pathogen that already exists. Aquaculture is also a means of introducing new pathogens to a region through the global transport of eggs. Disease and parasites can also spread from farm to farm, and some farmed fish industries have experienced crashes due to disease. There is risk of major outbreaks if adequate biosecurity planning is not in place.

## PRODUCTION SYSTEMS

Aquaculture can range from relatively primitive, low-cost, low-yield systems to complex, capital-intensive, high-yield "factory" fish farms. With increased complexity and cost comes increased risk, and thus greater need for aquaculture expertise and precise production models. To understand aquaculture and the issues surrounding it requires understanding some basic information about the types of production systems conventionally used to grow fish.

**Net Pens and Cages:** Designed to contain fish while allowing a free exchange of water and untreated waste, net pens are used in protected or semiprotected marine areas to raise high-density saltwater finfish. Freshwater species are also raised in cages in rivers or lakes. New technologies for open-ocean aquaculture include submerged cages designed to withstand stronger ocean currents. Net pens are associated with issues of water pollution, wild-fish feed, escapees, disease, and use of antibiotics and chemicals.

**Ponds:** Catfish and tilapia are often raised in manmade inland ponds, while marine shrimp are raised in coastal ponds. Ponds can be lined to reduce seepage and are often filled before production and drained at final harvest, with water added as needed. Water and sludge drained from ponds are often, but not always, treated before being released back into a natural water body. Ponds are associated with issues of water use, water pollution, land conversion, and habitat loss, as well as with chemical treatments to kill bacteria/disease between harvests.

**Raceways:** Raceways are flow-through systems that are most often sited along a river. These systems divert river water, pass it through the production system, then release it back to the waterway with or without wastewater treatment. Raceways are associated with issues of water pollution, wild-fish feed, land conversion, and habitat loss.

**Recirculating Tanks:** Fish are raised in large freshwater tanks, while water is filtered and treated as it cycles through the system. The percentage of water recirculated and recycled varies, but the most sophisticated of these systems require very little additional water inputs. Recirculating tanks are associated with issues of high energy consumption and wild-fish feed.

**Shellfish Culture:** Oysters, mussels, and other bivalves are raised in a variety of systems, including on ropes, or in bags or trays suspended from rafts or anchored long lines. They are also raised on intertidal beaches. Shellfish culture can be associated with issues of land conversion and habitat loss.

## Interviewees

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## Project Team

### Cheryl Dahle

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Cheryl Dahle is the Founder and Executive Director of Future of Fish. A journalist and entrepreneur who has worked at the intersection of business and social transformation for more than a decade, Cheryl Dahle conceived and co-led the effort to found Future of Fish. Prior to her work with fisheries, Cheryl was a director at Ashoka: Innovators for the Public, where she distilled knowledge from the organization's network of 2,500 fellows to provide strategic insight to foundations and corporations. As a consultant, she has served leading organizations in the space of hybrid business/social solutions, including Humanity United, Nike, the Robert Wood Johnson Foundation, the David and Lucile Packard Foundation and the Center for the Advancement of Social Entrepreneurship at Duke University. Cheryl spent 15 years reporting on social entrepreneurship and business for publications including Fast Company, The New York Times and CIO magazine. Cheryl founded and led Fast Company magazine's Social Capitalist awards, a competition to identify and recognize top social entrepreneurs. Before her work with nonprofit organizations, she was part of an incubation and startup team for which she helped secure $12 million in venture funding to launch an online environmental magazine.

### Colleen Howell, PhD

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Colleen Howell serves as the Research Director for Future of Fish. Specializing in technical and nontechnical writing, research, project management, survey development and data analysis, Colleen Howell was a principal researcher in the discovery phases that led to the founding of Future of Fish. As a scientific and sustainability consultant, she has worked for NASA's LAUNCH program, spearheaded the development of in-house sustainability goals for Saint Vincent's Day Home in Oakland, CA, created custom green event guidelines for The Gallup Organization, and created a carbon offset credit report for Architecture for Humanity. Colleen coauthored Shift Your Habit: Easy Ways to Save Money, Simplify Your Life, and Save the Planet (Crown/Three Rivers Press, 2010) and served as primary researcher for The Green Book: The Everyday Guide to Saving the Planet, One Simple Step at a Time (Crown/Three Rivers Press, 2007). She earned both an MS and a PhD in Environmental Sciences from UC Riverside.

## Marah Hardt, PhD

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Marah Hardt is the Media Director and Senior Researcher for Future of Fish. A scientist and storyteller, Marah Hardt works at the crossroads of research, creative communication, and strategy to build a sustainable future for people and the sea. As founder of OceanInk, Marah spent five years working as a consultant with interdisciplinary teams investigating coral reef health, fishery impacts, ocean acidification, and the greening of the global seafood supply chain. She was a founding researcher for Future of Fish and a contributing researcher and writer to The Green Blue Book (Rodale Press) and The Big Handout (Rodale Press). Prior to OceanInk, Marah was a research fellow at Blue Ocean Institute, where she created and launched their climate change program, including an initiative to engage scientists and religious leaders in constructive conversation about halting climate change. Her work has been published in scientific journals, books, and popular magazines (Scientific American, The American Prospect). She received her PhD in marine science from Scripps Institution of Oceanography.

## Peter Battisti

***Business Strategist***

Peter Battisti is the Business Services Director for Future of Fish. A co-founder and partner in multiple entrepreneurial ventures, Peter Battisti has 10 years of experience as an entrepreneur starting and operating renewable energy and real estate development companies. Through partnerships with high-net-worth investors and several wealth management funds, Peter has been a stakeholder in the placement of more than $20MM of real asset development. Following his passion for the start-up process and harnessing his entrepreneurial background, Peter chose to dedicate his time to working with socially responsible entrepreneurs to help launch their businesses. As an advisor and consultant, Peter has been intimately involved in developing and implementing business and investment strategies for dozens of start-up and early stage companies in the renewable energy, aquaculture, agriculture, and food service industries. To date, Peter has helped raise a total of $1.6MM of private-equity funds for his clients. Peter has had significant experience working on both sides of the "fundraising table", providing due-diligence services to high-net-worth investors in addition to raising funds for his own ventures and those of his clients through private-equity, tax-equity, institutional lenders, and CDFI channels.

FUTURE of FISH

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